AN INVESTIGATION OF THE MARKET EFFICIENCY OF THE NAIROBI SECURITIES EXCHANGE

by

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DECLARATION

I, Josephine M. Njuguna, declare that ***'An Investigation of the Market Efficiency of the Nairobi Securities Exchange'*****,** is my own work and that all the sources I have used or quoted have been indicated and fully acknowledged by means of complete references in the text and in the Bibliography.

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SUMMARY / ABSTRACT

This study tests for the market efficiency of the Nairobi Securities Exchange (NSE) after the year 2000 to determine the effect of technological advancements on market efficiency. Data that is used is the NSE 20 share index over the period 2001 to 2015; and the NSE All Share Index (NSE ASI) from its initiation during 2008 to 2015. We cannot accept the Efficient Market Hypothesis (EMH) for the NSE using the serial correlation test, the unit root tests and the runs test. However, we can accept the EMH for the more robust variance ratio test. Overall, the results of the market efficiency are mixed. The most significant finding is that the efficiency of the NSE has increased since the year 2000 which suggests that advancements in technology have contributed to the increase in the market efficiency of the NSE.

KEY TERMS

Key terms:

Efficiency market hypothesis, NSE, Serial correlations test, Unit root test, Runs test, Variance ratio test.

LIST OF ABBREVIATIONS / ACRONYMS

ADF	Augmented Dickey Fuller test
AIMS	Alternative Investment Market Segment
AMH	Adaptive Market Hypothesis
ASE	Athens Stock Exchange
ASI	All Share Index
EMH	Efficient Market Hypothesis
CAPM	Capital Asset Pricing Model
CDSC	Central Depository and Settlement Corporation
CEE	Central and Eastern Europe
CMA	Capital Market Authority
CMG	Capital Market Governance
EAC	East African Community
EMH	Efficient Market Hypothesis
FISMS	Fixed Income Securities Market Segment
FTSE	Financial Times Stock Exchange
GARCH	Generalised Auto-regressive Conditional Heteroscedasticity
GARCH-M	Generalised Auto regressive Conditional Heteroscedasticity in Mean model
GCC	Gulf Co-operation Council
GDP	Gross Domestic Product
GEMS	Growth Enterprises Market Segment
IFC	International Finance Corporation
JSE	Johannesburg Securities Exchange
MENA	Middle East and North African Countries
MIMS	Main Investment Market Segment
NASDAQ	National Association of Securities Dealers Automated Quotations
NSE	Nairobi Securities Exchange
NSE ASI	Nairobi Securities Exchange All Share Index
NYSE	New York Securities Exchange
RWH	Random Walk Hypothesis
S & P	Standard and Poors

LIST OF ABBREVIATIONS / ACRONYMS (contd)

SURKSS	Seeming Unrelated Regression of the Kapetenios-Shin-Snell test
TEE	Test of Evolving Efficiency
TOPIX	Tokyo Stock Price Index
UAE	United Arab Emirates
UK	United Kingdom
USA	United States of America

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter will discuss the background of the study, a brief theory of the efficient market hypothesis, an overview of the NSE, the research problem, research objectives and the scope of the study. The limitations of the study will be indicated and an outline of the chapters highlighted.

1.2 BACKGROUND

Stock markets play a pivotal role in economic development especially in developing economies. Yartey and Adjasi (2007) examined the economic importance of stock markets in Africa. The finding of the study shows that stock markets have contributed to the financing of the growth of large corporations in certain African countries. Claessens, Dasgupta and Glen (1995) observed that stock markets are tremendously efficient in allocating capital which improves the overall economic efficiency. They play a crucial role in encouraging savings and investment. They allow diversification across assets, which reduce the cost of capital and leads to increased investments and development. They also place the decision making in the shareholders' hands which leads to improved corporate governance and contributes to economic development.

Greenwood and Smith (1997:145) argued that "the relationship between the development of markets and economic development is that markets – especially financial markets – play a central role in economic development which in turn leads to the formation of new markets. They also observed that the economic importance of financial markets for growth derives from the fact that they fulfil various functions. Firstly, financial markets are the most important means of channelling investment capital to its highest return uses. Secondly, they provide liquidity and permit the efficient pooling of risk and thirdly, financial markets foster specialisation through entrepreneurship, entrepreneurial development and the adoption of new technologies."

Baier, Dwyer and Tamura (2004) examined the connection between the creation of stock exchanges and economic growth. The results show that economic growth increases relative to the rest of the world after a stock exchange opens. The evidence indicated that increased productivity is the primary way that a stock exchange increases the growth rate of output, rather than an increase in the growth rate of physical capital.

Ma (2004) observes that, the fact that stock markets possess the potential to be capital resource allocators does not imply that they always can perform the job of capital allocation well. Some stock markets do not allocate the capital to the industrial sectors experiencing high growth in product demand, or cannot introduce capital sufficiently quick to sectors that demand it. In such cases, the stock markets allocate capital resources inefficiently and the rate of expansion of the economy suffers. An allocationally efficient stock market should allocate capital resources into the most productive sectors as soon as possible. The author adds that allocational efficiency of a stock market should consist of both internal efficiency and external efficiency which is also referred to as operational efficiency and internal efficiency respectively.

Stock markets are operationally efficient when they possess liquidity, the condition of the market is orderly (i.e. there is continuity of trading and no market manipulation) and the markets have a well-functioning market system (Jüttner 1990). Informational efficiency refers to share prices reflecting all available information instantaneously (Fama 1970). It is only in this case that prices can provide the correct signals for efficient capital allocation. Operational and information efficiency are inherently related to each other because an operationally inefficient stock market may inhibit the spread of information which definitely block capital movements (Ma 2004).

Only when a statistical test passes the criteria for informational efficiency is the market deemed to be an efficient market (Ma 2004). The author emphasises that statistical tests have been widely applied in the body of literature known as *'Efficient Market Theory'* because informational efficiency is fully incorporated in allocational efficiency concerning stock markets. Some of the prerequisites of informational efficiency are met by the condition of operational efficiency; and the transaction data of stocks is available and suitable for the tests of informational efficiency of stock markets. Ma (2004) furthermore indicates that, it is clear that allocational efficiency, operational efficiency and information efficiency, are different categories with respect to stock markets. This study will test the efficiency of the Kenyan stock market by focusing on tests of informational efficiency.

Antoniou, Ergul and Holmes (1997:177) observed that efficiency of a stock exchange is extremely important because it enables for the prices to fully incorporate information. It also provides confidence to investors to participate in the stock market. It encourages the development of the market and could encourage investors to be involved in other stock exchanges in the region. If a stock exchange is not efficient, it will discourage investors to participate in the stock exchange hence, it will not encourage economic development.

The Efficient Market Hypothesis (EMH) is a finance theory that explains that information is quickly reflected in share prices such that investors are not able to earn excess risk adjusted returns. Malkiel (2005) showed that professional investment managers, both in the United States of America and abroad, do not outperform their index benchmarks and provide evidence that generally, market prices do seem to reflect all available information. This is emphasised by Malkiel (2003:5) in another study that indicates that the evidence is overwhelming whatever anomalous behaviour of stock prices may exist, it does not create a portfolio trading opportunity that enables investors to earn extraordinary risk adjusted returns.

In opposition to the EMH theory, Grossman and Stiglitz (1980:405) argued that because information is costly, prices cannot perfectly reflect the information which is available, since if it did, those who spent resources to obtain it would receive no compensation. There is a fundamental conflict between the efficiency with which markets spread information and the incentives to acquire information. In addition, two serious flaws on the EMH are noted (Anderson 1983). The first being that asset prices are indeterminate, and the second being the notion that information is not well-defined and hence bringing into question, the assumptions of the EMH. This then gives the view that stock markets are highly imperfect and liable to be speculative.

In defence of the EMH, Fama (1998:283) revealed that "market efficiency survives the challenge from the literature on long-term return anomalies. Consistent with the market efficiency hypothesis that the anomalies are chance results, apparent overreaction to information is about as common as under-reaction, and post-event continuation of pre-event abnormal returns is about as frequent as post-event reversal. Most important, consistent with the market efficiency prediction that apparent anomalies can be due to methodology, most long-term return anomalies tend to disappear with reasonable changes in technique."

Bernstein (2005) states that the EMH may not be an accurate description of reality since the market in itself is not truly efficient. However, no one has found important cases of lagged variables that consistently explain stock price returns. Very few investors consistently beat the market year after year on a risk-adjusted basis, though the market itself is not fully efficient such that all information is immediately known, understood and reflected in asset prices without any lag. The idea of efficiency is spreading outside the borders of United States, and markets worldwide that were once known as very inefficient are becoming more efficient all the time.

Arouri, Jawadi and Nguyen (2010) explain that understanding the efficiency of emerging stock markets has become important over the last decades as they are now reasonably integrated with developed and world markets. The authors noted that empirical studies on emerging market efficiency are however very challenging. This is because the heterogeneity of these markets in terms of market size and development levels often leads to country-specific results. Moreover, only a few studies focus on tests on EMH in emerging markets because the majority of them appear to not be efficient due to numerous market imperfections such as, transaction costs, poor quality of information disclosures, thin trading and inadequate financial and accounting regulations. Ultimately, their degree of efficiency may evolve through time, which typically reflects different stages of development and gradual process of liberalisation.

Henry (2000) reported that on average, during an eight-month window leading up to the implementation of its initial stock market liberalisation a country's aggregate equity price index experiences abnormal returns of 3.3% per month in real dollar terms. This result is consistent with the prediction of standard international asset pricing models that by allowing for risk sharing between domestic and foreign agents, stock market liberalisation may reduce the liberalising country's cost of equity capital. In contrast to these results, Kawakatsu and Morey (1999) examined whether emerging market equity prices have become more efficient after financial liberalisation. Using two sets of financial liberalisation dates, a battery of econometric tests and data from nine different countries, the study finds that in spite of theory suggesting the opposite liberalisation does not seem to have improved the efficiency of emerging markets. In fact, most of the statistical tests indicate that the markets were already efficient prior to the actual liberalisation.

Kim and Singal (2000) in a study on the experience of emerging economies in opening up stock markets, found that stock prices are less auto-correlated following the market opening. There is increased randomness of returns implied by an improvement in market efficiency. The advantages to the more efficient market are better allocation of capital and an increase in the productivity of capital.

Antoniou et al (1997) observed that the conventional tests of efficiency have been developed for testing markets, are characterised by high level of liquidity, sophisticated investors with access to high quality and reliable information and few institutional impediments. On the other hand, emerging markets are typically characterised by low liquidity, thin trading, possibly less well-informed investors with access to unreliable information and considerable volatility. The study finds that tests of market efficiency must take account of the characteristics of the market under investigation (Antoniou et al 1997:180). For emerging markets this requires the recognition that there may be non-linearities, thin trading and a changing regulatory framework [market evolution through time]. The authors underscore that it is only by directly incorporating these issues into tests of efficiency in emerging markets that we can address the more important issue of identifying the forces which lead to markets being efficient or inefficient.

Yang, Chae, Jung and Moon (2006) established that many research papers on developed markets have already been published. However since emerging markets have different characteristics to those of developed markets, they represent an active field of research.

Wheeler, Neale, Kowalski and Letza (2002), examine the changing pricing efficiency of the first stage of development of the Warsaw Stock Exchange. It is determined that emerging markets are less likely to be fully informationally efficient somewhat due to institutional rigidities which restrict information flows to the market and also due to the lack of experienced market participants to speedily incorporate new information into share prices. Tests for runs and auto-correlation were conducted on the market over the period 1991 to 1996, and also during segmented sub-periods during which different institutional arrangements applied. The authors find that as the number of trading days per week increased, the general level of efficiency, although low, steadily improved (except for the "bubble" period of 1993-1994). In a few stocks, inefficiencies were likely to be explained by opportunities to conduct off-market, out-of-hours transactions in specific stocks, and the stock exchange authorities' continuing power to suspend trading.

Butler and Malaikah (1992) examine stock returns in Saudi Arabia and Kuwait over the period 1985 to 1989. The study finds that the Kuwaiti market is similar to other thinly traded markets in proportion of individual stocks exhibiting statistically significant auto-correlations and price change runs. In contrast, all 35 Saudi stocks show a significant departure from the random walk. The institutional factors contributing to the market inefficiency include illiquidity, market fragmentation, trading and reporting delays, and the absence of official market makers.

However, Antoniou et al (1997:188) affirm that the informationally efficient emerging markets are brought about by improving liquidity, ensuring that investors have access to high quality and reliable information and minimising the institutional restrictions on trading. In addition, the slow evolution in the regulatory framework and lack of knowledge and awareness of investors in emerging markets may mean that they will initially be characterised by inefficiency, but over time will develop into efficient and effectively functioning markets which allocate resources efficiently. According to Abeysekera (2001), some of the noted differences in behaviour of stock returns between developed stock markets and certain emerging stock markets, can potentially be explained by poor markets structures, thin trading, relatively short series of data, short selling restrictions and distributional properties of returns in some of these markets.

The efficiency of stock markets is considered to have increased compared to the level of efficiency many years ago. This has been attributed to the advancement in technology that has enabled information to quickly reflect on the share prices. In a study conducted by Yang, Kwak, Kaizoji and Kim (2008) that analysed the time series of Standard and Poor's 500 Index (S & P 500), the Korean Composite Stock Price Index (KOSPI) and the Nikkei 225 Stock Average (NIKKEI), it was observed that before the year 2000, information used to get by slowly, hence resulting in the markets being less efficient. However, information flow is currently faster and more even because of the rapid development of communication through high speed internet, mobile technologies, and world-wide broadcasting systems. The expectation is of the present stock markets to become more efficient than past markets, confirming the EMH (Yang et al 2008).

Tóth and Kertész (2006) analysed the temporal changes in the cross-correlations of returns on the New York Stock Exchange (NYSE). The authors found that at the beginning of the eighties there was an average correlation of 0.15 to 0.20 between the logarithmic returns of smaller stocks and the previous days logarithmic returns of larger stocks, this correlation decreased under the error level by the end of the nineties. Since relevant time-dependent correlations on daily scale can be exploited for arbitrage purposes, this finding is a sign of increasing market efficiency. As trading and information processing gets faster, the time for each actor to react to the decisions of others decreases, so in order to exclude arbitrage opportunities, time-dependent correlations on daily scale have to diminish and vanish, and correlations - if they exist - must move to a smaller scale (higher frequency). This effect shows a considerable change in the structure of the market, indicating growing market efficiency even for a developed market.

Automation of stock exchanges has enhanced information efficiency as it facilitates the process of market prices quickly reflecting new information. Ciner (2002) investigated the information content of trading volume on the Toronto Stock

Exchange before and after the move towards fully electronic trading. The empirical analysis supports more accurate price discovery after electronic trading. The findings of the study indicate that the predictive power of volume for price variability disappears after full automation. Naidu and Rozeff (1994) scrutinise the reasons why automation could influence aspects of trading such as volume, volatility, liquidity, market efficiency and bid-ask spreads of the Singapore Stock Exchange after it fully automated in 1989. Examination of 28 securities, suggest that automation is associated with increases in volumes traded, return volatility and liquidity as defined by the ratio of volume to volatility. Improvements in market efficiency appear in reduced serial correlations of returns.

Hendershott and Moulton (2011) use the NYSE's introduction of its 'Hybrid Market' to study how increasing automation and trading speed within a market affects/market quality, both are increasingly important facets of competition among financial markets. However, very little is known about how changing a market's automation and speed affects the bid-ask spreads (cost of immediacy) and price discovery which are two crucial dimensions of market quality. The NYSE introduced its Hybrid market at the end of 2006, increasing automation and reducing the execution time for market orders from 10 seconds to less than one second. The authors find that the change raises the bid-ask spreads because of increased adverse selection and reduces the noise in prices, making prices more efficient.

Other studies have however found that automation has not lead to increased market efficiency. Freund and Pagano (2000) measured the degree of market efficiency at the New York and Toronto Stock Exchanges before and after automation using non-parametric statistical analysis. Overall, the results show the level of informational efficiency remains effectively unchanged during the automation period. Despite several deviations from a random walk process, the returns from stocks on these exchanges do not appear to exhibit consistent patterns that investors can exploit to generate abnormal returns. Sioud and Hmaied (2003) probe the effects of automation on the liquidity, volatility, returns and efficiency of shares traded on the Tunisian Stock Exchange. By the end of 1996, stocks listed on the exchange were transferred gradually from manual trading to automated trading.

The Tunisian Stock Exchange operates a continuous market for frequently traded securities and a ‘call auction’ for infrequently traded securities. The authors’ results show an improvement in the liquidity of shares following the automation, returns decreased and no significant effects on volatility or efficiency were detected.

African stock exchanges account for a small percentage of the overall market capitalisation of the world’s stock exchanges. In a study by the Kenyan Capital Markets Authority – Capital Market Authority (2010), the findings show that as at December 2009, the World Federation of Exchanges’ total market capitalisation was $46.5 trillion. African stock market capitalisation accounted for a meagre 2% during the period under review. In addition, the global equities turnover was approximately $113 trillion in 2008 making Africa’s contribution to this figure stand at a dismal 0.005% and it also accounted for 2% of global bond turnover. South Africa is the only exchange with a vibrant derivatives market while Nigeria is moving towards its implementation. In spite of all these challenges, African capital markets have continued to perform incredibly well. Average annual returns to Africa equity markets in dollar terms have averaged 14% from January 1995 to December 2004, relative to 8% for South Africa; 6.3% for G7 countries and 6.6% for the Global equities markets (Capital Markets Authority 2010).

1.3 An Overview of the Nairobi Securities Exchange (NSE)

The NSE was constituted in 1954 as a voluntary association of stockbrokers registered under the Societies Act (Nairobi Securities Exchange 2015b). The NSE comprises four counters: the Main Investment Market Segment (MIMS), the Alternative Investment Market Segment (AIMS), Fixed Income Securities Market Segment (FISMS) and the Growth Enterprise Market Segment (GEMS). The NSE is regulated by the Capital Markets Authority (CMA) and the Central Depository and Settlement Corporation (CDSC). The CMA is the “Government Regulator charged with licensing and regulating the capital markets in Kenya. It also approves public offers and listings of securities traded at the NSE (Nairobi Securities Exchange 2012b).”

The CDSC on the other hand "provides clearing, delivery and settlement services for securities traded at the NSE. It oversees the conduct of Central Depository agents comprised of stockbrokers and investment banks which are members of the NSE and custodians (Nairobi Securities Exchange 2012b)".

A summary of the revitalisation process on the market micro-structure of the NSE is highlighted (Ngugi, Murinde and Green 2002). The key elements include: firstly, establishment of a market regulator - CMA in January 1990; secondly, shift from a call trading system to an open outcry trading system in November 1991. The trading system was further restructured when the auction trading system was introduced in January 1995. Thirdly, free entry of foreign investors to trade on the exchange in January 1995.

Some of the recent accomplishments of the NSE were in July 2011, when it changed its name from the Nairobi Stock Exchange Limited to the Nairobi Securities Exchange Limited, and in September of the same year, it converted from a company limited by guarantee to a company limited by shares (Nairobi Securities Exchange 2012a). In November 2011, the NSE in partnership with FTSE International officially launched the FTSE NSE Kenya 15 index and the FTSE NSE Kenya 25 index (FTSE, 2012). These indices are designed to enhance the depth of information available and are also suitable as the foundation for Exchange Traded Funds (ETFs) and other index-linked products sought after by global investors (Nairobi Securities Exchange 2012a). It is the third initiative in Africa after Johannesburg Securities Exchange (JSE) and Casablanca Stock Exchange (Nairobi Securities Exchange 2011). It is hoped that the indices will improve capital flows into the domestic market and enhance liquidity and market capitalisation.

Another major milestone for the NSE was the launch of the live trading on the automated trading systems which was implemented in September 2006. Six years later, on 5th September 2012, the NSE Broker Back office started operations with a system capable of facilitating internet trading thereby improving the integrity of the Exchange trading system (Nairobi Securities Exchange 2015b). Furthermore, it launched a new system for trading corporate bonds and Government of Kenya

Treasury bonds on 26th September 2014. This system enabled online trading of debt securities and is integrated with the settlement system of the Central Bank of Kenya.

The Board of Association of Futures Markets admitted the NSE as an associate member of the association on 28th February 2013 this seeks to promote and encourage the establishment of new derivatives and related markets (Nairobi Securities Exchange 2015b). Also in 2013, the NSE was ranked the winner of *the Most Innovative Stock Exchange* category, by the Africa investor Index Series Awards as a result of initiatives to increase company listings and diversity asset classes. On 9th September 2014 the NSE became the second African exchange after the JSE to list on the MIMS after a successful initial public offering. On 18th March 2015 the NSE joined the United Nations-Sustainable Stock Exchanges initiative which aims to look into how stock exchanges can work together with investors, regulators and issuers to enhance corporate transparency and performance on environmental, social and corporate governance issues while encouraging responsible long-term approaches to investment.

1.4 THE RESEARCH PROBLEM

Very few studies have been conducted on the informational efficiency of the East African stock exchanges with majority of those studies focusing on the efficiency of the NSE. These studies have been conducted by: Dickson and Muragu (1994); Ngugi et al (2002); Jefferis and Smith (2005); and Mlambo and Biekpe (2007).

The NSE is the oldest and largest securities exchange in East Africa and most of the shares that are traded in the Tanzanian and Ugandan exchanges are cross-listed on the Kenyan exchange. It is in this context that this study will focus on testing the market efficiency of the NSE. Some of the recent studies on the EMH of the NSE have been conducted by Mlambo and Biekpe (2007) using daily closing prices and volume traded for individual stocks over the period 2nd January 1997 to 31st May 2002. A non-parametric test of independence, the runs test is used. The NSE was found to be efficient on the weak-form in that study. Dickson and Muragu (1994) use the serial correlation and runs test and the results are shown to not contradict the weak form of the EMH. Other studies have been conducted by Zhang, Wu, Chang and Lee (2012); Magnusson and Wydick (2002); and Appiah-Kusi and Menyah (2003) who have found the Kenyan market to be weak-form efficient. In contrast, Smith, Jefferis and Ryoo (2002), found the hypothesis that the Kenyan stock market follows a random walk is rejected as returns were auto-correlated.

This study will test the efficiency on the NSE over the period 2001 to 2015, using daily and weekly index prices of the NSE 20 share index and the NSE All Share Index (ASI). The tests that will be used are the serial correlation test, unit root tests, runs test and the variance ratio test. The results of which will be compared to those of previous studies on the Kenyan market.

However, since the year 2000, there have been both regulatory and technological developments. Cognisant of the observation by Yang et al (2008:246) that as a result of technology market efficiency increased significantly from the year 2000; and that by Lim (2009), on using both linear and non-linear tests to determine market efficiency, it is only proper to re-visit the issue for the NSE. Hence, this study seeks an answer to the research question: Has informational efficiency of the NSE improved since the year 2001?

The overarching research objective is to determine the level of informational efficiency of the NSE.

1.4.1 Subsidiary Objectives

1. To identify steps previously taken to improve informational efficiency of the NSE over the years.

2. To assess the level of efficiency of the NSE using daily and weekly index data from the NSE 20 share index, and the NSE ASI.

3. To determine whether the informational efficiency of the NSE has improved since the year 2001.

The general hypothesis for the study is:

H_0: The market under the study is weak-form efficient

H_a: The market under the study is not weak-form efficient

The four methods that were used to analyse the daily and weekly index data, are the serial correlation test, unit root tests, runs test and variance ratio test. The first three tests focus on the absolute efficiency approach and will be able to show whether the NSE is efficient or not. The later test will show the changes in efficiency over the period of study.

1.5 SCOPE OF THE STUDY

The significance of the study will be to establish the level of efficiency of the NSE. This will be compared with that of previous studies that have been conducted on the NSE. It can then be determined whether the measures that have been taken so far, have been sufficient in enabling the NSE to become more efficient or whether further steps need to be undertaken to make the Kenya stock market more efficient.

1.6 STUDY LIMITATIONS

The NSE 20 share index will test the efficiency of the exchange over the period January 2001 to January 2015. However, the NSE ASI was only initiated in 2008 and the data is available from February 2008 to January 2015. This shall be the longest period on any study on the market efficiency of the NSE. It will be tested on the Main Investment Market Segment of the NSE. Daily and weekly market data of the NSE 20 share index and the NSE ASI will be used in testing the efficiency of the NSE over the period of the study.

1.7 CHAPTERS OUTLINE

The following is the proposed chapter outline for this study:

Chapter 1: Introduction

The importance of a stock exchange on the economy is highlighted. A brief overview of the NSE is conferred. The research problem, research objectives as well as significance of the study, are discussed.

Chapter 2: Literature Review

The EMH theory is fully debated. Studies of the EMH in the developed markets, emerging markets and African markets are discussed. Finally studies on the same on the Kenyan market are analysed.

Chapter 3: Research Design and Methods

The research design used in the study is discussed. The four methods that were used to analyse the daily and weekly market data, are fully discussed. These methods are the serial correlation test, unit root tests, runs test and variance ratio test.

Chapter 4: Discussion of Results

Analysis of daily and weekly index data over the period 2001 and 2015 based on the four methods: serial correlation test, unit root test, runs test and the variance ratio test.

Chapter 5: Conclusion

A summary of the findings, the conclusion of the study, a summary of the contribution and a recommendation for future research will be discussed.

1.8 SUMMARY

This chapter discussed the background of the study, a brief theory of the EMH, the research problem, research objectives of the study. An outline of the chapters was provided. The next chapter will delve more into the theory of efficient markets in addition to empirical research on the various markets.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will discuss the theory of efficient market hypothesis, the determinant of efficient markets, types of market efficiency, the relationship between behavioural finance and market efficiency, adaptive market hypothesis, critic of the efficient market hypothesis, and finally a discussion on empirical research on efficient markets hypothesis on developed, emerging and African markets.

2.2 EFFICIENT MARKET HYPOTHESIS (EMH) THEORY

An efficient capital market adjusts security prices rapidly due to the infusion of new information. Current security prices therefore fully reflect all available information and are referred to as an informationally efficient market (Reilly and Brown 2003). Informational efficiency relates to the impact of information on market prices. The core of the EMH theory is about 'what' 'when' and 'how' information is used to determine prices on the markets (Ma 2004).

There are several assumptions that imply an efficient capital market:

1. "A large number of profit maximising participants who analyse and value securities independent of each other's.

2. New information regarding securities comes to the market in a random fashion, and the timing of one announcement is generally independent of others.

3. Profit-maximising investors adjust security prices rapidly to reflect the effect of new information. Although the price adjustment may be imperfect, it is unbiased. This means that sometimes the market will over-adjust and other times it will under-adjust, but you cannot predict which will occur at any given time. Security prices adjust rapidly because of the many profit-maximising investors competing against one another (Reilly and Brown 2003:177)".

The combination of the first and second assumption means that one would expect price changes to be random and independent. The adjustment process requires a large number of investors following the movements of the security, analysing the impact of new information on its value, and buying/selling the security until its price adjusts to reflect the new information. This means that efficient markets require some minimum amount of trading and that more trading by many competing investors should cause a faster price adjustment, in effect making the market more efficient (Reilly and Brown 2003).

According to Fama (1970), the EMH is a finance theory that explains that information is quickly reflected in share prices such that investors are not able to earn excessive risk adjusted returns. The author continues that the theory of efficient markets is concerned with whether prices at any point in time “fully reflect” available information. The theory only has empirical content, however, within the context of a more specific model of market equilibrium, that is, a model that specifies the nature of market equilibrium when prices “fully reflect” available information.

Fama and Litterman (2012) add that market efficiency indicates that prices reflect all available information and hence provide accurate signals for allocating resources to their most productive uses which is a fundamental principle of capitalism. In order to test market efficiency, a model is needed that describes what the market is trying to do in setting prices. Furthermore, it needs to specify the equilibrium relation between risk and return that drives prices, the reverse is also true. Majority of the asset pricing models assume that markets are efficient.

There is a natural mechanism for financial markets to converge towards an efficient state through price competition among market operators and exploitation of available arbitrage opportunities. As more market operators perform these arbitrage operations to take advantage of the price differential, it forces the share prices to their efficient values. Subsequently, profit opportunities are eliminated as the market moves to equilibrium, at this point the market is efficient. The convergence mechanism explains the process through which the market learns about new information. The speed of convergence is as quick as the market is liquid and large, and information is freely accessible and costless (Arouri et al 2010:93).

Chordia, Roll and Subrahmanyam (2005) investigate the speed of convergence to market efficiency. Daily returns for stocks listed on the NYSE are not serially correlated though order imbalances on the same stocks are highly persistent.

However, this can be reconciled if sophisticated investors react to order imbalances within the trading day by undertaking enough countervailing trades to remove serial dependence over a daily horizon. The authors find that it takes place via the pattern of intra-day serial dependence more than five minutes, but less than sixty minutes, for the convergence to market efficiency.

Busse and Green (2002), shed light on the degree of efficiency in a world of rapid information dissemination and fast, low-cost trade execution. The authors find that the prices of stocks discussed react positively during the Midday Call report on CNBC and experience a statistically significant increase. The response to negative reports is larger but more gradual. There is less evidence of a price response for stocks reacting positively during the Morning Call which suggests that either the information is already known by the market or not very relevant. The evidence from the study supports the view that active traders enhance market efficiency. Even though security prices do not fully reflect all information instantaneously, the market is efficient. Unless a trader acts almost immediately, he cannot generate profits based on widely disseminated news.

Goldman and Sosin (1979) conducted a study on information dissemination, market efficiency and the frequency of transactions. The authors observe that in contrast to the NYSE where, during trading hours, trades may be carried out almost continuously, the Paris Stock Exchange trades each security only a handful of times a day. Furthermore, this continental contrast in market structure led the authors to re-examine the role of speed in markets. The study finds that if sufficient uncertainty surrounds the dissemination of information, frequent transacting may be harmful to market efficiency. The hypothesis that is used in the study is able to show that the study's measure of market efficiency can be maximised when there is a unique non-zero time interval between consecutive trades.

The theory of efficient markets implies that share price movements are unpredictable. If they were not, an investor could accurately forecast that the price of a stock was going to rise tomorrow, and would immediately buy as many shares of the stock as possible. This will increase demand for the share, increasing its price today. The fact that the investor thinks the share's price will rise tomorrow makes it to rise today.

When markets are efficient, the prices at which shares currently trade reflect all available information, so future price movements are unpredictable (Cecchetti 2006).

An efficient market also requires that prices react to information without bias. This means that when new information is announced in the markets, it should be reflected correctly reflected in the prices. Prices should adjust to the new information by moving to an appropriate equilibrium price level and should be stable until further information arrives in the market. Profitable trading strategies can arise in the following cases: if the prices have overreacted to the new information by being higher than the appropriate equilibrium level; or the prices have underreacted to the new information by being lower than the appropriate equilibrium (Ma 2004:43).

2.3 DETERMINANTS OF AN EFFICIENT MARKET

Fama (1970) identified the conditions for efficient capital markets as the absence of transaction costs, freely available information to all agents and homogenous information for current and future asset prices. Yartey and Adjasi (2007) propose that an efficient stock market may reduce the costs of obtaining information by generating and disseminating firm specific information that efficient stock prices reveal. By reducing the costs of acquiring information, it facilitates and improves the acquisition of information about investment opportunities and improves the allocation of resources. Grossman and Stiglitz (1980) affirm that a pre-condition for the efficiency tests is that information and trading costs, that is, the costs of getting prices to reflect information, are always zero. However in reality there is always positive information and trading costs leading to the view that this version of the EMH is false. Ma (2004) reports that market efficiency increases subject to more information being employed correctly and instantly in share trading. It can also increase by reducing the marginal cost of gathering information.

Van Bergen (2011) reports that with the rise of computerised systems to analyse stock investments, trades and corporations, investments are becoming increasingly automated. Some computers given the right power and speed, can immediately process any and all available information and in addition, translate such analysis into an immediate trade execution hence result in increased market efficiency.

Additional suggestions by Van Bergen (2011:2) on how to achieve greater efficiency are:

1. Universal access to high speed and advanced computer systems of pricing analysis.
2. A universally accepted analysis system of pricing shares.
3. An absolute absence of human emotion in investment decision-making.
4. The willingness of all investors to accept that their returns or loses will be exactly identical to all other market participants.

The author adds that it is difficult to imagine even one of these criteria of market efficiency ever being met.

2.4 TYPES OF MARKET EFFICIENCY

A distinction is made between three potential levels of efficiency, each level relating to a specific set of information which is increasingly more comprehensive than the previous one (Keane 1983).

The first one is the weak efficiency where the market is efficient in the weak-form, if share prices fully reflect all security market information implied by all previous price movements. Price movements on one day are not correlated to the previous day's price movements - this is referred to as a 'random walk' (Barnes 2009). This implies the absence of any price patterns with prophetic significance. Moreover, investors are not able to profit from studying charts of past prices. Efficiency at this level rules out the validity of 'trading'-rules designed to produce above-average returns. Prices would respond only to new information or to new economic events (Keane, 1983). Therefore the hypothesis of weak-form efficiency implies that the so-called technical analysis which is based on lines and charts drawn from past prices would be unsuccessful in generating abnormal returns (Ma 2004).

Empirical studies on weak-form efficiency are normally conducted using two approaches. The most common approach is to directly test the random walk of stock prices. There is no rule that can be employed to gain abnormally high returns, if the stock prices behave like a random walk, the market is then regarded as a weak-form efficient market. Alternatively if the test statistics reject the RWH, the market is not weak-form efficient. Some popular methodologies that are used on this approach are the serial correlation coefficient test, the runs test and the variance ratio test (Ma 2004). The next approach is to establish whether trading based on a strategy created using past price performance, can earn abnormal returns. The test rejects the weak-form efficiency hypothesis if replicating a strategy, can earn abnormal returns. A traditional technique used in this case is called a filter introduced by Alexander (1961). This technique infers that if the price of a share moves up at least by x-percent, buy and hold the share until the price moves down at least by x-percent from a subsequent high, whereby the share can be sold and held in a short position. Therefore repeating the filter strategy cannot generate abnormally high returns in a weak-form efficient market (Ma 2004).

Reilly and Brown (2003:178) state, "This hypothesis implies that past rates of return and other historical market data should have no relationship with future rates of return". This is the least restrictive form of efficiency where the information subset is historical prices and return sequences. These tests are the most voluminous and the results are strongly in support (Brearley 1969). Jefferis and Smith (2004), summarise that stock markets that are weak-form efficient, have stock prices that fully reflect all historical information and do not provide information about future price changes. In case they do, there will be profit-making opportunities for investors and markets would be imperfect.

Fama (1970) indicates that the second form is the semi-strong efficiency. The semi-strong tests are the less restrictive form of market efficiency. In this case the information subset of interest includes all obviously publicly available information. Reilly and Brown (2003) establish the market is efficient in the semi-strong form, if share prices respond instantaneously and without bias to newly published public information. It, in effect, means that current share prices fully reflect all public information. The semi-strong hypothesis includes the weak-form hypothesis, because all the market information considered by the weak-form hypothesis is public. Public information also includes all non-market information, for instance, earnings, price-to-earnings and stock splits.

Reilly and Brown (2003:176) claim, “This hypothesis implies that investors who base their decisions on any important new information after it is public, should not derive above-average risk-adjusted profits from their transactions considering the cost of trading because the security price already reflects all such new public information”. Barnes (2009) states that the imperative point about the semi-strong form is that in addition to identifying that it refers only to publicly available information, it also recognises the existence of inside information, and that those in possession of it can outperform the stock market.

Studies on the semi-strong form of market efficiency generally test if there are abnormal returns associated with the issuance of information to the public (Ma 2004). If prices cannot react to the new information correctly, there should be an opportunity to make abnormal returns. The clearest and most reliable test for the abnormal returns with regards to the announcement of public information is called an event study. The first stage of the event study is to determine what the new information is. An example of this would be announcements of dividend issue and annual report stock splits. The second stage is the timing of the release of the announcement. The final stage is estimation of the abnormal return related to the announcement needs to be estimated.

The third form of efficiency is the strong-form efficiency which asserts that stock prices reflect all information from public and private sources. There is no group of investors that has monopolistic access to information relevant to the formation of prices. This hypothesis argues that no group of investors should be able to consistently derive above-average risk-adjusted rates of return (Reilly and Brown 2003). It includes the weak-form and the semi-strong form efficiency. In addition, the strong-form broadens the assumption of efficient markets, in which prices adjust rapidly to release of new public information, to assume perfect markets, in which all information is cost-free and available to everyone at the same time.

Fama (1970) theorises that the strong-form tests that are concerned with whether individual investors or groups have monopolistic access to any information relevant for price formation. The author point out that one would not expect such an extreme model to be an exact description of the world, and it is probably best viewed as a benchmark against which the importance of deviations from market efficiency can be judged. Barnes (2009) observes that all large markets are efficient in the weak and semi-strong forms, but they are not efficient in the strong form. Insiders and others who profit from inside information exist on a fairly large scale. The author argues that academics have had access to the necessary information to test the other forms of the EMH, however, they are unable to test the strong form because of the secrecy of inside traders. Moreover, Barnes (1996) insists that the academics have only been able to infer from observed market reactions before the announcement of important information that insider dealing has occurred to an extent that it has caused share prices to change.

Those who are likely to have privileged information are portfolio managers, corporate insiders and security analysts (Ma 2004). One way to determine this, is through an audit to identify whether there was a favourable bulk trade made by the suspected individual before the announcement of the information, either by purchasing a large number of shares in advance of a 'good' news release or selling a large number of shares before a 'bad' news release meaning that the private information has been employed. Empirical testing of strong form efficiency is difficult and more complicated than the tests of weak-form efficiency or semi-strong efficiency. Mainly due to it being almost impossible to identify the data on which the insiders access the private information. In addition, the differentiation between an abnormal return generated by reasonable analysis of public information and that generated by employing private information is difficult to distinguish. Ma (2004) finally emphasises that the insider always disguises the abnormal returns obtained by getting private information. Hence, the reference material relevant to insider trading is difficult to obtain.

According to Keane (1983) the importance of efficient market theory is that the creation of wealth depends on the optimal allocation of invest capital which is likely to be achieved through the securities markets. Security prices can be relied upon, firstly to reflect the economic signals which the market receives for the purpose of constructing their investment portfolios and secondly to provide useful signals to both suppliers and users of capital for establishing criteria for the efficient disposition of the funds at their disposal. Lack of confidence in the pricing efficiency of the market tends to focus the attention of both investors and raisers of capital away from a more positive recognition of the messages contained in the market's prices and instead focussing on potentially wasteful techniques of exploiting perceived inefficiencies. Therefore, it is critical to know whether the market's pricing mechanism is reliable, because, to the extent that it is, a set of decision-rules significantly different from those which are customarily advocated amongst market participators can be shown to be appropriate.

Keane (1986:63) argues that there is little dispute that the accumulated empirical evidence is inconsistent with any view other than the market, is a highly efficient information processor. However, what is not in agreement is the degree of efficiency, that is, whether there is adequate deviation in price behaviour to make it valuable for the ordinary investor to seek out opportunities for abnormal gain or whether the reasonable policy for most investors is simply to buy and hold an internationally diversified portfolio.

Support for the EMH is emphasised by Malkiel (2003:4) who referring to developed markets, indicates that "our stock markets are far more efficient and far less predictable than some recent academic papers would have us believe. Moreover, the evidence is overwhelming that whatever anomalous behaviour of stock prices may exist, it does not create a portfolio trading opportunity that enables investors to earn extraordinary risk adjusted returns". The author expounds that the main obstacle to inferences about market efficiency, is not the ambiguity about information and trading cost, but rather the joint-hypothesis problem is more serious. The joint testing refers to testing a proposition about equilibrium risk pricing (testing asset pricing models) and testing market efficiency (Fama and Litterman 2012). This means that the market efficiency must be tested jointly with some model of equilibrium, an asset-pricing model. Empirical literature on efficiency and asset-pricing models passes the acid test on scientific usefulness (Malkiel, 2003:4).

2.5 BEHAVIOURAL FINANCE AND MARKET EFFICIENCY

Another aspect of market efficiency is behavioural finance (Ritter 2003). It encompasses research that drops the traditional assumptions of expected utility maximisation with rational investors in efficient markets. It has two building blocks; the first being the cognitive psychology which is how people think, and secondly the limits to arbitrage which is when markets will be inefficient. The author argues that 'EMH argues that competition between investors seeking abnormal profits drives prices to their "correct" value. The EMH does not assume that all investors are rational, but it does assume that markets are rational. The EMH does not assume that markets can foresee the future, but it does assume that markets make unbiased forecasts of the future. In contrast, behavioural finance assumes that, in some circumstances, financial markets are informationally inefficient. (Ritter 2003:430)'.

In behavioural finance, over-confidence is known as a prevalent psychological bias, which can make markets less efficient by creating mispricing through excess volatility and return predictability (Ko and Huang 2007). The study develops a model in which over-confidence cause investors to over-invest in information acquisition when this information could improve market efficiency by moving prices closer to their true values. The impact of over-confidence on mispricing and information acquisition comparing their net effect on prices is studied. The authors find that over-confidence by and large improves market pricing as long as the level of overconfidence is not too high. Moreover, pricing can also improve even when over-confidence is high, depending on the amount of private information acquired compared to publicly available information.

Timmermann and Granger (2004) noted that if the behaviour of investors produces efficient markets by their continuous profit seeking, the reverse is that the EMH does not rule out predicting many other variables that although of general interest are not the basis for a profit making strategy. The authors indicate that these short-lived gains are likely to be made by the first users of new financial prediction methods. As these methods get widely used, the information may get incorporated into prices and the profits will cease to exist. The race for innovation to access gains will give rise to new generations of financial forecasting methods.

In defence of the EMH, Fama (1998:283) reports that "market efficiency survives the challenge from the literature on long-term return anomalies. Consistent with the market efficiency hypothesis that the anomalies are chance results, apparent over-reaction to information is about as common as under-reaction, and post-event continuation of pre-event abnormal returns, is about as frequent as post-event reversal. Most important, consistent with the market efficiency prediction that apparent anomalies can be due to methodology, most long-term return anomalies tend to disappear with reasonable changes in technique."

As a critic to Fama (1998:283), Shiller (2003:101-102) indicates that Fama's first criticism reflects an incorrect view of the psychological underpinning of behavioural finance. Since there is no fundamental psychological principle that people tend always to over-react or always to under-react, it is therefore no surprise that research on financial anomalies does not reveal such a principle either. Shiller (2003), observes that the second criticism is also weak. It is the nature of scholarly research, at the frontier, in all disciplines that initial claims of important discoveries are knocked down by later research. For instance, the most basic anomaly, of excess volatility relative to what would be predicted by the efficient markets model calls into question the basic underpinnings of the entire theory. Evidence regarding excess volatility seems to some observers at least, to imply that changes in prices occur for no fundamental reason at all.

Chaffai and Medhioub (2014) study the influence of psychological and emotional factors on the behaviour of Tunisian stock market investors. The study seeks to explain how the behavioural finance can affect the Tunisian stock market, firstly based on a questionnaire distributed to the Tunisian investors in the stock market and secondly, by using the multiple correspondence analysis. The study concludes that persons having a high level of education are subject to behavioural biases and agents who invest amounts between 1,000 and 20,000 Tunisian Dinars, are most vulnerable to behavioural biases leading to the conclusion that the information on the market cannot lead to market efficiency.

2.6 ADAPTIVE MARKET HYPOTHESIS (AMH)

In financial markets, the weak-form of the EMH infers that price returns are serially uncorrelated sequences, that is, prices should follow random walk behaviour (Rodriquez, Aguilar-Cornejo, Femat and Alvarez-Ramirez 2014). However, the authors add that recent developments in evolutionary economic theory (Lo 2004), have come up with a new version of the EMH, the concept - adaptive market hypothesis (AMH) by proposing that market efficiency is not an all-or-none concept, instead market efficiency is a characteristic that changes continuously over time and across markets.

Lo (2005) argues that the battle between proponents of the EMH and champions of behavioural finance has never been more pitched with little consensus as to which side is winning or what the implications are for investment management and consulting. The AMH is a paradigm under which the EMH and market inefficiency can co-exist in an intellectually consistent manner (Lo 2004). Convergence to equilibrium is therefore neither guaranteed, nor likely to occur, and it is therefore incorrect to assume that the market must move towards some ideal state of efficiency (Lo 2005).

A study by Urquhart and Hudson (2013), empirically investigates the AMH in three of the most established stock markets in the world; the US, UK and Japanese markets using very long run data. Five yearly sub-samples are created using daily data and are then subjected to linear and non-linear tests to determine how the independence of stock returns has behaved over time. Results from the linear auto-correlation, runs and variance ratio tests show that each market has evidence of being an adaptive market with returns going through periods of independence and dependence. Interestingly, the results from the non-linear tests show strong dependence for every sub-sample in each market, however, the magnitude of dependence differs quite significantly. The linear dependence of stock returns varies over time but non-linear dependence is strong throughout. The overall results indicate that the AMH provides a better description of the behaviour of stock returns than the EMH.

AMH is tested through four well-known calendar anomalies (Monday effect, January effect, Halloween effect and turn-of-the-month effect) in the Dow Jones Industrial Average from 1900 to 2013 (Urquhart and McGroarty 2014). Sub-sample analysis and rolling window analysis are used in the study. Implied investment strategies based on each calendar anomaly are created and determinations of which market conditions are more favourable to the calendar anomaly performance are considered. The findings show that all four calendar anomalies support the AMH with each calendar anomaly's performance varying over time. However, some of the calendar anomalies are only present during certain market conditions. Overall, the study shows that the AMH offers a better explanation of the behaviour of calendar anomalies than the EMH.

Ghazani and Araghi (2014) examine the existence of the AMH as an evolutionary alternative to the EMH by applying daily returns on the TEPIX index in the Tehran Stock Exchange in Iran. The sample period is from 1999 to 2013. Four different tests (linear and non-linear) are used to study adaptive behaviour of returns. The study finds from linear (automatic variance ratio and automatic portmanteau) and non-linear (generalised spectral and McLeod-Li) tests represent the oscillatory manner of returns about dependency and independency which is in line with the AMH.

2.7 VIEWS NOT IN FAVOUR OF THE EFFICIENT MARKET HYPOTHESIS (EMH)

Grossman and Stiglitz (1980:405) argued that "because information is costly, prices cannot perfectly reflect the information which is available, since if it did, those who spent resources to obtain it would receive no compensation. There is a fundamental conflict between the efficiency with which markets spread information and the incentives to acquire information". There are two serious flaws on the EMH that have been identified by Anderson (1983). The first is that asset prices are indeterminate and the second being the notion of information not being well defined, hence bringing into question the assumptions of the EMH. Furthermore, Anderson (1983) alleges that the definition of rational expectations as being "expectations formed conditionally on all available information", is ambiguous since it may not be possible to define the relevant information set in a precise way. This then gives the view that stock markets are highly imperfect and liable to speculative manias which is not consistent with the assumptions of the EMH.

Cunningham's (1994) stance is that history reveals that the random walk model is based on linear mathematical models which have become obsolete due to the recent advances in the mathematics of non-linear dynamics. A new perspective for analysing public capital markets that breaks down the binary perception of markets as either efficient or not efficient, is offered by the chaos theory which suggests that the problem is not so simple. The author instead offers insights that provide for a broader vision of both public capital markets and the appropriate nature and degree of rules to regulate them hence implying that what makes markets inefficient, are deeper structural forces. Therefore, it calls for the opening of a new chapter in a broad range of securities and corporate law issues that focus on the non-linear aspect of EMH which, nearly for two decades, have been dominated by linear thought, policy and practice in American corporate life (Cunningham 1994).

According to Ball (2009:13) the limitations of the EMH are six-fold:

1. The EMH theory does not make any statements about the 'supply side' of the information market with regards to how much information is available, whether it comes from accounting reports, government statistical releases, what its reliability is, how continuous it is, the frequency of extreme events and so forth. This is because the theory only addresses the demand side of the market by indicating that given the supply of information, investors will trade on it until there are no further gains from trading.
2. The author notes that information is modelled in the EMH as an objective commodity that has the same meaning for all investors, while in reality each investor could have different information and beliefs.
3. Information processing is assumed in the EMH to be costless, and thus information is incorporated into prices immediately and accurately. However, while the cost of acquiring public information is negligible, the cost of processing information is not considered in the EMH.
4. The EMH assumes the markets are costless to operate although in reality stock markets though low-cost are not entirely costless.

5. The EMH implicitly assumes continuous trading thus ignores liquidity effects. The study notes that there is evidence that illiquidity is a ‘priced’-factor, hence the lower liquidity should be compensated with higher returns despite the fact that the measure of liquidity is unclear. This was highlighted in the 2007 global financial crisis when liquidity was a major factor.
6. EMH does not take into account taxes since investors pay taxes on dividends and capital gains.

Ball (2009) identified aspects of limitations of the EMH which are in terms of the limitations of the tests themselves. Testing the efficiency of the price response to information is done by comparing the returns earned from trading on the information with the returns expected from passive investing. Early empirical work used the Capital Asset Pricing Model (CAPM) which is a one factor model to estimate expected returns. The authors however, indicate that CAPM did a poor job of predicting returns on average because it was either a bad model or the betas were difficult to measure accurately. This led to the use of the Fama-French three-factor model which is better in predicting returns though it seems to be based more on a foundation of empirical correlations, than on solid asset pricing theory (Ball 2009). Since tests of market efficiency are “joint tests” which as earlier explained by Fama and Litterman (2012), refer to testing a proposition about equilibrium risk pricing (testing asset pricing models) and (testing) market efficiency. Therefore, the market’s ability to incorporate new information in prices and a particular model of asset pricing, any error in the model affect the reliability of the test of efficiency.

Haug and Hirschey (2006) contribute that analysis of broad samples of value-weighted and equal-weighted returns of US, equities documents that abnormally high rates of return on small-capitalisation stocks continue to be observed during the month of January. A possible explanation for the January effect was that tax reporting prior to 1987 was in the December-January reporting period however the Tax Reform Act of 1986 changed the reporting period to October to November therefore there should not be any seasonal tendencies. However, the January effect in small-cap stock returns is remarkably consistent over time. After a generation of intensive study, the January effect continues to be a serious challenge to the EMH.

Basu (1977) empirically investigates the relationship between investment performance of equity securities and their P/E ratios. The EMH denies the possibility of earning excess returns, but the price-ratio hypothesis asserts that P/E ratios due to exaggerated investor expectations may be indicators of future investment performance. This is implied by low P/E portfolios earning superior returns on a risk-adjusted basis. This leads to the belief that the suggestion of the price-ratio hypothesis on the relationship between investment performance of equity securities and their P/E ratios to be valid. This is inconsistent with the EMH.

Schwert (2003) reports on the size effect. The author mentions that Banz (1981); and Reinganum (1981); indicated that small-capitalisation firms on the NYSE, inducted the higher average returns than was predicted by Sharpe (1964) – Lintner (1965) capital asset pricing model (CAPM) from 1936 to 1975.

Schwert (2003) also reports on the turn-of-the-year effect. This effect was illustrated by Keim (1983); and Reinganum (1983); where most of the abnormal return to small firms (measured relative to CAPM) occurs during the first two weeks in January. Roll (1983) posited that the higher volatility of small-capitalisation stocks caused more of them to experience substantial short-term capital losses that investors might want to realise for income tax purposes before the end of the year. As a result, the prices of small-cap stocks may be reduced in December due to the selling pressure leading to an increase in prices in early January, as investors repurchase these stocks to re-establish their investment positions.

A new hypothesis: that the EMH is day-of-the-week-dependent is proposed, by applying the test to firms belonging to the banking sector and listed on the NYSE (Narayan, Narayan, Popp and Ahmed 2015). There is significant evidence that the EMH is day-of-the-week dependent. The authors find that for 62% of firms, the unit root null hypothesis is rejected on all the five trading days, in addition, when investors do not account for unit root properties in devising trading strategies, they obtain spurious profits.

There is a link between the number of institutional investors and information efficiency of prices in an exchange. Boehmer and Kelley (2009) examine how institutional activities affect the relative informational efficiency of prices, in a broad sample of NYSE stocks between 1983 and 2004. The study finds that stocks with greater institutional ownership are priced more efficiently and that variation in liquidity does not drive this result. One mechanism through which prices become more efficient is institutional trading activity, even when institutions trade passively. Efficiency is also directly related to institutional holdings even after controlling for institutional trading, analyst coverage, short selling, firm characteristics and variation in liquidity.

Panagiotidis (2005) investigates the relationship between market capitalisation and efficiency for the Athens Stock Exchange (ASE). The EMH is tested for this market after introduction of the euro for three different indices. The underlying assumption is that stock prices would be more transparent; their performance easier to compare; the exchange rate risk eliminated and as a result the new currency should strengthen the argument in favour of the EMH. The FTSE/ASE 20, which consists of 'high capitalisation' companies and the FTSE/ASE Mid 40, which consists of medium sized companies and the FTSE/ASE Small Cap which covers the next 80 companies, are used. The RWH is rejected in all these cases.

Daouk, Lee and Ng (2006) examine the link between capital market governance (CMG) and several measures of market performance. The authors develop a composite CMG index that captures three dimensions of security laws:

1. the degree of earnings opacity,
2. the enforcement of insider laws, and
3. the effect of removing short-selling restrictions.

The findings of the study show improvement in the CMG index are associated with decreases in the cost of equity capital, increases in market liquidity (trading volume, market depth and US foreign investments), and increases in market pricing efficiency (reduced price synchronicity and IPO under-pricing).

2.8 FINANCIAL CRISIS AND STOCK MARKET EFFICIENCY

Lim, Brooks and Kim (2008) investigate the effects of the 1997 financial crisis on the efficiency of eight Asian stock markets applying the rolling bi-correlation test statistics for the three sub-periods of pre-crisis, crisis, and post-crisis. On a country-by-country basis, the results demonstrate that the crisis adversely affected the efficiency of most Asian stock markets, with Hong Kong being the hardest hit, followed by Philippines, Malaysia, Singapore, Thailand and Korea. However, most of the markets recovered in the post-crisis period in terms of improved market efficiency.

Lim (2008) empirically examined the relative efficiency of eight economic sectors in the Malaysian stock market and the impact of the 1997 Asian financial crisis on the reported sectorial efficiency. The rolling bi-correlation test statistic was used over the period 1st January 1994 to 31st October 2006. The sector of tin and mining is found to be the most efficient, while the property sector experiences the most persistent deviations from random walk over time. The subsequent sub-periods analysis reveals that the highest inefficiency occurs during the crisis period for all economic sectors except tin and mining. However, all these seven crisis-stricken sectors managed to stage a turnaround in the USD pegged period where capital controls were imposed by the Malaysian government.

Mahmood, Xinping, Shahid and Usman (2010), examine the efficiency of the Chinese stock market and the impact of the global financial crisis on the efficiency of the Chinese stock market. Data is divided into two periods, one before the global financial crisis and the other, during the crisis. Various tests are applied on stock market returns to determine the unit root in data series for both the Shenzen and Shanghai stock exchanges separately. The findings indicate that the Chinese stock market is weak-form efficient, hence, past data of stock market movements may not be useful to make excess returns and the global financial crisis has no significant impact on the efficiency of the Chinese stock market.

Smith (2012) in a study on the changing and relative efficiency of European emerging stock markets finds that the global financial market crisis of 2007-2008 coincided with return predictability in the Croatian, Hungarian, Polish, Portuguese, Slovakian and UK stock markets. However, not all markets were affected, the crisis had minimal impact on weak-form efficiency in stock markets in Greece, Latvia, Romania, Russia and Turkey.

Rejeb and Boughrara (2013) investigate the impact of financial liberalisation on the degree of informational efficiency in emerging stock markets taking into account the effect of financial crises. A treatment effects model with time-varying parameters is estimated for 13 emerging economies from January 1986 to December 2008. The study finds that there is greater efficiency in recent years and financial liberalisation not only improves the degree of efficiency, but it also decreases the probability of financial crises. The authors suggest that improving efficiency depends upon certain internal characteristics, such as the level of development, the degree of liquidity and the quality of investment that are themselves functions of the evolution of financial liberalisation process.

Choudhry and Jayasekera (2012) conduct a study that compares the efficiency characteristics between the banking sectors of the UK and the US during the global financial crisis of 2007 to 2011. Results show that most banks in the UK and the US seem to support the market efficiency during both the pre-crisis and crisis periods. The level of market efficiency however seems to decline significantly from the pre-crisis to the crisis period.

Hiremath and Kumari (2014) investigate the AMH in India. The linear test results indicate a cyclical pattern in auto-correlations suggesting that the Indian stock market switched between periods of efficiency and inefficiency and more importantly, the market has become efficient from the year 2003. The non-linear test results indicate strong presence of non-linear dependence in Indian stock returns throughout the sample period, indicating possible predictability of returns and consequent excess returns. The non-linearity in stock returns was highest during various financial crises' originating outside India, showing an association of informational inefficiency and financial crises. In addition, the vulnerability of the Indian stock market to the external shocks in a financially liberalised economy is evident from the outflow of foreign institutional investments owing to external events. There is evidence of the influence of financial crises and large reversal (outflow) of foreign institutional investment on efficiency of stock market, should be interpreted as identifying an association rather than causality. The study finds that the Indian stock market is still evolving and not fully adaptive. The linear independence weaker presence of non-linear dependence in returns from 2009 is sufficient to conclude that the Indian stock market is moving towards efficiency.

A study conducted by Choudhry and Jayasekera (2014), empirically investigates the asymmetric effect of news on the time-varying beta of selected banks from seven European countries during the crisis and pre-crisis periods. It applies daily data from thirteen large banks from France, Germany, Greece, Ireland, Italy, Portugal and Spain. The sample size ranges from 2002 to 2013 and includes the current global financial crisis (2007 to 2013). The bivariate BEKK GARCH model is first used to estimate the time-varying beta and then linear regression is applied to investigate the asymmetric effect of news on the beta. The asymmetric effects are investigated based on both market and non-market shocks. Results show that some evidence of market efficiency can be seen via non-market shocks; however, the market shocks indicate that the European banks foster a significant amount of uncertainty leading to asset mispricing. These results have some implications to investors, especially hedge funds, as they would be presented with relatively more profitable arbitrage opportunities during a crisis period, where asset mispricing is evident.

2.9 DEVELOPED MARKETS

A study by Kim, Shamsuddin and Lim (2011) finds strong evidence of time-varying return predictability of the Dow Jones Industrial Average Index from 1900 to 2009. Return predictability is found to be driven by changing market conditions consistent with the implication of the AMH. No statistically significant return predictability is observed during market crashes however, return predictability is associated with a high degree of uncertainty. During times of economic or political crises, stock returns have been highly predictable with a moderate degree of uncertainty in predictability. The study finds return predictability has been smaller during economic bubbles than in normal times, in addition evidence shows that return predictability is associated with stock market volatility and economic fundamentals. The study finds evidence that inflation, risk-free rates and stock market volatility, are important factors that influence stock return predictability over time. Furthermore, there is evidence that the US market has become more efficient after 1980 which is probable as the US market has implemented various measures of market innovation in the 1960s and 1970s, and macro-economic fundamentals have become much more stable since 1980. Apart from the sub-prime lending crisis, there have been fewer occurrences of major economic and political crises after 1980, than before that period. The findings of the study align with the AMH, which argues that dynamic market conditions direct the degree of stock market efficiency.

Ito and Sugiyama (2009) measure a time-varying structure of market inefficiency and find the degree of market inefficiency varies through time. Data from the monthly returns of the S&P 500 stock index from January 1955 to February 2006 is used. The US stock market was the most inefficient during the late 1980s as the estimated coefficients climb to the highest level during the whole sample period. The estimated coefficients have a falling trend from the late 1990s, and go to the lowest level at the year 2000. The US stock market becomes the most efficient around the year 2000 in the last half-a-century.

In testing the efficiency of some developed markets, Chan, Gup and Pan (1992) examined the relationships among the stock markets in Hong Kong, South Korea, Singapore, Taiwan, Japan and the United States. The findings of the study suggest that the stock prices in major Asian markets and the United States are weak-form efficient in the long run. Borges (2010) tests the weak-form market efficiency to stock market indexes of the UK, France, Germany, Spain, Greece and Portugal over the period, January 1993 to December 2007, using runs test and the joint variance ratio tests. The findings of the study reveal mixed evidence of the EMH. The hypothesis is rejected on daily data for Portugal and Greece due to first-order positive auto-correlation in the returns. France and UK data rejects the EMH due to the presence of mean reversion in weekly data - this reversion has been stronger in recent years. The tests for Germany and Spain do not allow the rejection of the EMH hence, making them to be the most efficient. Cajueiro and Tabak (2004a; 2005) find that for the developed markets, US and Japan are the most efficient in their study with the US being the most efficient.

Hung, Lee and Pai (2009) re-examine the market-efficiency for large and small capitalisation of the TOPIX (Tokyo Stock Price Index) and FTSE using parametric and non-parametric Variance ratio tests of, Lo and MacKinlay (1988), and Wright (2000). The results show that the weak-form EMH, is supported for large-cap stock indices; however, it is rejected for the small-cap indices. Rolling multiple variance ratio tests are further used to confirm the results.

Jarrett (2008) investigates the weak-form of the EMH for the Hong Kong Stock Exchange, which is the largest exchange in the Pacific-Basin of Asia. Data is collected on 601 firms listed on the Hong Kong Stock Exchange in 2002. The study seeks to determine whether the data indicate that the time-series of closing prices is a random walk, or if there are predictable properties. The results indicate that predictive short-term properties exist, allowing a forecaster to conclude that the time series of closing prices are not random. Hence, the market is not weak-form efficient. A prior study on the Hang Seng Index on the Hong Kong Stock Exchange used variance ratio tests with both homoscedastic and heteroscedastic error variances to examine the RWH (Cheung and Coutts 2001). The results suggested that the Hang Seng follows a random walk model, thus the index is weak-form efficient.

Gan, Lee, Hwa and Zhang (2005) re-examine the market efficiency in New Zealand Stock Exchange and Australia Stock Exchange stock indices to investigate whether Groenewold's (1997) findings still hold in the period after financial liberalisation from January 1990 to January 2003. It also seeks to establish whether the US NYSE and the Japanese NIKKEI stock indices have any influence on the NZSE and ASX indices. The finding of the study shows evidence of weak-form efficiency for NZSE and ASX stock indices using the Augmented-Dickey Fuller and Phillip-Perron unit root tests. In opposition to the initial findings, the Engle-Granger co-integration test results suggest that the NZSE stock index is co-integrated with and granger caused by the ASX index, both violating the semi-strong form market efficiency of NZSE. Even though the NZSE is a small stock market, its stock index is relatively independent in comparison to the NYSE and NIKKEI stock indices.

In a study to determine a closing call's impact on market quality at Euronext Paris, Pagano and Schwartz (2003) analyse the impact of the innovation on market quality. It entails Euronext Paris refining its trading system to include electronic call auctions at market closing in 1996 for its less liquid continuous B-stocks, and in 1998 for its more actively traded continuous A-stocks. Results of the study indicate the introduction of the closing calls, lowered execution costs for individual participants and improved price discovery for the larger market. Moreover, market quality is improved at market openings.

Lee, Gleason and Mathur (2000) addresses the efficiency of the French International Futures and Options Exchange, by testing four financial contracts traded on the MATIF-CAC40 Index futures, ECU Bond Futures, National Bond Futures and PI-BOR 3-Month Futures. The findings from serial correlations, unit root tests and variance ratio tests indicate that the RWH cannot be rejected for these contracts.

The description of equity market return series as random in nature has been questioned in recent times by application of new statistical tools (Opong, Mulholland, Fox and Farahmand 1999). The authors conduct a study using recent advances in chaos theory to examine the behaviour of the FTSE All Share, 100, 250, and 350 equity indices. The study rejects the hypothesis that the index series examined in this study are random, independent and identically distributed. The findings show that the FTSE stock index returns series is not truly random, as some cycles or patterns show up more frequently than would be expected in a true random series.

The validity of the weak-form of the EMH is tested for the London Stock Exchange on the FTSE 30 share index where it is found to not be valid (Al-Loughani and Chappell 1997). This series therefore does not follow a random walk. The period chosen for the study is during a time when economic policy specifically relating to financial markets is expected to be relatively homogeneous. Hence, any departure from random walk will not have been brought about by changes in government policy.

Worthington and Higgs (2009) study the weak-form market efficiency of the Australian stock market. Daily returns from 6th January 1958 to 12th April 2006 and monthly returns from February 1875 to December 2005, are tested for random walks using serial correlation coefficients and runs tests, Augmented Dickey-Fuller, Phillips-Perron and Kwiatkowski, Phillips, Schmidt and Shin unit root tests and multiple variance ratio tests. The results from serial correlation tests indicate inefficiency in daily returns and borderline efficiency in monthly returns, whereas the runs tests show that both series are weak-form inefficient. Unit root tests propose weak-form inefficiency in both return series. Findings of the more stringent and least restrictive variance ratio tests show that the monthly returns series is characterised by a homoscedastic random walk, although the daily series violates weak-form efficiency due to the short-term auto-correlation in returns.

Chan, Gup and Pan (1997) carry out a study on 18 countries (Australia, Belgium, Canada, Denmark, Finland, France, Germany, India, Italy, Japan, Netherlands, Norway, Pakistan, Spain, Sweden, Switzerland, United Kingdom and United States) on international stock market efficiency and integration which analyses them individually and collectively in regions to test for the weak-form market efficiency. The study found that the monthly stock indices of these equity markets are efficient individually.

In a study that specifically focused on the Swedish stock market, Frennberg and Hansson (1993) test the RWH on a set of monthly data for the period 1919 to 1990 using both the variance ratio test and the test of auto-regressions of multi-period returns. The study finds that the Swedish stock prices have not followed a random walk in the past 72 years.

Cajueiro, Gogas and Tabak (2009) probe empirical evidence of strong long-range dependence in the end of the 1980s and beginning of the 1990s for the Greek stock market prior to financial market liberalisation that occurred during that period. With the deepening of the liberalisation process, generalised Hurst exponents converged to levels which characterised more efficient and developed markets. The convergence to random walk provides empirical evidence of the benefits of liberalising the capital account and portfolio flows. Stock markets may evolve and converge to more mature markets, increasing their degree of efficiency.

Floros, Jaffry and Lima (2007) analyse the presence of fractional integration or long memory in the daily returns of the Portuguese stock market. The data that covers two periods, 4th January 1993 – 13th January 2006 (full sample) and 1st February 2002 – 13th January 2006 (data is after the merger of the Portuguese Stock Exchange with Euronext). The results from the full sample show strong evidence of long memory in stock returns. When data after the merger are considered, weaker evidence of long memory is found. It is concluded that the Portuguese stock market is more efficient after the merger with Euronext.

Pukthuanthong-Le and Thomas III (2008) find that although they confirmed earlier findings that trend-following trading rules once worked, profitability has been negligible since the year 2000 for the British pound, Swiss franc, Japanese yen and Canadian dollar (based on U.S. dollar futures prices). Trend following has been worthless since the year 2000 for these currencies supporting the notion that the major currency markets have become weak-form efficient after many years of inefficiency. Hakkio and Rush (1989) test for market efficiency and use recent developments in the theory of co-integration to provide new methods of testing various aspects of foreign exchange market efficiency for the sterling and deutschemark exchange markets. The evidence is inconsistent with market efficiency for both Germany and the United Kingdom.

Evidence of random walk behaviour of Euro exchange rates using ranks and signs is investigated by Belaire-Franch and Opong (2005) using the recently developed tests based on ranks and signs as well as the traditional variance ratio tests. The results show that adjustments for multiple tests must be included so as to avoid size distortions. In general, these adjustments provide evidence consistent with random walk behaviour of Euro exchange rates.

The dynamic behaviour of market volatility is assessed by forecasting the volatility implied in transaction prices of the S & P 100 index options (Harvey and Whaley 1992). The study tests and rejects the hypothesis that volatility changes are unpredictable. Although the statistical model delivers accurate forecasts, abnormal returns are not possible in a trading strategy which considers transaction costs into account indicating that predictable time-varying volatility is consistent with market efficiency.

Craig, Dravid and Richardson (1995) inquire whether information is rationally incorporated into stock prices across international markets. The authors find that the Japanese Nikkei index-based futures traded in the US provide full information about simultaneous overnight Japanese returns. Additionally, existing cross-dependence between the US and Japanese stock index returns is incorporated by the information content of the derivatives securities.

Chung and Hrazdil (2010a) in a subsequent study to Chordia, Roll and Subrahmanyam (2008), analyse all NASDAQ firms with respect to their short-horizon return predictability. The findings confirm that increased liquidity enhances market efficiency and show that this effect is increased during periods with new information. After controlling for liquidity and information effects, the NASDAQ firms are shown to experience an improvement in market efficiency, only from the sixteenth to the decimal tick size regimes. The study finds that suggestions of market efficiency are not uniform across the different portfolios formed on the basis of trading frequency, volume and market capitalisation.

Chung and Hrazdil (2010b) in a follow up study on a large sample examine short-horizon predictability from past order flows of large, actively traded NYSE firms, across three tick size regimes concluding that higher liquidity facilitates arbitrage trading which enhances market efficiency. The authors extend the Chordia et al (2008) study, to a comprehensive sample of all NYSE firms and examine the dynamics between liquidity and market efficiency during informational periods. The study finds that although all NYSE firms experience an overall improvement in market efficiency across periods of different tick size regimes, this improvement varies substantially across the portfolios of sample companies formed on the basis of trading frequency, market capitalisation and trading volume. After controlling these factors, the authors find a positive association between a continuous measure of liquidity and market efficiency and show that this effect is increased during periods that contain new information.

2.10 EMERGING MARKETS

In a study on differentiation of emerging equity markets by Kumar and Tsetsekos (1999), the authors argue that emerging security markets as defined by the International Finance Corporation (IFC), have characteristics differentiated from their counterparts in industrialised nations due to differential levels of economic development as well as their origins. The results of the study show that emerging equity markets are not similar to developed markets which in turn support the view that the two sets of markets are segmented. As the institutional infrastructure in emerging markets improves, it is expected that there will be greater convergence between these markets. Institutional infrastructure comprises of a broad legal framework recognising property rights, disclosure requirements, accounting practices conforming to international standards, supervision and regulation of these markets.

Divecha, Drach and Stefek (1992), remark that emerging markets have volatile returns which are homogeneous within each market but, heterogeneous across markets. In these markets, correlations are uniformly higher between stock returns compared to the developed markets (homogeneity effect). The correlations between emerging market stock returns, as well as between emerging market and developed market stock returns tend to be low (heterogeneity effect). In addition, emerging markets have concentrated structures in that a small number of stocks have a significant percentage of the market capitalisation, and the returns of these stocks tend to influence the overall market return. The main factor influencing individual stock returns in emerging markets is the aggregate market return which accentuates volatility.

For years empirical testing has been a subject of major stock markets, the same cannot be said of many emerging markets (Jefferis and Smith, 2004). However, new empirical methods have been developed which provide new opportunity for analysis of efficiency in both developed and emerging markets. Antoniou et al (1997) are of the opinion that the conventional tests of efficiency have been developed for testing markets which are characterised by high level of liquidity, sophisticated investors with access to high quality and reliable information and few institutional impediments. On the other hand, emerging markets are typically characterised by low liquidity, thin trading, possibly less well informed investors with access to unreliable information and considerable volatility. “Tests of market efficiency must take account of the characteristics of the market under investigation. For emerging markets this requires the recognition that there may be non-linearities, thin trading and a changing regulatory framework (market evolution through time). It is only by directly incorporating these issues into tests of efficiency in emerging markets that we can address the more important issue of identifying the forces which lead to markets being efficient or inefficient” (Antoniou et al 1997:180).

The key condition for market efficiency to hold is the quality and availability of market wide and company-specific information. Once this condition is fulfilled, the test of market efficiency can be implemented to evaluate how such information is being processed by the markets. Prior experience implies that in emerging markets, the quality of both information and processing is lower compared to developed markets. Several factors effectively contribute to prevent emerging markets from being efficient markets. These are infrequent and discontinuous trading, low market liquidity, low quality and quantity of information disclosure, untimely financial reporting and inappropriate accounting regulations, capital flow restrictions and market regulation, and discriminatory taxation (Arouri et al 2010).

Bekaert and Harvey (1997) conducted a study on understanding the behaviour of volatility in emerging equity markets. The authors find that volatility in fully integrated markets is strongly influenced by global factors, whereas, in segmented markets it is more likely to be influenced by local factors. The more open economies in terms of world trade are found to have significantly lower volatilities. The study also finds that capital market liberalisation significantly decreases volatility in emerging markets which can have key effect on the cost of capital in these markets.

Lim and Brooks (2010) conduct a study on why emerging stock markets experience more persistent price deviations from a random walk over time. The authors use the rolling bi-correlation test for aggregate stock price indices of 50 countries over the sample period 1995 to 2005. The findings show that stock markets in economies with low per capita GDP, in general experience more frequent price deviations than those in the high income group. This clustering effect is not due to market liquidity or other structural characteristics, but instead can be explained by cross-country variation in the degree of private property rights protection. The assumption is that weak protection deters the participation of informed arbitrageurs, leaving those markets dominated by sentiment-prone noise traders whose correlated trading causes stock prices in emerging markets to deviate from the random walk benchmarks for persistent periods of time.

A similar study on why emerging markets have synchronous stock price movements produced the same results (Morck, Yeung and Yu 2000). The study finds that stock prices move together more in emerging markets than in developed economy stock markets. This finding is not due to market size and is only partially explained by higher fundamentals correlation in low-income economies. However, measures of property rights do explain this difference. The systematic component of returns variation is large in emerging markets, and appears unrelated to fundamentals co-movement, consistent with noise trader risk. Among developed economy stock markets, higher firm-specific returns variation is associated with stronger public investor property rights. The authors propose that strong property rights promote arbitrage, which capitalises detailed firm-specific information.

Arouri et al (2004) reports that only a few studies have focused on testing the informational efficiency of emerging markets, compared to a large amount of works on the US and other developed markets. The authors add that it is widely accepted that the majority of emerging markets are less efficient than developed markets because of some market imperfections. For instance, poor quality of information disclosure, inadequate financial and accounting regulation, thin trading and transaction costs. As a result, recent studies on emerging markets have focused on the weak-form efficiency, whereas literature on developed markets is concerned about all three forms of efficiency.

The martingale hypothesis is tested for 15 European emerging stock markets located in Croatia, the Czech Republic, Estonia, Hungary, Iceland, Latvia, Lithuania, Malta, Poland, Romania, Russia, the Slovak Republic, Slovenia, Turkey and the Ukraine (Smith 2012). Developed stock markets in Greece, Portugal and the UK are also included for comparative purposes. Rolling window variance ratio tests based on returns and signs and with wild bootstrapped *p*-values are used with daily data over the period commencing in February 2000 and ending in December 2009. Changes in efficiency are captured via the fixed-length rolling sub-period window which is also used to identify events which coincide with departures from weak-form efficiency and to rank markets by relative efficiency. Overall, return predictability varies widely. The study finds the most efficient stock markets are Turkish, UK, Hungarian and Polish while the least efficient are the Ukrainian, Maltese and Estonian.

Worthington and Higgs (2006a) investigate the weak-form market efficiency of Asian equity markets. Daily returns for ten emerging markets (China, India, Indonesia, Korea, Malaysia, Pakistan, Philippines, Sri Lanka, Taiwan and Thailand), and five developed markets (Australia, Hong Kong, Japan, New Zealand and Singapore) are examined for random walks. All of the markets are weak-form inefficient based on the serial correlation and runs tests. The unit root tests show weak-form efficiency in all markets, excluding Australia and Taiwan. Variance ratio tests which are stricter indicate that, none of the emerging markets are characterised by random walks hence, are not weak-form efficient. Amongst the developed markets, only Hong Kong, New Zealand and Japan are consistent with the strict random walk criteria.

Karemera, Ojah and Cole (1999) use multiple variance ratio tests of Chow and Denning (1993) to examine the stochastic properties of local currency and US dollar-based equity returns in 15 emerging capital markets. The study finds that the random walk model, is consistent with the dynamics of returns in most of the emerging markets analysed which is in contrast to many random walk test results recognised with the use of single variance ratio techniques. In addition, a runs test, suggests that most of the emerging markets are weak-form efficient.

Ariff (1996) in a study on the effects of financial liberalisation on four South East Asian financial markets (Indonesia, Malaysia, Singapore and Thailand) over the period 1973 to 1994, discovers that significant openness was achieved in the late 1980s with nearly complete current and capital account openness, in Malaysia and Singapore as far back as 1978. Indonesia adopted critical reforms in 1988 while Thailand adopted these in 1990. The author comments that the effects of these major liberalisation policies may be seen in the higher levels of openness and lower levels of inefficiencies in the financial markets of Malaysia and Singapore. The opposite is true for Indonesia and Thailand as would be expected from the relatively less liberalised financial environment until 1988. These markets are found to be more responsive to international factors while that also causes greater financial market efficiency.

Arouri et al (2009) demonstrate that there is significant improvement in informational efficiency in emerging markets over recent years. The convergence speed toward efficiency appears to be higher for markets that have noticeably developed in size and liquidity in addition to embarked on comprehensive liberalisation programs. Though most of the results are country specific, better market conditions before market openings appear to guarantee the positive impact of such policies on informational efficiency. Furthermore, the authors demonstrate that empirical results show that the weak-form efficiency measure fluctuates through time, which is consistent with the gradual changes in emerging markets over the recent decades. Nonetheless the speed of convergence towards efficiency depends on specific conditions in each market. It is also demonstrated that changes in market efficiency are significantly related to market liberalisation policies even when control variables are considered.

Groenewold and Ariff (1998) use daily closing values for share-price indexes for ten countries in the Asia-Pacific to determine the effect of liberalisation of both, the domestic capital market regulations and the openness to international financial flows on market efficiency. The study finds that several measures of market efficiency are unaffected by de-regulation while measures based on regression and auto-correlation point to greater predictability after de-regulation. The counter-intuitive finding for the international case may be due to greater integration of international capital markets. However, the domestic phenomenon remains a puzzle.

Cajueiro and Tabak (2004b) concerned with the assertion that emerging markets are becoming more efficient over time, verify if this assertion is true or not by proposing the calculation of the Hurst exponent over time using a time window with four years of data. The data used comprised the bulk of emerging markets for Latin America and Asia. The results show that this assertion seems to be true for most countries as on the average there seems to be a downward trend on the Hurst exponent. This does not hold for countries such as Brazil, the Philippines and Thailand.

Cajueiro and Tabak (2004a) test for long-range dependence and efficiency in stock indices for eleven emerging markets and also for the US and Japan by using a "rolling sample" approach and calculating median Hurst exponents, R/S and modified R/S statistics so as to determine relative efficiency of these equity markets. The evidence suggests that Asian equity markets show greater inefficiency than those of Latin America excluding Chile and that developed markets rank first in terms of efficiency. The authors summarise that there is a positive relationship between market capitalisation and efficiency, and an inverse relationship between trading costs and the measures of market efficiency. Further to this study, Cajueiro and Tabak (2005) also employ a "rolling sample" approach whereby they use time-varying Hurst exponents to examine for long-range dependence for volatility of equity returns. The authors rank efficiency for emerging markets squared and absolute returns (volatility) for emerging markets and compared to developed economies (U.S. and Japan). The findings imply that Asian countries are more efficient than those of Latin America excluding Mexico. There is strong evidence of long memory in equity volatility.

Cuñado, Biscarri and Gracia (2006) investigate whether the dynamic behaviour of stock market volatility in six emerging economies has changed over the period 1976 to 2004. The authors ascertain there is a reduction in the impact of new information, whereby markets react less intensely to news associated with the development or liberalisation of the stock market. There are less uniform results regarding the persistence of volatility across countries. This indicates that swings from fundamental explanations of volatility may have merit after liberalisation, the enhanced depth of the financial market allows for less volatile movements in stock prices and better interpretation of new information.

In a study on the liquidity of emerging markets, Lesmond (2005) finds that they are characterised by volatile but substantial returns that are balanced off by liquidity costs. Using the bid-ask spread as a basis they range from 1% for the Taiwanese market to over 47% for the Russian market. The liquidity measures that are used are the Roll's measure (Roll 1984), the Amivest measure (Amihud, Mendelson and Lauterbach 1997), Amihud's measure (Amihud 2002), turnover and the LOT measure (Lesmond, Ogden and Trzcinka 1999). In testing the impact of legal origin and political institutions on liquidity levels, the finding of the study shows that countries with weak political and legal institutions have significantly higher liquidity costs than do countries with strong political and legal systems, even to the exclusion of legal origin or insider trading enforcement. Higher incremental political risk is associated with a 10 basis point increase in transaction costs using the Lesmond, Ogden and Trzcinka estimate, or a 1.9% increase in price impact costs, using the Amihud estimate.

Chordia et al (2008) indicate that short-horizon predictability from order flows is an inverse indicator of market efficiency. The authors find that such predictability is diminished when bid-ask spreads are narrower and has declined over time with the minimum tick size. Variance ratio tests put forward that prices were closer to random walk benchmarks in the more liquid decimal regime than in other regimes suggesting that liquidity stimulates arbitrage activity which, in turn, improves market efficiency. Moreover, as the tick size decreased, open-close/close-open return variance ratios increased while return auto-correlations decreased. This proposes an increased incorporation of private information into prices during more liquid regimes.

Bae, Ozoguz, Tan and Wirjanto (2012), investigate whether the degree of accessibility of foreign investors to emerging stock markets or investibility as a proxy for foreign investment, has a significant influence on the diffusion of global market information into stock prices in emerging markets. The authors examine the relation between a stock's accessibility for foreigners and its stock return dynamics, and show that greater investibility is associated with faster diffusion of global market information into stock prices. Firstly, the findings of the study show that greater investibility improves the speed of price adjustment to global market information, as the participation of foreign investors appears to help the transmission of information that is global in nature. Secondly, returns on highly investible stocks lead those on non-investible stocks, but not vice versa. This lead-lag relation is independent of factors such as size or volume, and it is due to investible stocks incorporating global information more quickly than non-investible stocks. Finally, the authors find that shares which 'foreign investors' trade, react faster to global information than shares which 'local investors' trade. The returns of B-shares can predict those of A-shares and not vice versa. The findings of the study are consistent with the view that financial liberalisation in the form of greater investibility, yields informationally more efficient stock prices in emerging markets.

Tabak (2003) tests the RWH for a set of daily Brazilian stock data provided by the Sao Paulo Stock Exchange Index (Ibovespa) in the period of 1986 to 1998. A rolling variance ratio test for different investment horizons was conducted and concluded that prior to 1994, the RWH is rejected but after that period, it cannot be rejected. Institutionally maturing markets, increasing liquidity and the openness of the Brazilian markets for international capital can explain this increase of efficiency in the Brazilian stock market. Evidence suggests that the release of foreign capital control is one of the main determinants of increased efficiency in the Brazilian equity market since there was a huge increase in inflows of foreign portfolio capital after 1994.

Costa and Vasconcelos (2003) conduct an empirical study of the Ibovespa index of the Sao Paulo Stock Exchange which detects the existence of long-range correlations. The level of correlation was above ½ on the time-dependent Hurst exponent [H(t)] curve before introduction of financial market liberalisation policies through the introduction of the Collor plan in the early 1990s and continued with the Real Plan in 1994. These structural reforms led to a more efficient stock market in Brazil evidenced by a reduction in the level of correlation with the Hurst exponent staying close to ½.

Grieb and Reyes (1999) re-examine the presence of random walk in stock prices in Brazil and Mexico using variance ratio tests on weekly stock returns for indexes as well as individual firms. Results of the study show mean reversion in Mexico at both the index level and firm level. This is indicative of the absence of a random walk. In contrast, the Brazil indices show a greater tendency toward random walk but the results for the individual firms suggest mean reversion. The findings cannot be attributed to a firm size effect although evidence is presented in favour of a greater degree of non-synchronous trading for Brazilian securities than for Mexico securities.

The weak-form of the EMH is tested for Central and Eastern Europe (CEE) equity markets for the period 1999 to 2009, using the auto-correlation analysis, runs test and variance ratio test (Guidi, Gupta and Maheshwari, 2011). The results show that stock markets of the CEE do not follow a random walk process. The presence of daily anomalies is also tested on the same data set using a basic model and a more advanced Generalised Auto-regressive Conditional Heteroscedasticity in Mean (GARCH-M) model. The results show that day-of-the-week effect is not evident in most markets except for some. Overall, the authors establish that some of these markets are not weak-form efficient. Hence, an informed investor can identify mispriced assets in the markets by studying the past prices and make abnormal profits.

Schotman and Zalewska (2006) examine the incidence of non-synchronous trading and test for market integration in Central European emerging markets. The findings confirm that predictability of these markets has decreased over time. The estimated time-paths of the auto-correlation coefficient start at values significantly different from zero and gradually become indistinguishable from zero as time progresses indicating that these markets have become more efficient.

Laopodis (2003) investigate whether financial market liberalisation announcements in emerging economies have had any effect on the efficient operation of their equity markets. The author empirically examines Greece and its emerging stock market, the Athens Stock Exchange (ASE). The findings suggest that the Greek equity market was weak-form efficient before these announcements were made. The ASE was operating as a random walk hinting that investors could not engage in systematically profitable ventures because future long-term returns were independent of past returns. In a similar study a year later, Laopodis (2004) studied whether Greece’s financial market liberalisation efforts had any effect on the efficient operation of the ASE. Various tests for structural change, market integration and efficiency determine that the ASE was weak-form efficient, and was operating as a random walk prior to any market liberalisation announcements were made. Moreover, the study finds that political uncertainties of the 1990s did not increase return volatility in the ASE in the post-liberalisation period.

These results are in contrast to those obtained in a study on the Athens Stock Exchange using GARCH type models and tests for their validity (Siourounis 2002). Correct specification of the different models indicates that the weak efficient market hypothesis does not hold for this market. There is strong empirical evidence that the market follows a pattern where the previous period's daily returns are correlated with today's returns and current volatility is positively related to past realisations.

Smith and Ryoo (2003) study the RWH for five medium-size European emerging stock markets using multiple variance ratio tests. The hypothesis is rejected for four of these markets, Greece, Hungary, Poland and Portugal. The Istanbul stock market follows a random walk; liquidity in this market is found to be greater than any of the other markets. This means that it has a more active price-formation process with important implications for weak-form efficiency. Ozdemir (2008) look into whether the Turkish stock market is efficient or not using weekly data for the period, 2nd January 1990 to 14th June 2005. The results of the Istanbul Stock Exchange National 100 price index show that the market is weak-form efficient.

To determine whether market efficiency has improved in transition economies, Rockinger and Urga (2000) investigate the evolution of the Czech, Polish, Hungarian and Russian stock markets over the period April 1994 to June 1999. The findings show that the Hungarian market is not predictable over the entire sample and satisfies the criteria for weak efficiency. The Czech market becomes less predictable between April 1994 and December 1994, yet according to its market characteristics, predictability should have improved during this period. The market was efficient since spring 1995. From spring 1999 predictability disappeared ensuring that weak market efficiency held. The Polish market shows an evolution of predictability very similar to the Czech market. The Russian market is found to be significantly predictable. There is a small amount of evidence available concerning market characteristics, hence, it is not possible to determine whether this market has become more- or less-efficient.

Rockinger and Urga (2001) present a model based on the Kalman-filter framework that allows for time-varying parameters, latent factors and a general GARCH structure for the residuals, extending the model by Bekaert and Harvey (1997) which enables to test if an emerging stock market becomes more efficient over time and more integrated with other established markets. The study finds that the Hungarian stock market has a low level of predictability, possibly due its high liquidity, and that among the other transition economies in the study it was already in existence 10 years before it officially opened in 1994. The Polish and Czech markets are found to have high predictability. The peaks for the Czech market are in November 1994 and April 1997. The Polish market remained constantly high in predictability. The Russian market has a very different pattern where it evolved from a market with negative auto-correlation to a market with no predictability by June 1997.

The degree of return predictability is measured by Dyakova and Smith (2013) for forty Bulgarian stocks, two Bulgarian stock market indices and thirteen other South East European stock market indices using three finite-sample variance ratio tests. Daily data corrected for infrequent trading is used in a fixed-length rolling window to capture short-horizon predictability and rank Bulgarian stocks and South West European stock market indices by relative predictability. The study finds that the degree of return predictability for both stocks and stock market price indices differs widely. Specifically for the Bulgarian market, the degree of predictability is greater, the less liquid the stock is in the market. In addition, the study finds the degree of predictability is negatively related to capitalisation, liquidity and market quality for market indices. Small, new, relatively illiquid and less-developed stock markets are found to be more predictable than large, liquid, developed markets.

Hasanov and Omay (2007) probe the efficiency of eight transition stock markets namely: Bulgarian, Chinese, Czech, Hungarian, Polish, Romanian, Russian and Slovakian. These markets are tested on whether the price series of these markets contain unit root. The study employs non-linear unit root test procedure recently developed by Kapetanios, Shin and Snell (2003), that has a better power than standard unit root tests when the series under consideration are characterised by a slower speed of mean reversion. The findings of non-linear unit root tests point out that only Bulgarian, Czech, Hungarian and Slovakian price series contain unit root, consistent with weak-form efficiency.

Ryoo and Smith (2002) use multiple variance ratio tests to examine the RWH for the Korean stock market under five regimes of daily price limits from March 1988 to December 1998. Using a sample of 55 actively traded stocks selected to cover a wide range of sectors, the hypothesis is tested under each price limit regime. As price limits were relaxed, the proportion of stock prices in the sample which follow a random walk increases which led to the stock market approaching a random walk. The only period that was an exception was during the Korean Financial Crisis.

An investigation by Wang, Liu and Gu (2009) of the change in efficiency brought by price-limited reform of the Shenzhen stock market, it was found to be becoming more and more efficient via analysing the change of the Hurst exponent.

Ma and Barnes (2001) test the weak-form efficiency of the China's stock markets by examining both the Shanghai and Shenzhen stock markets. The authors employ serial correlation, runs and variance ratio tests. The behaviour of market indices and daily individual shares' prices exhibit correlated return patterns. China's stock markets can be argued to be weak-form efficient by Fama's (1965) standards however, a comparison of these results with those of other countries indicate that Fama's (1965) benchmark is not strict enough. China's stock markets were found to not be weak-form efficient in the latter case.

The efficiency of the Chinese A-share and B-share markets, are tested following the deregulation of the B-share market which widened ownership to include domestic investors (Fifield and Jetty 2008). Parametric and non-parametric variance ratio tests are employed on daily data of 370 shares over the period 1996 to 2005. The authors find that A-shares are more efficient than B-shares although the efficiency of both markets has improved after the regulatory change. The results propose that the Chinese stock markets are symbolised by information asymmetry, even though the timely access to high quality information that domestic investors enjoy has improved the efficiency of the B-share market.

Hung (2009) adopts single and multiple variance ratio tests to review the weak-form EMH of the A- and B-shares markets of the Shanghai and Shenzen exchanges in the Chinese stock market. The study also looks into the influence of the relaxation of investment restrictions on the B-share markets on the market efficiency of Chinese stock market. All stock indices reveal evidence of weak-form EMH. The change in market efficiency may result from the regulatory transformation associated with the relaxation of investment restrictions on the B-share market. The improvement of market efficiency can be explained by the increase of liquidity and maturity accompanied by deregulation and liberalisation.

A study conducted by Charles and Darné (2009a), examines the RWH for the Shanghai and Shenzen stock markets for both A- and B-shares. The study uses daily data over the period 1992 to 2007, and tests the hypothesis with new multiple variance ratio tests, Whang-Kim sub-sampling and Kim's wild bootstrap tests, as well as the conventional multiple Chow-Denning test. The authors find that class B-shares for the Chinese stock exchanges do not follow the RWH and are significantly inefficient while the class A-shares seem more efficient.

Cajueiro and Tabak (2004c) tested the EMH for China, Hong Kong and Singapore, using the long memory dependence approach. Evidence suggests that Hong Kong is the most efficient market followed by Chinese A-type shares and Singapore, and finally by Chinese B-type shares. This suggests that liquidity and capital restrictions may play a role in explaining results of market efficiency tests.

The market efficiency of the China and Hong Kong stock markets are scrutinised by Liu (2011) from 2002 through 2009 by using the run tests, unit root tests and non-linear dependence test (BDSL test). The findings of the study show that the run test suggests weak-form inefficiency in all index series. Unit root tests indicate weak-form efficiency in all index series. Non-parametric variance ratio tests indicate weak-form efficiency in Shanghai index A and Hang Seng index daily series, but not in the Shenzhen Index A, Shenzhen Index B and Shanghai Index B daily series. Moreover, tests also suggest that all weekly index series except Hang Seng index violate weak-form efficiency. However, the non-linear dependence test shows Hang Seng daily and weekly, and Shanghai A daily index series are not characterised by weak-form efficiency. Test results reveal that Hong Kong and Shanghai A stock markets are more efficient than other China stock markets.

An analysis of whether a group of selected Asian stock market returns (Hong Kong, Indonesia, Japan, Korea, Malaysia, Philippines, Taiwan, Thailand and Singapore), follow a martingale process that is studied using daily and weekly price indices from 1990 to 2005 (Kim and Shamsuddin 2008). The martingale property is important as it has strong implications to the stock market efficiency in the weak-form. The study finds that market efficiency varies with the level of equity market development. The developed or advanced emerging markets (Hong Kong, Japan, Korea, Singapore and Taiwan), show weak-form efficiency while the less developed emerging markets (Indonesia, Malaysia, Philippines) are found to be inefficient. The Singaporean and Thai markets have become efficient after the Asian crisis in 1997. In spite of financial market liberalisation, these less developed emerging markets have shown little sign of market efficiency.

Hoque, Kim and Pyun (2007) re-examine the RWH for eight emerging equity markets in Asia: Hong Kong, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand. Two new variance ratio tests are used, Wright's rank and sign, and Whang-Kim sub-sampling tests in addition to the conventional Lo-MacKinlay and Chow-Denning tests. The study finds that the stock prices of the eight Asian countries do not follow the random walk with the possible exception of Korea and Taiwan.

Füss (2005) test the RWH and market efficiency for seven Asian emerging markets taking into account the effect of financial market integration. Single variance ratio tests of Lo and MacKinlay and multiple variance ratio tests of Chow and Denning, are employed to examine the stochastic properties of local index returns and to test the hypothesis that stock market prices follow a random walk. In addition, a non-parametric runs test is used to test weak-form market efficiency. Weekly stock prices in major Asian emerging markets are found to not follow a random walk in the pre-liberalisation period. In contrast, during the post-liberalisation period, weak-form EMH is generally adopted at the 5% level except for the smaller stock markets of Indonesia and Thailand.

Cheong, Nor and Isa (2007) study the asymmetry and long-memory volatility in the Malaysian stock market. Both the long-memory GARCH models (asymmetry component GARCH & symmetry and asymmetry component GARCH), provide good description of the long-memory behaviour in the Malaysian stock market volatility compared to the standard GARCH model. The presence of long-memory volatility enables for ranking the degree of market inefficiency, which also leads to the rejection of EMH in the Malaysian stock market.

Nguyen, Chang and Nguyen (2012) probe whether the Taiwan equity market is efficient using the modified and estimated Dockery and Kavussanos' multivariate models using a set of Taiwanese panel data. The study's findings strongly suggest that the Taiwan stock market is not informationally efficient mainly due to its lack of broadness and depth of the market. Moreover, when the number of stocks included in the sample exceeds five, the null hypothesis of the EMH is rejected throughout.

Abeysekera (2001) examines the behaviour of stock returns on the Colombo Stock Exchange in order to identify its consistency with the weak-form of the EMH. Data employed included daily, weekly and monthly returns of stock indices for the period, January 1991 to November 1996. The study used the exchange's reported sensitive share index and a 40-security value weighted index, adjusted for dividends, splits, rights and bonuses. Results of the study show that the stocks traded do not behave in a manner consistent with the weak-form of the EMH.

Smith (2007) questions whether five Middle Eastern stock markets are efficient. For the five stock markets examined: Israel, Jordan, Kuwait, Lebanon and Oman, multiple variance ratio tests are used to investigate whether stock price indices follow a random walk. The results show that the RWH is rejected for the Kuwaiti domestic companies and the Muscat Securities Market. For the Tel-Aviv, Amman and Beirut stock markets, and non-Kuwaiti companies traded on the KSE, stock price indices follow a random walk and these markets are regarded to be weak-form efficient.

Dropsy (2004) analyses the relationship between financial liberalisation, emerging stock market efficiency and currency crises. The study finds financial liberalisation did not improve the weak-form efficiency of Latin American and East Asian emerging stock markets.

Bonilla, Romera-Meza and Hinich (2006) apply the Hinich portmanteau bi-correlation test to study episodic non-linear events in seven Latin America stock market indices. The results reveal that all the stock returns series are characterised by brief periods of highly significant non-linearity followed by long time periods in which the returns follow pure noise process. The authors reject the EMH for the seven Latin America markets. This opens the possibility of return predictability, however, the episodic nature of the non-linearities makes it difficult to know when the serial dependencies will appear and when they will vanish.

Abedini (2009) tests for market efficiency in three stock markets in the GCC that include Bahrain, Kuwait and Dubai using the daily general index for the period between January 2005 and November 2008 for each market. The methods used are the auto-correlation function test, runs tests, variance ratio test and the Augmented Dickey Fuller (ADF) unit root test. The findings of the study show that EMH could be rejected for daily data in the runs test. EMH could be accepted for daily data for all markets in the auto-correlation function test and ADF test. The results of the variance ratio show that EMH can be accepted for daily price general index for Dubai, but may be rejected for Bahrain and Kuwait. Overall, the results reveal that the stock markets in the GCC are moving towards being efficient. These markets need to be reformed to improve their efficiency and secure the flow of information to market participants. Furthermore, the size of market capitalisation, the small number of listed companies and lack of significant market makers are essential factors that significantly reduced the level of efficiency in the stock markets of the GCC (Abedini 2009).

In a study to measure the behaviour of stock prices in the Bahrain Stock Exchange, Asiri (2008) aimed to measure the weak-form efficiency of this market. Random walk models such as unit root tests are used. Auto-regressive integrated moving average and exponential smoothing methods are also used. Cross-sectional time series are used for the forty listed companies over the period 1st June 1990 to 31st December 2000. The study finds that random walk with no drift and trend, is confirmed for all daily stock prices and each individual sector. The other tests, auto-regressive integrated moving average, auto-correlation tests and exponential tests, also support the efficiency of the Bahrain stock market in the weak-form.

Al-Khazali, Ding and Pyun (2007) revisit the empirical validity of the RWH in eight emerging markets in the Middle East and North Africa (MENA) countries (Bahrain, Egypt, Jordan, Kuwait, Morocco, Oman, Saudi Arabia and Tunisia) employing a non-parametric variance ratio test. After correcting for measurement biases caused by thin and infrequent trading, the authors cannot reject the RWH for the MENA markets.

Squalli (2006) conducts tests for market efficiency in the represented sectors of the Dubai Financial Market and the Abu Dhabi Securities Market. Data consists of daily sectoral indexes between 2000 and 2005. Variance ratio tests reject the RWH in all sectors of the United Arab Emirates financial markets, except in the banking sector of the Dubai financial market. Runs test find the insurance sector in the Abu Dhabi market to be the only one that is weak-form efficient.

A study by Moustafa (2004) on the behaviour of stock prices in the United Arab Emirates stock market is also conducted. The data consisted of the daily prices of forty three stocks included in the Emirates market index over the period 2nd October 2001 to 1st September 2003. The study uses only the non-parametric runs test for randomness because the returns of all the forty-three sample stocks do not follow the normal distribution. The author finds that the returns of forty stocks out of the forty-three stocks are random at a 5% level of significance. The implication is that the empirical study supports the weak-form EMH of the UAE stock market.

The RWH is tested for the Budapest Stock Exchange using variance ratio tests with both homoscedastic and heteroscedastic error variances (Dockery and Vergari 1997). The results show that the Budapest Stock Exchange is a random walk market. Buguk and Brorsen (2003) also test the random walk of the EMH for the Istanbul Stock Exchange using its composite, industrial and financial index weekly closing prices. Results from three of the tests show that all three series follow a random walk though non-parametric tests provide evidence against a random walk.

Butler and Malaikah (1992) examine stock returns in Saudi Arabia and Kuwait over the period 1985 to 1989. The study finds that the Kuwaiti market is similar to other thinly-traded markets in proportion of individual stocks exhibiting statistically significant auto-correlations and price change runs. In contrast, all thirty-five Saudi stocks show a significant departure from the random walk. The institutional factors contributing to the market inefficiency include illiquidity, market fragmentation, trading and reporting delays, and the absence of official market makers.

A study by Lim (2009) explores the existence of non-linear serial dependence in five stock markets in the Middle East and Africa. The stock indices for the study are drawn from Morgan Stanley Capital International. The countries included are: Egypt, Israel, Jordan, Morocco and South Africa. Earlier efficiency studies in the above regions have focused only on short-term linear predictability. However, the results from application of a battery of non-linearity tests reveal that after removing all short-term linear dependence, the stock returns still contain predictable non-linearities that contradict the unpredictable criterion on weak-form EMH.

Lagoarde-Segot and Lucey (2008) study the informational efficiency in relation to the theoretical underpinning in a set of seven emerging MENA stock markets. The authors aggregate the results of random walk tests and technical trade analysis into a single efficiency index and then analyse the impact of market development, corporate governance and economic liberalisation on the MENA stock markets. The findings highlight heterogeneous levels of efficiency in these markets. The efficiency index seems to be affected by market-depth while corporate governance factors also have explanatory power. However, the impact of overall economic liberalisation does not appear significant.

Gupta and Basu (2007) examine the weak-form efficiency in two Indian stock exchanges that represent the majority of the equity market in India for the period 2001 and 2006. Three different unit root tests are used; ADF test, the Phillip-Perron test and the KPSS test. The results show that the series does not the follow the random walk model and there is evidence of auto-correlation in both markets rejecting the weak-form EMH. An earlier study on the Bombay Stock Exchange provides empirical evidence on weak-form EMH and the day-of-the-week effect over the period 1987 to 1994 (Poshakwale 1996). The results show evidence of day-of-the-week and that the market is not weak-form efficient.

Cooray and Wickremasinghe (2007) study the efficiency in stock markets of India, Sri Lanka, Pakistan and Bangladesh. To examine weak-form stock market efficiency, the following tests are carried out: ADF, the Phillips-Perron, Dickey-Fuller Generalised Least Square and Elliot-Rothenberg-Stock. Weak-form efficiency is supported by the classical unit root tests; however, it is not strongly supported for the Bangladesh market under the Dickey-Fuller Generalised Least Square and the Elliot-Rothenberg-Stock tests. To examine semi-strong form efficiency, co-integration and Granger causality tests are used. A high-degree of interdependence among the South Asian stock markets is detected, hence, the semi-strong form efficiency is not supported.

Mobarek, Mollah and Bhuyan (2008) hypothesise whether the return series on the Bangladesh stock market is independent and follows the random walk model. The authors assess whether the Dhaka Stock Exchange deviates from idealised efficiency. The sample primarily includes all the listed companies on the exchange over the period 1988 to 2000. The findings reveal that the security returns do not follow the random walk model and the significant auto-correlation coefficient at different lags reject the null hypothesis of weak-form efficiency. This inconsistency with the EMH supports the proposition that the market does not respond to new information instantaneously.

Kumar and Kumar (2015) in a study on the Indian stock market inquire whether the market is efficient thus following a random walk using daily closing prices of the NSE Midcap 50 Index over the duration, 15th September 2010 to 28th November 2014. Existence of the random walk is examined through auto-correlation, Q-statistics and the runs tests. The results show that the Indian stock market was not efficient in the weak-form during the testing period indicating that the stock prices in India do not reflect all the information in the past stock prices and abnormal returns can be achieved by investors through exploiting the market inefficiency.

In a study that focuses on the existence of weak-form efficiency in the Karachi Stock Exchange of Pakistan, daily stock returns are used to check the weak-form efficiency in this market over a period of 15 years from July 1997 to April 2012 (Nawaz, Sarfaz, Hussain and Altaf 2013). The following tests are used to check the hypothesis: Kolmogrov-Smirnov test, runs test, ADF and Phillips-Perron unit root tests. The study finds the market is not distributed normally and there are patterns in the price which through predicting the future prices, technical analysts can get the benefit in the short run. In the long run considering only monthly data, there are no patterns in the price and the Karachi Stock Exchange is considered to be weak-form efficient.

2.11 AFRICAN MARKETS

Since the early 1990s there has been significant development in African capital markets. Before 1989 there were a mere five stock markets in sub-Saharan Africa and three in North Africa. As of 2007, there were 19 stock exchanges. Most African stock markets doubled their market capitalisation between 1992 and 2002 with the exception of South Africa. Total market capitalisation for African markets excluding South Africa in 1992 was at US$113 423 million, and it increased to US$244 671 million by 2002 (Yartey and Adjasi 2007). Apart from South Africa and Zimbabwe, the average market capitalisation of the other African stock markets is about 27% of GDP. This is in contrast to an emerging market like Malaysia that has a capitalisation ratio of about 135% (Yartey 2007). The JSE dominates other African stock markets in terms of market capitalisation as it accounts for nearly 90% of the total market capitalisation (Irving 2005).

The transition from a bank-based to a security market-based financial system has resulted in the establishment of many new equity markets in Sub-Saharan Africa over a very brief period of time. The radical policy shift towards increased privatisation has created a demand for greater access to capital. This in turn has required a move to liberalisation and deregulated markets in order that financial sector development and reform can facilitate economic growth (Piesse and Hearn 2005).

Another school of thought argues that stock market development in Africa would be a costly irrelevance which cannot be afforded and for a number of others, it is likely to do more harm than good (Singh 1999). The author maintains that African countries would do better to use their scarce human, material and institutional resources to improve their banking systems rather than to promote stock markets.

Kenny and Moss (1998) report that the ability to integrate and modernise African economies including the successful development of financial institutions such as stock exchanges will be vital for a more successful future on the African continent. The authors find that stock markets help this process by not only attracting foreign capital and providing a vehicle for privatisation, but also because their presence in an economy improves the overall business and investment climate, and reinforces other elements of economic reform.

Most African stock markets have few active stocks that trade, with these stocks making up a large percentage of the total market capitalisation except for South Africa, Egypt and to some extent Nigeria (Andrianaivo and Yartey 2009). The main reasons for having many infrequently traded stocks are due to serious informational and disclosure deficiencies (Yartey and Adjasi 2007). Moreover, supervision by regulatory authorities is deemed insufficient. These markets are known to be small in size with a low market capitalisation and few listed companies. Both South Africa and Egypt account for more than 50% of all listed companies in the entire continent. Irving (2005) remarks that the development of the Eastern and Southern Africa's exchanges are hindered by few stocks dominating total trading activity, high poverty levels, weak economic fundamentals and environment, a reluctance by some local companies to become less reliant on bank finance and issue securities and a lack of public awareness of the benefits of investing among those with the financial means to do so.

The African long-term bond market is the least developed segment of the continent's capital market as it attracts the least portion of the total financial system assets (Andrianaivo and Yartey 2009). The highest growth in non-intermediated debt markets in Africa has come from the government sector. Corporate debt markets are underdeveloped in most African countries and fall behind the government bond market in ranking. Evidence from seven sub-Saharan African countries (Botswana, Ghana, Kenya, Mauritius, Nigeria, Tanzania, Uganda and Zambia) shows a noteworthy increase in the volume of non-government domestic debt from $90 million in 2001 to $801 million in 2006.

The determinants of stock market development in Africa as found by Yartey and Adjasi (2007) are the following:

1. a stable macro-economic environment which promotes information symmetry; and
2. banking sector development.

Yartey (2007) found that a 1% increase in banking sector development leads to an increase in stock market development in Africa of 0.59% after controlling for macro-economic stability, economic development and quality of legal and political institutions. Thirdly, institutional development is crucial as good quality institutions that are efficient and accountable tend to broaden the appeal and confidence in equity investment, and lead to stock market development. Finally, strong shareholder protection in publicly traded companies is important as investors are more willing to invest in such companies. La Porta, Lopez-de-Manes, Shleifer and Vishny (1999) finds evidence for the importance of minority rights protection by using indicators of the quality of shareholder protection as written in laws. They demonstrate that the quality of shareholder protection is correlated with the capitalisation and liquidity of stock markets in 49 countries around the world.

Yartey (2007) scrutinises the determinants of stock market development in Africa using panel data of thirteen countries for the period 1991 to 2001. In particular, the author examines the impact of financial intermediary sector development on stock market development. The findings of the study show that income level, gross domestic investment, financial intermediary development, stock market liquidity and institutional quality are important determinants of stock market development in Africa. The author concludes that a well-developed financial intermediary sector and good quality institutions are prerequisites for stock market development in Africa.

In a study on the effect of stock market development on economic growth in 14 African countries in a dynamic panel data modelling setting, Adjasi and

Biekpe (2006) find a positive relationship between stock market development and economic growth. Further analyses based on the level of economic development and stock market capitalisation are also conducted. For countries classified as upper-middle income economies, there is a significant positive influence of stock market development on economic growth. For moderately capitalised markets based on market capitalisation groupings, stock market developments play a significant role in growth. However, for the low income African countries and less developed stock markets, there needs to be greater growth and development in their markets to bring about economic gains from stock markets.

There are various ways to increase capital market development in Africa. Yartey and Adjasi (2007:18-27) propose the following methods:

1. Automation which is expected to reduce costs associated with manual systems and inefficiencies of African stock markets resulting in increased trading activity and liquidity.

2. De-mutualisation which changes the legal status, structure and governance of an exchange from a non-profit organisation to a profit making one.

3. The promotion of institutional investors as currently they are not active investors, so that they can encourage financial innovation and efficient market practices.

4. Strengthen regulation and supervision so as to promote stability and protect investors hence, solving agency problems and information asymmetry arising from inside information.

5. Attraction of capital flows mainly through portfolio investment, foreign direct investment and remittances; and also encouraging foreign participation in African capital markets.

6. Increase public knowledge on the role of stock markets could increase the investor base and improve liquidity, thus encouraging the development of capital markets in Africa.

Some national exchanges have proposed that these efforts should be carried out on a regional basis. For instance, the NSE has proposed that all three East African

Communities (EAC) exchanges jointly conduct a regional public awareness and educational campaign (Irving 2005). The EAC Common Market Protocol has put high in its agenda, regionalisation of the East Africa Capital Markets as a pre-requisite to the realisation of the East African Monetary Union (Nairobi Securities Exchange 2015a). The regionalisation strategy for the capital markets aims to integrate the legal and regulatory environment via harmonisation of the national requirements whereby each country will recognise the regulatory regime of other countries through harmonisation of policies and approximation of laws.

Markets that are integrated with world capital markets through their link with a highly-developed market which acts as a regional hub, perform better than those that are segmented (Piesse and Hearn 2005). A major factor in the success of national stock markets is the provision of the necessary institutions to provide investor confidence. This is observed in the case of markets that are G30 compliant as they have a clear advantage, since countries that have achieved this are potential members of an integrated system for electronic trading and settlement. G30 is a club-like organisation whose members are central and prominent bankers from big private banks. It was instituted to discuss global banking regulation and to influence legislation (Corporate Europe Observatory 2012).

Ngugi et al (2002) investigate the response of emerging stock markets in Africa to various reforms implemented during the revitalising process capturing mainly market efficiency and volatility during the period January 1988 to December 1999, specifically for the Nairobi Securities Exchange. The three main types of reforms implemented in these markets since the 1990s are identified, in other words: revitalisation of the regulatory framework, modernisation of trading systems and relaxation of restrictions on foreign investors. The authors find that there are benefits of investments to improve market micro-structure. Markets with advanced trading technology, tight regulatory system and relaxed foreign investors' participation, show greater efficiency and lower market volatility. The direction of causality between efficiency and volatility varies across the market. In general, it is deduced that reforms help to reduce volatility which in turn leads to higher efficiency. In some markets though, the result of the reforms are too recent to show any clear response pattern.

Mlambo and Biekpe (2003) observe that stock markets around the world are making efforts to improve market efficiency by improving information dissemination, making stock price information accessible to a broader range of investors and introducing electronic or computer-based trading systems. This has enabled market participants to have equal opportunities to access all relevant information. There is a positive correlation between most stock market development indicators and internet access; therefore, stock market liquidity and efficiency can be improved by providing information online, and also promoting the infrastructure to improve internet accessibility. The study finds that African residents have limited internet access in comparison to foreign residents; the latter are restricted in their participation on African stock markets due to strict regulations and lack of up-to-date online information content from some African stock markets. The authors recommend that these are important issues that should be addressed by African governments' otherwise African stock markets will continue to lack liquidity and efficiency.

African stock exchanges have not been well-researched. However, more studies have been carried out for the more developed African markets than the less developed African markets. Most of the studies relating to market efficiency on the African stock markets have been conducted on the JSE which is the largest and most developed securities exchange in Africa.

The weak-form of the EMH is tested for eight African stock markets using three finite-sample variance ratio tests (Smith and Dyakova 2014). Short-horizon predictability is captured via rolling windows and it tracks changes in predictability, and is also used to rank markets by relative predictability. The findings show the stock markets experience successive periods when they are predictable and then not predictable, which is in consistent with the AMH. The degree of predictability varies widely. The most efficient African stock markets are the Egyptian, South African and Tunisian markets, while those that are inefficient are the Kenyan, Zambian and Nigerian markets.

Ntim, Opong, Danbolt and Dewotor (2011) investigate and compare the weak-form efficiency of a set of 24 African continent-wide stock price indices and those of eight individual African national stock price indices using variance ratio tests based on ranks and signs. The authors find that there are statistically significant improvements in the informational efficiency of the African continent-wide stock price indices, compared to the individual efficiency of the individual national stock price indices. The majority of the African continent-wide stock price indices returns are weak-form efficient, however, none of the individual national indices are efficient using the ranks and signs tests. The policy implication of this evidence is that the African equity price discovery process can be expected to significantly improve if African stock markets integrate their operations. Economically, this is likely to result in improved liquidity and more efficient allocation of capital which theory suggests will have a positive impact on economic growth. The authors suggest the starting point may be the harmonisation of listing rules, ideally from regional groupings and strategic alliance and co-operations among African stock markets.

In a study by Mabhunu (2004), the author tested the weak-form efficiency of the JSE where stock returns used in the analysis were controlled for thin trading which led to the returns being independent of each other across time. The results revealed that the JSE is efficient in the weak-form. Philpott and Firer (1994) consider the share price anomalies and the efficiency of the JSE. The results of the study prove conclusively that share price anomalies on the JSE are common, often of a large magnitude and frequently persist for long periods. In this study though the JSE is found not to be an efficient market, there may well be "pockets of efficiency" since no price anomalies were found for certain pairs of shares.

Appiah-Kusi and Menyah (2003) study the weak-form efficiency of eleven African stock markets. Unlike most previous studies, the authors acknowledge the possibility of non-linearity in the return-generating process, and account for this in the design of a test method that accommodates both linear and non-linear specifications. The study also takes into account the problem of thin-trading that is found in small equity markets. This was addressed by computing returns with a procedure that recognises this problem. The authors used the EGARCH-M model to track changes in risk and return over time. Firstly, the results show that the return generation process is non-linear in all the eleven markets in the sample and in five of the markets, investors demand a time-varying risk premium for the risks they bear. The majority of the markets in the sample do not exhibit weak-form efficiency. The Nigerian market is found to be inefficient despite prior evidence to the contrary which underpins the appropriateness of the modelling approach which produces a significant time-varying risk premium for the Nigerian market which linear models would not have been able to capture. The markets in Egypt, Kenya and Zimbabwe confirm existing results by Claessens, Dasgupta and Glen (1995); Cooper (1982); and Dickson and Muragu (1994); that they are weak-form efficient. The South African market is not consistent with weak-form efficiency. The Mauritius and Morocco markets are weak-form efficient, however, the markets in Botswana, Ghana, Ivory Coast and Swaziland are not consistent with weak-form efficiency.

Ahmed (2013) undertakes a study where a battery of variance ratio tests are applied onto weekly data as recommended by Lo and MacKinlay (1988), to investigate the informational efficiency of the Egyptian Stock Exchange over the period 1997 to 2007. The results indicate that the exchange moved towards efficiency in the second sub-period which after the price limits imposed on the share movements, were expanded and accompanied by adopting trading halt for a few minutes if prices hit their new limits.

Mlonzi, Kruger and Nthoesane (2011) investigate whether there are any significant abnormal returns (whether positive or negative), related to the public announcement of earnings and to establish whether the EMH applies to the JSE ALtX market. The findings of the study indicate that there is substantial negative share price reaction to earnings announcements which during a recessionary period, leads to shareholders' wealth being eroded. Additionally, the ALtX shows the weak-form of market efficiency, hence, an opportunity to exploit the market for profits when the market is performing well.

Some suggestions on improving the efficiency of the JSE were offered by Bhana (2007) in a study that evaluated the market reaction to share repurchases in South Africa. It is recommended that the JSE makes comprehensive disclosure outlining the benefits to shareholders of share repurchases, as it will improve the credibility of the repurchase announcement and will also assist in improving the efficiency of the JSE.

Jefferis and Smith (2004) test the RWH and the weak-form efficiency for seven JSE indices using multiple variance ratio tests and a test of evolving efficiency (TEE). Four of these are found to follow random walks and are weak-form efficient: The All Share 40, Industrial 25, Datastream Total Market and Gold indices. The remaining three - the Mid Cap, Industrial and Small Cap indices - are found not to follow random walks and are not weak-form efficient, and the TEE does not indicate any trend toward efficiency over the sample period. The stock price indices that have large capitalisation are found to be weak-form efficient and more liquid, and variance ratio tests indicate that these stocks more frequently follow random walks. On the other hand, indices with small capitalisation indices are not weak-form efficient.

Tijjani, Power and Fifield (2009) interrogate the extent to which the equity prices of firms listed on the Nigerian Stock Exchange are consistent with the EMH. The authors investigate the weak-form efficiency of the Nigerian Stock Exchange using weekly returns for the 69 most actively traded shares over the period 1995 to 2005 using various tests including tests of auto-correlations and technical trading strategies. The analysis indicates that the Nigerian market may be weak-form efficient for ordinary investors who operate in a costly trading environment.

The weak-form efficiency of the Nigerian stock market is reviewed using a sample data over the period 1986 to 2010 (Nwosa and Oseni 2011). It specifically focuses on the efficiency of the exchange after the sharp decline in stock prices following the global financial crisis. The tests were conducted using serial auto-correlation and regression method of analysis. The authors found that the market is informationally inefficient as the stock prices do not exhibit a random walk. The study recommended the need for strong and adequate supervision by the regulatory authorities and greater development of the market through appropriate policies that increase the informational efficiency of the market.

Ajao and Osayuwu (2012) test the weak-form of EMH in the Nigerian capital market by analysing the month-end value of the All Share Index from 2001 to 2010. The serial correlation technique of data analysis was used to test for independence of successive price movements, and the distributive pattern while the runs test was used to test for randomness of share price movement. The findings of the serial correlation show that the correlation coefficients did not violate the two-standard error test, while the Box-Ljung statistic show that none of the serial correlation coefficients was significant and the Box pierce Q-statistics shows that the overall significance of the serial correlation test was poor, while the result of the distribution pattern shows that the stock price movements are approximately normal on the basis of this results. The conclusion of the study is that successive price changes of stocks traded on the floor of the Nigerian Capital Market are independent and random, thus, the Nigerian Capital Market is efficient in the weak-form.

Smith (2008) tested the random walk and martingale hypotheses for eleven African stock market price indices (Botswana, Cote d'Ivoire, Egypt, Ghana, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tunisia and Zimbabwe) using joint variance ratio with finite sample critical values over the period, beginning in January 2000 and ending in September 2006. The RWH is rejected in all eleven markets. In four stock markets - Egypt, Nigeria, Tunisia and South Africa - weekly returns are a martingale difference sequence. This means there is no presence of return predictability thus the markets are efficient (Lim and Luo 2012). In general the returns in the more liquid markets are a martingale difference sequence but this is not the case in less liquid markets.

Mlambo and Biekpe (2007) investigated the weak-form efficiency of ten African stock markets using the runs test methodology for serial dependency. The findings of the study show that there is seriously thin-trading for all the markets especially for Namibia and Botswana which are both dual-listed on the JSE. In all markets studied (except Namibia), a significant number of stocks rejected the random walk. The weak-form efficiency of the Namibian Stock Exchange is attributed to its correlation with the JSE. Kenya and Zimbabwe are also concluded to be weak-form efficient as a significant number of stocks conformed to the random walk. All stocks in the Mauritius sample rejected the random walk resulting in the conclusion that stock prices on the Mauritius market tend to deviate from the RWH. The same conclusion was determined for Ghana. On the Egypt, Botswana and BRVM (a regional stock exchange covering eight West African countries) stock exchanges, there was a possibility of predicting the pattern in the share prices that could lead one to be able to determine the next price.

A study by Jefferis and Smith (2005) tests the changing efficiency of African stock markets through time using the GARCH approach with time-varying parameters starting in early 1990 and ending in June 2001. The authors find that the JSE is weak-form efficient throughout the period and three stock markets become weak-form efficient towards the end of the period; Egypt and Morocco from 1999 and Nigeria from early 2001. These contrasts with Kenya and Zimbabwe that show no tendency towards weak-form efficiency and the Mauritius market display a slow tendency to eliminate inefficiency.

Smith et al (2002) examine the RWH for eight African stock markets using the multiple variance ratio tests. The hypothesis that a stock market price index follows a random walk is tested for South Africa, medium sized markets (Egypt, Kenya, Morocco, Nigeria and Zimbabwe), and two small new markets (Botswana and Mauritius). The hypothesis is rejected in seven of the markets excluding South Africa where the JSE All Share index follows a random walk. The authors recommend further study on the prices of individual equities taking into account their size and liquidity.

Few studies have been conducted on the smaller African markets. Some of these markets are Swaziland, Mozambique and Botswana. Hearn and Piesse (2010) review the role of financial markets in providing a vehicle for economic growth and development for Swaziland and Mozambican stock markets. Results of the study illustrate that any potential gains to the domestic investment community are limited, if there is insufficient liquidity and the political economy remains in the hands of the social elite whereby ownership does not disperse. The authors find that the potential growth of small developing markets is severely constrained by poverty and wealth inequality and thus the impact of development is minimal.

Mollah (2007) seeks evidence of market efficiency and determines if the Botswana stock market series follows the random walk model. Triangulation econometric approach is employed to assess the predictability of daily return series of the Botswana Stock Exchange, and to test the null hypothesis of random walk model for the period 1989 to 2005. The results reject the null hypothesis of random walk model for the daily return series.

The study of the EMH for African countries is revisited by Zhang et al (2012). The authors apply the panel seeming unrelated regression of the Kapetanios-Shin-Snell (SURKSS) test with Fourier function to investigate the time series properties of stock prices in five African countries, Egypt, Kenya, Morocco, South Africa and Tunisia; over the test period of January 2000 to April 2011. The univariate unit root and panel-based unit root tests show that the unit root hypothesis cannot be rejected for these five countries. However, results from the panel SURKSS test with a Fourier function indicate that unit root hypothesis can be rejected for Egypt and Morocco. The authors find that the weak-form EMH holds in three countries, namely, Kenya, South Africa and Tunisia.

One of the first tests on the efficiency of the NSE was conducted by Parkinson (1984) who examined the exchange for the period 1974 to 1978 to determine its role in the development process and the degree to which it conforms to the pattern of stock exchange behaviour elsewhere. The results of the study showed that there were imperfections in the pricing of securities. However, the very thinness which probably causes these imperfections would almost certainly render impossible their use as the basis of any investment strategy which would yield profits in excess of those normally earned. There was also evidence that security prices were not well-described by the Capital Asset Pricing Model (CAPM). Regressions of excess company return on excess market return showed negligible explanatory power. Similarly, regressions of excess portfolio return on excess market return, showed levels of explanatory power which were very low in comparison to those measured in other markets.

The other major study on the NSE was by Dickson and Muragu (1994) who examined whether the behaviour of the price series on the NSE was consistent with the weak-form of the EMH. The data was based on fifty five equity securities listed on the NSE that fulfilled the following criteria: firstly, they were quoted over the period 1st January 1979 to 31st December 1988; secondly, they had complete dividend history during the period of study; and thirdly, the share must have given rise to a minimum of sixty observations to ensure goodness-of-fit in tests. These results did not categorically show that the market was weak-form efficient, but rather that the results did not contradict the weak-form efficient of the EMH. The authors recommended that many more studies be conducted on the NSE using longer time intervals and different methodologies in order to come up with a strong conclusion on the weak-form efficiency.

A study by Onyuma (2009) investigates whether the day-of-the-week effect and the month-of-the-year anomaly existed in the NSE over the period 1980 to 2006. The results show the existence of the day-of-the-week effect and the January effect.

There is a significant difference in the return between Monday and Friday which is the best performing day of the week. The month-of-the-year anomaly was present in all periods with exception during the crisis when an unusual positive return in June and July was observed. This implies that the market does not follow a random walk as there are patterns through which an investor can predict to get a profitable gain. Hence, existing studies regarding the EMH on the NSE provide conflicting results.

2.12 SUMMARY

This chapter has discussed the theory of efficient market hypothesis and adaptive market hypothesis, critic of efficient market hypothesis, and empirical research on efficient markets hypothesis. Chapter three will discuss the methodological issues and the selected estimation models that will test the efficiency of the NSE.

CHAPTER 3

RESEARCH DESIGN AND METHODS

3.1 INTRODUCTION

The purpose of the study is to determine the level of informational efficiency of the NSE. The methodological issues and the selected estimation models that will test the efficiency of the NSE will be discussed. This will be followed by an explanation of the data, and the research approach that was followed.

3.2 METHODOLOGICAL ISSUES

Smith and Dyakova (2014) have identified three main approaches to distinguish studies of the weak-form EMH. The first one being the conventional and widely used, absolute efficiency approach which takes efficiency as an all-or-nothing case. It tests the random walk and/or martingale hypothesis for a particular stock or set of markets over a single period. The results lead to the supposition that a stock market is either predictable or not predictable for that period (Asal 2000; Angelov 2009; Borges 2011).

The second approach analyses the change in efficiency over time; which is achieved in three ways. Firstly, one set of studies applies the absolute efficiency test for two separate time periods. Such studies may find that a market is efficient in one time period and not in another; however, the weaknesses of these are that they are limited to a discrete change at a predetermined point in time.

The second set of studies avoids this by using a fixed-length rolling window to generate many subsamples (Belaire-Franch and Opong 2005; Kim and Shamsuddin 2008; Hung 2009; Ito and Sugiyama, 2009), while the third set of studies employ the generalised ARCH in mean (GARCH-M), in mean models with time-varying parameters (Emerson, Hall and Zalewska-Mitura 1997; Zalewska-Mitura and Hall 1999; Jefferis and Smith 2005; Abdmoulah 2010).

The AMH explains the changing degree of market efficiency. Prices generally reflect the information that emerges from specific groups of market participants and environmental conditions. Individuals in financial markets are bounded in their degree of rationality and make choices that are merely satisfactory. A key consequence is that return predictability is time-varying due to changing environmental conditions and changes in the population of market participants. Profit opportunities exist from time-to-time, declining as they are exploited - at the same time new arbitrage opportunities arise as conditions change. These changes impact on the degree of market efficiency resulting in a change in return predictability over time. Results from a number of studies that carry out efficiency tests in a rolling window are in line with the AMH (Kim et al 2011; Lim et al 2008; Niemczak and Smith 2013).

Smith and Dyakova (2014) suggest a third approach, that of relative efficiency which measures the efficiency of one market against another, ranking them according to their relative efficiency. This is achieved by using a fixed-length rolling window to test the random walk many times, then the proportion of rolling windows with a significant test statistic can then be used to rank markets by relative efficiency (Lim 2007; Lim and Brooks 2010). As an alternative, two or more efficiency tests can be carried out for a set of stock markets; the results for each market are combined into a single measure of relative efficiency.

The following methods have been used to test the efficiency of financial markets:

- ***Serial Correlation Test***

Serial correlation tests or auto-correlation tests, are used to determine whether the observations in time series data are correlated with their lags or not (Kutner, Nachtsheim, Neter and Li 2005). The auto-correlation test is a parametric test that makes assumptions that the data is normally distributed (Kumar and Kumar 2015). This test is a reliable measure for the testing of either dependence or independence of random variables in a series (Patel, Radadia and Dhawan 2012). If auto-correlations are found in a series, the returns are not independent (Urquhart and Hudson 2013). The serial correlations test is considered to be one of the best tests for examining weak-form efficiency because the relationship between price changes in the current period and its value in the previous period is measured by auto-correlation (Abedini 2009).

If stock returns follow a random walk, investors may not be able to successfully predict future returns because future price movements are not related to past price movements. However, if stock returns do not follow a random walk due to significant auto-correlations being found in times series data, the market can be considered as inefficient in the weak form because it would be possible to make accurate predictions about the future price movements based on past, price movements (Kumar and Kumar 2015).

The null hypothesis for serial correlation tests is: "There is zero serial correlation at the first *k* auto-correlations" $(\rho_1 = \rho_2 = \cdots = \rho_k = 0)$. Positive auto-correlation indicates predictability of return (Patel et al 2012). For a large sample, the Ljung and Box (1978) Q-statistic follows the chi-square distribution with *k*-degrees of freedom:

$$Q_{LB} = N(N+2)\sum_{j=1}^{k} \frac{{\rho_j}^2}{N-j} \qquad [3.1]$$

Where N =number of observations, $\rho_j =$ the jth auto-correlation and $k =$ number of auto-correlations. Ignoring the sign, a high Q-statistic in the above equation means that the auto-correlation is high and it indicates that the stock price is related to the previous prices. This evidence would be against the weak-form efficient market hypothesis. Therefore, if the Q-statistic value is greater than or equal to the critical value obtained from the chi-square table, then the null hypothesis is rejected at the 5% level of significance (Aumeboonsuke and Dryver 2014).

The statistics Q is an improvement over the original portmanteau statistics as it is suitable for smaller samples where the time series depart from normality. It is used to determine the significance of auto-correlations out of a lag k of seven. For modest sample sizes, the sampling distribution of Q is known to have a much lower mean than the asymptotic chi-square even when the data are normally distributed (Wheeler et al 2002).

Another description of the auto-correlations by Urquhart and Hudson (2013), is that auto-correlations (ρ_k) occur when the covariances and correlations between different disturbances are not all non-zero (i.e. $Cov(\varepsilon_i, \varepsilon_j) = \sigma_{ij}$ for all $i \neq j$, where ε_t is the value of the disturbance in the ith observation).

$$\rho_k = \frac{\gamma_k}{\gamma_0} \qquad [3.2]$$

Where γ_1 is the covariance at lag k and γ_0 is the variance. Therefore, when auto-correlations are present, the first order autoregressive process contains values of ε_t lagged by just one period, indicating that the disturbance in period t is influenced by the disturbance in the previous period, ε_{t-1}, in this case it means that $\rho > 0$ and there is positive auto-correlation. On the other hand, if $\rho < 0$ there is negative auto-correlation. A random walk process is implied when the null hypothesis is $\rho = 0$

The random walk is valid, if the calculated serial correlation coefficient is not statistically different from zero. As a result, previous stock price movements cannot be used to predict future behaviour of stock price movement (Nwosa and Oseni 2011).

Griffin, Kelly and Nardari (2010) observe that several studies by authors such as Conrad and Kaul (1988); Conrad, Kaul and Nimalendran (1991); Mech (1993) and Boudoukh, Richardson and Whitelaw (1994), have demonstrated that return auto-correlations could be due to factors other than simple mispricing. These factors are time-varying expected returns, micro-structure frictions (such as stale limit orders, inefficient market making, and bid-ask bounce), and non-synchronous trading. In order to reduce the likelihood of auto-correlation being the result of time-varying expected return, Griffin et al (2010), focus on short-term return (one day to five weeks). The authors add that micro-structure frictions like bid-ask bounce are most problematic when focusing on one- and two-day auto correlations at the individual firm level. This enables to control for auto-correlations that is induced by the micro-structure effect, the study focuses on weekly frequency, uses screens when stocks are required to trade frequently and it skips a trading day in some results while in others it is required the skipped day to contain trading activity (Mech, 1993).

Limitations of the serial correlation test are firstly, individual securities returns are likely to have statistically insignificant auto-correlation due to company-specific or “idiosyncratic” noise that makes it difficult to detect the presence of predictable components (Lo and MacKinlay 1988). The authors add that the idiosyncratic noise is largely attenuated by forming portfolios. We would expect to uncover the predictable “systematic” component more readily when securities are combined. Secondly, Lo and MacKinlay (1988) observe that spurious auto-correlation in stock returns may result due to infrequent trading. The reasoning behind the artificial serial correlation is small capitalisation stocks trade less frequently than larger stocks, hence, new information is first impounded into larger capitalisation stocks and then into smaller stock with a lag.

- ***Unit Root Tests***

A time series has a unit root if its level form is non-stationary, but becomes stationary after first differencing (Nwosa and Oseni 2011). Rahman and Saadi (2008) state that a unit root is a necessary pre-requisite for the RWH, however, it is not a sufficient condition. The presence of a unit root specifically is not sufficient to imply a random walk since the return series must also be serially uncorrelated or serially independent.

Application of ADF test is appropriate to determine a unit root. It is based on the following ordinary least squares (OLS) regression (Abedini 2009):

$$\Delta y_1 = a + by_{t-1} + \sum_{j-1}^{k} cpy_{t-1} + \mu t \qquad [3.3]$$

Where y_t equals the logarithm of a stock price at time t_1, Δ stands for changes, and Δ is a sequence of independent, normally distributed random variables with a mean of zero and constant variance while k is the number of lagged changes.

Buguk and Brorsen (2003) indicate that the ADF test statistic is the ratio of the estimated b to its calculated standard error obtained from an OLS regression. The authors add that the null hypothesis is $b = 0$; against the one-sided (lower-tail) alternative hypothesis, $b < 0$. The null hypothesis is rejected if the pseudo t -statistic is larger than the critical value.

The Phillips-Perron test is a non-parametric method to test unit root and is similar to the Dickey-Fuller test (Liu 2011). It incorporates an alternative (non-parametric) method of controlling for serial correlation when testing for a unit root by estimating the non-augmented Dickey-Fuller test equation and modifying the test statistic so that its asymptotic distribution is unaffected by serial correlation (Worthington and Higgs 2006a). The Z_t-statistic of Phillips and Perron (1987, 1988), is a modification of the Dickey-Fuller t-statistic which allows for auto-correlation and conditional heteroscedasticity in the error term of the Dickey-Fuller regression. This is based on the estimation of the equation:

$$\Delta X_t = \alpha_0 + \alpha_1 T + \alpha_2 X_{t-1} + \omega_t \qquad [3.4]$$

However, the ADF test is possibly biased and lacks power as argued by Schwert (1989): and DeJong, Nankervis, Savin and Whiteman (1992); who indicate that the ADF unit root test of Said and Dickey lacks power against a trend stationary alternative. Critics of the ADF and Phillips-Perron tests have observed that the ADF unit root test fail to reject the null hypothesis of a unit root for many time series, allowing for error auto-correlation using the Phillips-Perron test does not necessarily improve these results (Worthington and Higgs 2006a).

The equation that shows the random walk relationship is:

$$\Delta y_t = \delta y_{t+1} + \varepsilon \qquad [3.5]$$

$\delta = (\rho - 1)$, and

$\Delta y_t = (y_t - y_{t-1})$

If the AR 1 regression, equals $\rho = 1$, the time series y_t has a unit root it is equal to zero ($\delta = 0$). Therefore, if the time series has a unit root, it is non-stationary.

The hypotheses for unit root tests are:

$H_0: \rho = 1$ (The time series is non-stationary and there is unit root)

$H_A: \rho \neq 1$ (The time series is stationary and there is no unit root)

The following standard ADF model will be used in this study:

$$\Delta y_t = \delta y_{t+1} + \varepsilon \qquad [3.6]$$

Where y_t is random walk.

If the null hypothesis of a unit root in share prices of a time series is not rejected, it means that the consecutive changes in share prices over the period are random. In view of that, the stock market is weak-form efficient (Chan et al 1992).

Earlier studies on this test mainly use conventional unit root tests, particularly ADF test and find that the log-levels of stock prices are non-stationary concluding the markets under study are weak-form efficient (Lim and Brooks 2011). Recent studies on the unit root test have adopted structural-break or panel unit root tests (Lean and Smyth 2007). The argument in favour of the former is that if a structural break is present in the data, there is a possibility the break is interpreted as the existence of a unit root and will lead to under-rejection of the null hypothesis. This methodology has further been refined to allow for multiple structural breaks. The panel unit root test are justified based on univariate unit root tests having low power when the sample size is small rather than being measured on the frequency of observations, it is measured in terms of time span of the data.

- ***Runs Test***

Urquhart and Hudson (2013), state that a runs test investigates the randomness of a series of stock returns. It differs from the serial correlations test in that it does not require returns to be normally distributed. The test is suitable because using statistical tests of significance that assume normality such as the serial correlations test when it does not exist, can produce misleading results (Urrutia 1995). This test is considered to be a linear test although it can also detect non-linearity in a returns series, however, the result obtained will be different to the linear serial correlation test. Borges (2010) asserts that the runs test is based on the premise that if price changes (returns) are random, the actual number of runs should be close to the expected number of runs. A run is a succession of identical symbols either positive or negative returns in this case which are followed or preceded by different symbols (Urquhart and Hudson 2013). Hence, a run is a sequence of positive or negative returns. The number of positive runs is shown by P, while N shows the number of negative runs.

The efficiency in the market shows the succeeding price variation should be independent of each other (Patel et al 2012). Runs test is the most commonly used non-parametric test of the RWH as it does not require that return distributions are normally or identically distributed, a condition that most stock-return series cannot satisfy. In addition, it eliminates the effect of extreme values often found in returns data (Al Khazali et al 2007). The runs test being a non-parametric test, does not make assumptions about the magnitude of share price changes (Wheeler et al 2002). Mlambo and Biekpe (2007) emphasise this point that the runs test is also used if there is non-normality of the return series and is not affected by any extreme values in the return series, hence, does not require constant variance of the data. This point is further emphasised by Mobarek and Keasey (2000) who indicate that since this test is a non-parametric test, it has an advantage over parametric tests because the runs test ignores the properties of the distribution of the series.

There are two approaches to consider in the runs test (Borges 2011). The first approach defines a positive return as any return greater than zero and a negative return as any return that is below zero. The second approach defines each return according to its position with respect to the mean return of the period under analysis. A positive return comes about when the return is above the mean return, and a negative return is when the return is lower than the mean return. The advantage of the second approach is that it allows for and corrects the effect of an eventual time drift in the series of returns.

The null hypotheses for the runs test are:

$H_0: R = E(r)$ (Successive changes in the prices of the indexes are random)

$H_a: R \neq E(r)$ (Successive changes in the prices of the indexes are not random)

The formula for the runs test as given by Wallis and Roberts (1956) is:

$$m = \frac{\{N(N+1) - \sum_{i=1}^{3} n_i^{2}\}}{N} \qquad [3.7]$$

Where *m* is the total expected number of runs, *N* is total number of observations, and n_i is the number of observations in each category *i*. For a large number of observations $(\mathrm{N} > 30)$, the sampling distribution of *m* is approximately normal and the standard error of *m* is given by:

$$\sigma_m = \left\{\frac{\sum_{i=1}^{3} n_i^{2}\left[\sum_{i=1}^{3} n_i^{2} + N(N+1)\right] - 2N\sum_{i=1}^{3} n_i^{3} - N^{3}}{N^{2}(N-1)}\right\}^{1/2} \qquad [3.8]$$

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

$$Z = \frac{R \pm 0.5 - m}{\sigma_m} \qquad [3.9]$$

Where *R*=actual number of runs, *m*=expected number of runs and 0.5=continuity adjustment. If R $\leq$ m, the Z value is negative which implies a positive serial correlation; on the other hand, if R $\geq$ m, the Z value is positive which implies a negative correlation. The positive serial correlation means that there is a positive dependence of stock price indicating a violation of the random walk hypothesis (Patel et al 2012).

The null hypothesis of independence of the series is rejected when the z-value is greater than the critical value. If the z-value is less than the critical value, we conclude that the returns are independent. Moreover, the sample will not be independent if it contains too many or too few runs. The independence of returns can be assessed by analysing the distribution of the duration of runs. A positive z-value is obtained if the actual runs (R) are more than the expected runs (m), while a negative z-value is realised if the actual runs are less than the expected runs.

The null hypothesis of the runs test is tested by observing the number of runs or the sequence of successive price changes with the same sign, i.e. positive, zero or negative. Each change in return is classified according to its position with regard to the mean return. Therefore, it is a positive change when return is greater than the mean, a negative change when the return is less than the mean and zero when the return is equal to the mean (Guidi, Gupta and Maheshwari 2011).

A lower than expected number of runs indicates the market's overreaction to information, subsequently reversed, while higher numbers of runs reflect a lagged response to information. Any case, would suggest an opportunity to create excess returns (Poshakwale, 1996). The runs test converts the total number of runs into a Z-statistic. For large samples, the Z-statistic gives the probability of a difference between the actual and expected number of runs. If the Z-value is greater than, or equal to 1.96, the null hypothesis is rejected at the 5% level of significance (Sharma and Kennedy 1977).

- ***Variance Ratio Tests***

Single variance ratio tests

Füss (2005) comments that the traditional tests of random walks such as tests of serial correlation and unit root tests are susceptible to errors because of spurious auto-correlation brought about by non-synchronous trading which is characteristic of stock markets in developing countries. As a solution to these problems, Lo and MacKinlay (1988) developed tests for random walk based on variance ratio estimators. These tests are specifically useful for investigating stock returns that are frequently not normally distributed.

Variance ratio tests

Originated from the pioneering work of Lo and MacKinlay (1988) which was later modified and extended by Chow and Denning (1993).

Karemera et al (1999: 174) summarised these tests as follows:

Let S_t denote the log of the equity return series being considered at time t.

The hypothesis of pure random walk is given by the equation:

$$S_t = \mu + S_{t-1} + u_t \qquad [3.10]$$

Where μ is a drift parameter and u_t is a random error term. The usual stochastic assumption on μ_t is the Gaussian error structure, $E(u_t) = 0$ and $E({u_t}^2) = {\sigma_u}^2$.

The null hypothesis for the variance ratio test is:

$H_0 = VR(q) = 1$ means the markets under the study are weak-form efficient

$H_a \neq VR(q) \neq 1$ means the markets under the study are not weak-form efficient (Patel et al 2012).

Lo and MacKinlay (1988) developed tests of random walks under alternative assumptions of homoscedasticity and heteroscedasticity on u_t. Key to the test is the fact that, under the RWH the increments in asset price series are serially uncorrelated and that variance of the increments increase linearly in the sampling intervals. Such that for weekly data, if random walk is the true process generating the stock price series, the variance of the weekly series should be five times the variance of a daily series.

Abedini (2009) state the variance ratio is calculated by dividing the variance of returns estimated from the longer interval by the variance of returns estimated from the shorter interval and then by normalising this value to one by dividing it by the ratio of the longer interval to the shorter interval as follows:

$$Var(P_t - P_t - q) = {}_qVar(P_t - P_{t-1}) \qquad [3.11]$$

Where q is any positive integer, the variance ratio, $VR_{(q)}$ is determined as follows:

$$VR_{(q)} = \frac{\frac{1}{q}Var(p_t - p_{t-p})}{Var(p_t - p_{t-1})} = \frac{\sigma^2(q)}{\sigma^2(1)} \qquad [3.12]$$

For a sample size of nq+1 observation $(P_0, P_1, \dots, P_{nq})$, the formulas for computing $\sigma^2(q)$ and $\sigma^2(1)$ are given in the following equations:

$$\sigma^2(q) = \frac{\sum_{t=q}^{nq}\left(p_t - p_{t-q} - q\mu\right)^2}{h} \qquad [3.13]$$

Where

$$h = q(nq + 1 - q)(1 - \frac{q}{nq}) \qquad [3.14]$$

And

$$\mu = \frac{1}{nq}\sum_{t=1}^{nq}(p_t - p_{t-1}) = \frac{1}{nq}\left(p_{nq} - p_0\right) \qquad [3.15]$$

And

$$\sigma^2(1) = \frac{\sum_{t=1}^{nq}(p_t - qp_{t-1} - \mu)^2}{(nq-1)} \qquad [3.16]$$

The variance ratio test techniques test the RWH for two main desirable statistical properties (Karemera et al; 1999). Firstly, Lo and MacKinlay (1988) derived the asymptotic distribution of the variance ratio estimators and formulated an asymptotic standard normal test, $Z(q)$, to indicate the statistical significance of the variance ratios. Secondly, they provided an alternative statistic, $Z^*(q)$ that is robust to heteroscedasticity and non-normal disturbances. Given these attributes and the ease of computation and interpretation, variance ratio tests are appealing, especially for practitioners (Karemera *et* al; 1999:174-175).

The standard normal $Z(q)$ and $Z^*(q)$ test statistics are computed as follows (Abedini, 2009):

$$Z(q) = \frac{VR(q) - 1}{[\emptyset(q)]^{1/2}} \approx N(0,1) \qquad [3.17]$$

$$Z^*(q) = \frac{VR(q) - 1}{[\emptyset^*(q)]^{1/2}} \approx N(0.1) \qquad [3.18]$$

Where $\emptyset(q)$ and $\emptyset^*(q)$ are the asymptotic variance of the variance ratio under the assumption of homoscedaticity and the heteroscedasticity respectively:

$$\emptyset(q) = \frac{2(2q-1)(q-1)}{3q(nq)} \quad [3.19]$$

$$\emptyset^*(q) = \sum_{j=1}^{q-1} \left[\frac{2(q-j)}{q}\right]^2_{\partial(j)} \quad [3.20]$$

Where $\partial(j)$ is the heteroscedasticity - consistent estimator and computed as follows:

$$\partial(j) = \frac{\sum_{t=j+1}^{nq}(p_t - p_{t-1} - \mu)^2 (p_{t-j} - p_{t-j-1} - \mu)^2}{\sum_{t=1}^{nq}(p_t - p_{t-1\hat{\mu}})^2} \quad [3.21]$$

Note that both standard normal Z-statistics and Z*-statistics are approaching N(0, 1).

Karemera et al (1999) finds that the single variance ratio tests is suitable for testing individual variance ratios for a specific aggregation interval, q. In using these tests, a comparison is made between test statistics, $Z_{(q)}$ and $Z^*{}_{(q)}$ and the critical values of the standard normal tables. Indeed, the RWH requires that variance ratios for all observation intervals, q's, be simultaneously equal to unity (1.0). Charles and Darné (2009b) identify that the central idea in variance ratio tests is founded on the observation that when returns are uncorrelated over time, the variance should be 1.0 which indicates that the returns are serially uncorrelated. Luger (2003) finds the variance methodology exploits the fact that the variance of uncorrelated increments is linear in the sampling interval.

Griffin et al (2010) postulate that under the null hypothesis of a random walk with uncorrelated increments, variance ratios should equal one at all lags. Positive serial correlation is indicated when the variance ratios are significantly above one while negative auto-correlation is implied when variance ratios are below one. Since both positive and negative auto-correlation represent departures from a random walk, the absolute value of the variance ratio statistic minus one ($|VR - 1|$) is used as a measure of relative efficiency. The authors find this approach to be advantageous because if a market consists of share with both over- and under-reaction to past returns, both would be captured.

Charles and Darné (2009b) postulate that if the data-generating process of time series is a random walk, the expected value of variance ratio (*x*; *k*) should be equal to 1.0 for all horizons *k*. The variance ratio should be higher (lower) than 1.0, if returns are positively (negatively) correlated. Therefore, a time series is found to be mean reverting if variance ratio (*x*; *k*) is significantly lower than unity at long horizons *k*. This is an indication of negative serial correlation. It is mean averting, i.e. explosive, if variance ratio (*x*; *k*) is significantly higher than 1.0 at long horizons. This is an indication of positive serial correlation

Karemera et al *(*1999) reports that Lo and MacKinlay (1988) developed the test for random walk based on variance ratio estimators which focus on the uncorrelatedness of variance increments because there are departures from random walks that unit root test cannot detect.

Mobarek and Fiorante (2014) postulate that the variance ratio tests have been proven to be successful in testing the random walk properties of stock price series as they tend to yield more powerful and accurate results compared to other tests, for instance, the unit root tests, various ARIMA and auto-regressive models.

Lo and MacKinlay (1989:236) indicate “the simplicity, reliability and flexibility of the variance ratio test make it a valuable tool for inference”. The variance ratio test is shown to produce reliable inferences even for moderate sample sizes under the two most commonly advanced null hypotheses: firstly, the random walk with independently and identically distributed Gaussian increments, and secondly, with uncorrelated but heteroscedastic increments. Moreover, under the specific heteroscedastic null, the test is somewhat more reliable than both the auto-correlation tests, e.g. Dickey-Fuller and Box-Pierce portmanteau tests.

Charles and Darné (2009b) suggest that while the intuition behind the variance ratio test is rather simple, conducting a statistical inference using the variance ratio test is less straight forward. This is due to the variance ratio typically using overlapping data in computing the variance of long-horizon returns which was suggested by Lo and MacKinlay (1988). However, the use of overlapping data also adds to the difficulties of analysing the exact distribution of the variance ratio test statistic. The disadvantage of the Lo and MacKinlay test is that the variance ratio test is identified to be a single-test of unity for each variance ratio. This means that the test ignores the joint nature of the hypothesis and may lead to inaccurate inferences (Karemera et al 1999).

Multiple variance ratio tests

Chow and Denning (1993:400) find that the variance ratio test exploits an important property of the RWH – the variance of increments of a random walk is linear in any and all the sampling intervals (q). Examining multiple variance ratio estimates requires a multiple comparison statistical approach. The authors provide such an approach.

Chow and Denning (1993) provide a simple modification for testing multiple variance ratios. Single variance ratio tests that failed to control the joint test size for the multiple variance ratio estimates resulted in very large Type 1 errors. Monte Carlo results indicate that the size of the test is close to its nominal size and that is as reliable as the Dickey-Fuller and the Phillips-Perron unit root tests. Charles and Darné (2009b:511) offers:

> *"The question as to whether or not a time series is mean reverting requires that the null hypothesis holds true for all values of k. In view of this, it is necessary to conduct a joint test where a multiple comparison of variance ratios over a set of different time horizons is made. However, conducting separate individual tests for a number of k values may be misleading as it leads to over-rejection of the null hypothesis of a joint test, above the nominal size."*

As stressed by Chow and Denning (1993), this sequential procedure leads to an oversized testing strategy. Thus, the weakness of Lo-MacKinlay's test is that it ignores the joint nature of testing for the RWH.

Chow and Denning (1993:400) study's testing procedure – treating the Lo and MacKinlay test statistic as Studentised Maximum Modulus variates - is able to reduce the Type 1 error and control the size of a multiple variance ratio test. Karemera et al (1999) emphasises that the Chow and Denning (1993) method, controls the size of the multiple variance ratio test by comparing the Lo and MacKinlay (1988) Z and Z^* statistics with the studentised maximum modules. In addition, Chow and Denning (1993) find that Monte Carlo evidence suggests that the power of the test is comparable to that of the Dickey-Fuller and Phillips-Perron unit root tests against a stationary AR(1) alternative, and is more powerful than the test against the two unit root alternatives.

Other variance ratio methods

Even though the individual Lo-MacKinlay multiple variance ratio tests are quite powerful at testing for homoscedastic or heteroscedastic nulls, it is important to note that these tests are asymptotic tests in that their sampling distributions are approximated by their limiting distributions (Charles and Darné 2009b). The authors find that the sampling distribution of the variance ratio statistic can be far from normal in a finite sample, showing severe bias and right skewness. Moreover, the finite sample deficiencies may give rise to serious size distortions or low power, which can lead to misleading inferences. To avoid this problem, Charles and Darné (2009b:504) assert that some alternatives have been recommended, such as a power-transformed variance ratio statistic by Chen and Deo (2006), exact variance ratio test based on rank and signs by Wright (2000), a sub-sampling method by Whang and Kim (2003) and a bootstrap method by Kim (2006).

Wright (2000) proposed the rank-based and sign-based variance ratio tests in order to be free from the problem of size distortions and obtained exact versions of the conventional variance ratio under more general distributional assumptions. The non-parametric test is also found to be more powerful than the conventional variance ratio test when return data are highly non-normal and non-stationary (Wright 2000).

Al-Khazali et al (2007) observe that the non-parametric test offers potential advantages for the study of stock exchanges that are relatively small and marked by infrequent and thin trading. Non-parametric-based tests, in addition, do not rely on the existence of moments, and are more robust in the presence of conditional heteroscedasticity. As a result, they are superior to the Lo and MacKinlay test and should be more powerful than a wide range of models of serial correlation such as auto-regressive moving average and fractionally integrated alternatives with non-normal innovations.

Hung et al (2009) find that the variance ratio based on ranks and signs has two advantages as it aims to enhance the testing power of the Lo and MacKinlay variance ratio test. Firstly, the Lo and MacKinlay variance ratio test is derived from the symptotic theory, and hence, it is borne with the problem of size distortions unlike the statistics proposed by Wright which are free from this problem. Secondly, Wright's statistics are more powerful than the alternatives since the distributions of most financial data are largely non-normal.

- ***Changing and relative efficiency***

Conventional tests of the random walk hypothesis such as the variance ratio test, lead to the inference that stock price or stock price index does or does not follow a random walk at a predetermined significance level. Although such tests can be applied to successive time periods, they cannot readily capture gradual changes in efficiency over successive observations (Jefferis and Smith 2005).

Tests for changing efficiency detect changes in weak-form efficiency through time (Jefferis and Smith 2005). Variance ratio tests are carried out in fixed-length rolling windows, whereby the tests focus on successive periods and capturing changes in weak-form efficiency. They also provide measures of relative efficiency and make it possible to compare the degree of weak-form efficiency across markets (Smith, 2012).

The rolling approach is calculated for the first window of a specified length, it then rolls one point forward eliminating the first observation and including the next one for re-estimation of the H-statistic. This procedure continues until the last observation is used (Lim 2007). The author adds that efficiency ranking can be done via the percentage of sub-samples with a significant test statistic, where a higher percentage indicates more frequent stock price deviations thus a lower degree of informational efficiency. The key objective of using rolling window estimation is to measure how often the random walk hypothesis is rejected by the test statistic over the full sample period. Application of the rolling window captures the persistence of stock price departures from a random walk benchmark over time (Lim and Brooks 2011). Structural changes in the return generating process and exogenous events can cause return predictability to evolve through time (Timmermann 2008).

Early variance ratio tests by Lo and MacKinlay (1988); and Chow and Denning (1993); were asymptotic tests with low power and poor size properties in finite samples. As a result they have been replaced by a new generation of the variance ratio test, the joint sign (JS) test proposed by Kim and Shamsuddin (2008); wild bootstrap (*JM**) test proposed by Kim (2006) and the automatic variance ratio (AVR*) test developed by Kim (2009). These tests are known to have very good power and no size distortions with 500 observations (Smith and Dyakova 2014).

3.3 SELECTED ESTIMATION MODELS

The techniques that will be used to test the market efficiency of the NSE are the serial correlations test, unit root tests and the runs test which are based on absolute efficiency. In addition, the variance ratio test will also be tested and is based on relative efficiency. These techniques will test the level of efficiency of the NSE.

Serial correlations test is a parametric test, it requires returns to be normally distributed. It is the best test for examining weak-form efficiency because the relationship between price changes in the current period and its value in the previous period is measured (Abedini 2009).

The unit root tests were conducted to test for the stationarity status of the times series for both the daily and weekly data. Two unit root tests were examined for this study, the ADF unit root test and the Phillips-Perron test. The presence of a unit root indicates support for the RWH implying market efficiency (Lagoarde-Segot and Lucey 2008).

Runs test determines whether successive price changes are independent (Abraham, Seyyed and Alsakran 2002). It is a non-parametric test as it does not require returns to be normally distributed (Urquhart and Hudson 2013), that is, its validity is not dependent on the shape of the underlying distribution, hence, a fitting statistical technique to test the weak-form market efficiency (Abedini 2009). It is considered to be a linear test and it can also detect non-linearity in a returns series although the results differ from the linear test. Moreover, this test is not affected by any extreme values in the return series therefore it does not require constant variance of the data (Mlambo and Biekpe 2007). It serves as a good complement to the serial correlation test because while serial correlation coefficients may be significantly affected by a single outlier, the results from the runs test are not seriously affected by a few outliers.

The variance ratio test is known to be more powerful compared to other tests such as the unit root and produces more accurate results. In addition, it is easy to calculate and interpret (Mobarek and Fiorante 2014). It is very useful to investigate share returns that are not normally distributed (Lo and MacKinlay 1988), and provides a test statistic that is suitable to heteroscedasticity (Karemera et al 1999). It is also not susceptible to errors that arise due to spurious auto-correlation that comes about due to non-synchronous trading, a feature common in developing countries (Füss 2005).

3.4 DATA

The data was availed from the NSE and from Bloomberg. The market efficiency of the NSE is analysed using the NSE 20 share index and the NSE ASI using both daily and weekly data respectively. In total, four time-series were analysed. The time period of each of the time series differ as indicated in table 3.1 below. The start of the period for the NSE 20 share index is January 2001 and for the NSE ASI is February 2008 when it was initiated. The end of the period for both indexes is in January 2015. Each of the indexes is traded on the main investment market segment of the exchange. The currency base denominated is in Kenyan Shillings (Ksh).

TABLE 3.1: *Duration of the Time Series*

Time series	***Duration***
NSE 20 share index: Daily data	02 January 2001 – 30 January 2015
NSE 20 share index: Weekly data	05 January 2001 – 30 January 2015
NSE ASI: Daily data	25 February 2008 – 30 January 2015
NSE ASI: Weekly data	29 February 2008 – 30 January 2015

The data that was analysed consisted of index returns that are transformed to natural logs of both the daily or weekly prices of the index.

$$r_t = \ln\left(\frac{P_t - P_{t-1}}{P_{t-1}}\right) \times 100 \qquad [3.22]$$

The price returns (r_t) are expressed in percentage terms were calculated as the ending index price minus the beginning index price divided by the beginning index price multiplied by 100. The natural logarithm (ln) of the price returns was calculated for each of the time series on MS Excel. The results of which were transferred to the E-views software for analysis of the descriptive statistics, serial correlations test, unit root tests and variance ratio test. The same results were also transferred to the SPSS software to conduct the runs test.

3.5 RESEARCH APPROACH

To determine the market efficiency of the NSE, four tests were conducted which are as follows:

1. Serial correlations test
2. Unit root tests
3. Runs test
4. Variance ratio test

- ***Descriptive Statistics***

Descriptive statistics of the daily and weekly index returns (Δp_t) were first calculated. In each time series a summary of the following statistics were calculated; mean, median, maximum, minimum, standard deviation, skewness, kurtosis, Jarque-Bera and probability.

Skewness measures the symmetry in a distribution (Abedini 2009). If the value of skewness is zero, the distribution symmetry is perfectly normal. If the skewness is a large positive, the distribution has a right tail while if the skewness is a large negative, the distribution has a left tail.

Kurtosis is used to measure the thickness of the tails (Abedini 2009), and a popular measure of kurtosis is the ratio of the fourth central moment to the square of the second central moment, thus, the critical value is three. For a normal distribution, the value of the measure is equal to three. If the value of kurtosis is more than three, the tail of the graph of the density function will be short and/or fat and is referred to as being leptokurtic. If the value of the kurtosis is less than three, the tail of the graph of the density function will be tall and/or thin and is referred to as being platokurtic.

Abedini (2009) infers that the first condition for price change following RWH is that it conforms to a normal distribution. The Jarque-Bera statistics is used to test for the normal distribution where results of this test were supported by the kurtosis test and the skewness test.

Jarque-Bera tests whether a series is normally distributed. The statistic is given by (Abedini 2009):

$$JB = \frac{n}{6}\left(S^2 + \frac{(K-3)^2}{4}\right) \qquad [3.23]$$

where n is the number of observations, S is the measure of skewness, defined as:

$$S = \frac{\mu_3}{\sigma^3} = \frac{\mu_3}{(\sigma^3)^{3/2}} = \frac{\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x})^3}{\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x}^2)^{3/2}} \qquad [3.24]$$

and K is a measure of kurtosis, described as:

$$K = \frac{\mu_4}{\sigma^4} = \frac{\mu_4}{(\sigma^2)^2} = \frac{\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x})^4}{\left(\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x})^2\right)^2} \qquad [3.25]$$

Abedini (2009) explains that under the null hypothesis of normality, the Jarque-Bera statistics is distributed x^2 with 2 degrees of freedom. The null hypothesis of normality is rejected if Jarque-Bera $> x^{2(2)}$. The 0.05 critical value for the Jarque-Bera test is 5.99 (Smith et al 2002).

- ***Serial Correlations Test***

The serial correlations test was conducted via the correlogram test available on E-views. The test was conducted on the following time series: NSE 20 share index: Daily data, NSE 20 share index: Weekly data, NSE ASI: Daily data and NSE ASI: Weekly data. The test was conducted on level data with 36 lags for each time series.

The null and alternative hypotheses for the serial correlations test are:

$H_0: P_k = 0$ (price changes are independent)
$H_a: P_k \neq 0$ (price changes are not independent)

$$Q_{LB} = N(N+2)\sum_{j=1}^{k}\frac{{\rho_j}^2}{N-j} \qquad [3.26]$$

Where *N*=number of observations. The $\rho_j =$ the jth auto-correlation. The *k*=number of auto-correlations (Aumeboonsuke and Dryver 2014).

- ***Unit Root Tests***

The unit root tests were conducted using the E-views software. Two unit root tests were conducted, the ADF test and the Phillip-Perron test. The tests were conducted on the following time series: NSE 20 share index: Daily data, NSE 20 share index: Weekly data, NSE ASI: Daily data and NSE ASI: Weekly data. The tests on the unit root were conducted on level data with each test including both the intercept, and the trend and intercept. While including the lag length, the automatic selection, Schwarz info criterion and maximum lags of 29 were used.

The hypotheses for unit root tests are:

$H_0: \rho = 1$ (The time series is non-stationary and there is unit root)

$H_a: \rho \neq 1$ (The time series is stationary and there is no unit root)

The ADF unit root test is based on the following ordinary least squares (OLS) regression (Abedini 2009):

$$\Delta y_1 = a + by_{t-1} + \sum_{j-1}^{k} cpy_{t-1} + \mu t \qquad [3.27]$$

The null hypothesis is $b = 0$; against the one-sided (lower-tail) alternative hypothesis, $b < 0$.

The Phillips-Perron test is based on the estimation of equation:

$$\Delta X_t = \alpha_0 + \alpha_1 T + \alpha_2 X_{t-1} + \omega_t \qquad [3.28]$$

The null hypothesis is rejected if the pseudo t statistic is larger than the critical value.

- ***Runs Test***

The runs test was conducted via the SPSS software since it is not available on the E-views software. All four times-series were tested for randomness on level data.

The null and alternative hypotheses for the runs tests are:

$H_0: R = E(r)$ (Successive changes in the prices of the indexes are random)

$H_a: R \neq E(r)$ (Successive changes in the prices of the indexes are not random)

$$E(r) = \frac{\{N(N+1) - \sum_{i=1}^{3} n_i^2\}}{N} \qquad [3.29]$$

Where E_r is the total expected number of runs, *N* is total number of observations, and n_i is the number of observations in each category *i*. For a large number of observations $(\mathrm{N} > 30)$, the sampling distribution of E_r is approximately normal and the standard error of $E(r)$ is given by:

$$\sigma_r = \left\{\frac{\sum_{i=1}^{3} {n_i}^2\left[\sum_{i=1}^{3} {n_i}^2 + N(N+1)\right] - 2N\sum_{i=1}^{3} {n_i}^3 - N^3}{N^2(N-1)}\right\}^{1/2} \qquad [3.30]$$

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

$$Z = \frac{R \pm 0.5 - E(r)}{\sigma_r} \qquad [3.31]$$

For large samples, Z will be normally distributed with a mean of zero and a variance of one. For tests of significance, the standardised normal variable Z two-tailed test will be used (Moustafa 2004).

- ***Variance Ratio Test***

The variance ratio test was conducted using the E-views software. The original version of the variance ratio test by Lo and MacKinlay was tested. The data specification on the software was that it should be an exponential random walk. The test specification was computed using original data which are the price returns after the data has been transformed and it includes demean data that allows for drift. The probabilities should be asymptotic normal. The test periods were an equal-spaced grid and differed depending of the share index used. No additional options were specified.

The null hypothesis for the variance ratio test is:

$H_0 = VR(q) = 1$ (The markets under the study are weak-form efficient)

$H_a \neq VR(q) \neq 1$ (The markets under the study are not weak-form efficient)

3.6 SUMMARY

This chapter discussed the methodological issues that relate to the tests of market efficiency that were used in the study. A discussion on selected estimation models, data and the research approach followed. Chapter four will discuss the results obtained from the serial correlations test, unit root tests, runs test and variance ratio test.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter reports empirical results of the tests of the efficiency of the NSE and interprets them to answer the research objective that seeks to determine the level of efficiency of the NSE. The research findings will be reported and an analysis of the findings will be discussed.

4.2 RESULTS OF THE TESTS OF MARKET EFFICIENCY

4.2.1 Descriptive Statistics

The descriptive statistics of each of the time series were conducted via the E-views software. The NSE ASI: Weekly data has the highest mean of 0.031326 followed by the NSE 20 share index: Weekly data, NSE ASI: Daily data and finally the NSE 20 share index: Daily data. The NSE ASI: Weekly data has the highest median of 0.058297 and the NSE 20 share index: Daily data has the lowest median of 0.001321. The NSE ASI: Weekly data has the highest maximum value of 3.618155 and lowest minimum value of: -2.411904. The NSE ASI: Weekly data has the highest standard deviation of: 0.569308 while the NSE 20 share index: Daily data has the lowest standard deviation of 0.109775.

A normal distribution has skewness of zero. If the skewness is a large negative the distribution has a left tail. In this case, the skewness of all four time-series is positive with the highest being the NSE ASI: Daily data at 1.091112 and the lowest is the NSE ASI: Weekly data of 0.113425 which means that the distribution has a right tail. The kurtosis of a normal distribution is equal to three. If the kurtosis is less than 3, it means the tail of the graph of the density function will be tall/thin and is known to be platokurtic.

In this case, the kurtosis of all four time-series is greater than 3, the highest being the NSE 20 share index: Daily data with 19.85817 and the lowest being the NSE 20 share index: Weekly data being 8.699999. This means the tail of the graph of the density function is short/fat and is known to be leptokurtic.

Jarque-Bera statistic is a test of the normal distribution whose results is supported by the kurtosis test and the skewness test. The null hypothesis of normality is rejected if:

Jarque-Bera $> x^{2(2)}$.

The 0.05 critical value for the Jarque-Bera test is 5.99. All four time-series have Jarque-Bera statistics that are significantly higher than 5.99, the highest being the NSE 20 share index: Daily data which is 41869.89 and the lowest being the NSE ASI: Weekly data which is 716.4793. This means that we reject the null hypothesis of a normal distribution and accept the alternative hypothesis of non-normal distribution. This finding is confirmed by results of the skewness test that indicates the distribution has a right tail while the kurtosis test confirms that the distribution is leptokurtic. Results of the descriptive statistics are reported on table 4.1 below.

For detailed results on the descriptive statistics, refer to Figures 1 to 4 in the appendix.

TABLE 4.1: *Results of the Descriptive Statistics*

Series (Observations)	Mean	Median	Maximum	Minimum	SD	Skewness	Kurtosis	Jarque-Bera Statistic	Probability
NSE 20 Share Index Daily data	0.003612	0.001321	1.313339	- 1.262414	0.109775	0.547178	19.85817	41869.89	0.000000
NSE 20 Share Index Weekly data	0.017900	0.011458	1.963580	- 1.274222	0.322315	0.640592	8.699999	1043.853	0.000000
NSE ASI Daily data	0.006670	0.004268	1.768218	- 0.996621	0.195704	1.091112	16.82577	14195.60	0.000000
NSE ASI Weekly data	0.031326	0.058297	3.618155	- 2.411904	0.569308	0.113425	9.897935	716.4793	0.000000

4.2.2 Serial Correlations Test

The null and alternative hypotheses for the serial correlations test are:

$H_0: P_k = 0$ (Price changes are independent)

$H_a: P_k \neq 0$ (Price changes are not independent)

The results of the correlogram test show that auto correlation (AC) test of all four time series are not equal to 0 therefore the time series are stationary. The graphic view of the AC in tables 1 to 4 of the Appendix shows a slow decline in the trend suggesting stationarity. In addition, the p-values of all four times-series are equal to 0. The Q-statistics should be significant with p-values that are close to 0 and less than 0.05. The null hypothesis will be rejected meaning the price changes are not independent and will violate the RWH. The NSE 20 share index and the NSE ASI (both daily and weekly data) are found to not be weak-form efficient based on the serial correlation test. Results of the correlogram test are reported on Table 4.2 below. For detailed results on the correlogram test, refer to Tables 1 to 4 in the appendix.

TABLE 4.2: Results of the Serial Correlations Tests

	NSE 20 Share Index Daily data				***NSE 20 Share Index Weekly data***				***NSE ASI Daily data***				***NSE ASI Weekly data***			
Lags	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	0.369	0.369	478.62	0.000	0.168	0.168	20.687	0.000	0.506	0.506	445.48	0.000	0.206	0.206	15.492	0.000
2	0.246	0.128	692.60	0.000	0.078	0.052	25.212	0.000	0.275	0.026	577.04	0.000	0.062	0.020	16.891	0.000
3	0.119	-0.009	742.41	0.000	0.055	0.035	27.447	0.000	0.122	-0.035	603.05	0.000	-0.010	0.027	16.924	0.001
4	0.031	-0.043	745.80	0.000	-0.018	0.038	27.694	0.000	-0.015	-0.094	603.47	0.000	-0.103	0.101	20.808	0.000
5	0.022	0.012	747.49	0.000	-0.008	-0.005	27.743	0.000	-0.043	0.005	606.68	0.000	0.055	0.103	21.931	0.001
6	-0.032	-0.044	751.20	0.000	0.083	0.089	32.838	0.000	-0.035	0.012	608.88	0.000	0.171	0.159	32.741	0.000
7	-0.017	0.005	752.28	0.000	0.119	0.100	43.373	0.000	-0.033	-0.010	610.80	0.000	0.132	0.062	39.185	0.000
8	-0.009	0.009	752.59	0.000	0.015	-0.031	43.536	0.000	-0.018	-0.001	611.36	0.000	0.077	0.012	41.373	0.000
9	0.031	0.045	755.99	0.000	0.024	0.004	43.971	0.000	0.014	0.029	611.70	0.000	-0.003	-0.015	41.377	0.000
10	0.030	0.007	759.12	0.000	0.019	0.011	44.228	0.000	0.017	-0.002	612.19	0.000	-0.022	0.011	41.561	0.000
11	0.028	0.003	761.82	0.000	0.018	0.024	44.460	0.000	0.017	0.000	612.70	0.000	0.061	0.074	42.950	0.000
12	0.026	0.005	764.22	0.000	0.069	0.060	47.972	0.000	0.023	0.012	613.64	0.000	0.145	0.106	50.857	0.000
13	0.022	0.008	765.99	0.000	0.064	0.026	51.071	0.000	0.025	0.014	614.75	0.000	0.081	-0.009	53.298	0.000
14	0.041	0.029	771.80	0.000	0.011	-0.023	51.165	0.000	0.007	-0.015	614.85	0.000	0.007	-0.049	53.316	0.000
15	0.032	0.011	775.50	0.000	0.067	0.063	54.523	0.000	-0.030	-0.044	616.44	0.000	0.004	0.021	53.323	0.000
16	0.024	0.001	777.53	0.000	0.040	0.020	55.703	0.000	-0.040	-0.008	619.31	0.000	-0.076	-0.054	55.512	0.000
17	0.012	-0.005	778.03	0.000	0.072	0.062	59.644	0.000	-0.055	-0.022	624.59	0.000	-0.020	-0.017	55.671	0.000
18	-0.008	-0.018	778.28	0.000	0.058	0.019	62.144	0.000	-0.042	0.005	627.70	0.000	0.127	0.096	61.806	0.000
19	-0.025	-0.022	780.41	0.000	0.052	0.015	64.189	0.000	-0.027	-0.003	629.00	0.000	0.062	-0.010	63.264	0.000
20	-0.023	-0.003	782.35	0.000	0.018	-0.004	64.438	0.000	-0.015	-0.001	629.42	0.000	0.015	-0.038	63.347	0.000
21	-0.028	-0.010	785.11	0.000	0.014	0.006	64.586	0.000	-0.038	-0.046	631.91	0.000	-0.067	-0.071	65.061	0.000

TABLE 4.2: Results of the Serial Correlations Tests (contd)

	NSE 20 Share Index Daily data				**NSE 20 Share Index Weekly data**				**NSE ASI Daily data**				**NSE ASI Weekly data**			
Lags	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
22	-0.015	0.005	785.92	0.000	0.031	0.015	65.338	0.000	-0.031	-0.002	633.65	0.000	-0.005	0.076	65.071	0.000
23	-0.012	-0.004	786.45	0.000	-0.020	-0.040	65.630	0.000	-0.006	0.024	633.71	0.000	-0.004	-0.007	65.078	0.000
24	-0.011	-0.008	786.90	0.000	0.054	0.040	67.840	0.000	0.046	0.064	637.44	0.000	0.031	-0.015	65.456	0.000
25	0.005	0.010	786.97	0.000	0.059	0.033	70.473	0.000	0.079	0.035	648.40	0.000	0.068	0.022	67.254	0.000
26	0.022	0.022	788.73	0.000	0.035	0.014	71.432	0.000	0.099	0.035	665.60	0.000	0.026	0.011	67.517	0.000
27	0.029	0.014	791.73	0.000	0.009	-0.018	71.489	0.000	0.110	0.040	686.85	0.000	0.050	0.071	68.508	0.000
28	0.060	0.046	804.65	0.000	0.015	-0.003	71.669	0.000	0.092	0.017	701.73	0.000	-0.011	-0.006	68.556	0.000
29	0.049	0.010	813.02	0.000	0.047	0.044	73.335	0.000	0.065	0.006	709.10	0.000	0.076	0.095	70.852	0.000
30	0.062	0.030	826.81	0.000	0.008	-0.012	73.383	0.000	0.043	0.011	712.36	0.000	0.099	0.038	74.703	0.000
31	0.030	-0.014	829.99	0.000	0.004	-0.025	73.397	0.000	0.024	0.008	713.38	0.000	0.039	-0.007	75.319	0.000
32	0.017	-0.001	831.07	0.000	0.010	-0.012	73.481	0.000	0.018	0.010	713.93	0.000	0.032	0.015	75.720	0.000
33	0.017	0.012	832.08	0.000	-0.070	-0.080	77.238	0.000	0.032	0.028	715.76	0.000	-0.101	-0.120	79.786	0.000
34	0.029	0.031	835.06	0.000	-0.048	-0.035	79.017	0.000	0.034	0.010	717.77	0.000	-0.103	-0.064	84.071	0.000
35	0.033	0.016	838.84	0.000	0.026	0.038	79.557	0.000	0.041	0.020	720.74	0.000	0.006	0.029	84.084	0.000
36	0.020	-0.002	840.32	0.000	-0.013	-0.030	79.691	0.000	0.048	0.015	724.88	0.000	-0.035	-0.080	84.567	0.000

4.2.3 *Unit Root Tests*

The hypotheses for the unit root tests are:

$H_0: \rho = 1$ (The time series is non-stationary and there is unit root)
$H_A: \rho \neq 1$ (The time series is stationary and there is no unit root)

For the ADF unit root test, the test statistics are significant at 10%, 5% and 1% levels respectively. The null hypothesis will therefore be rejected which leads to acceptance of the alternative hypothesis, that the time series are stationary and have no unit root. The time series therefore do not follow a random walk.

Similar results are applicable for the Phillips-Perron unit root test. The test statistics are significant at: 10%, 5% and 1% levels respectively. The null hypothesis will be rejected leading to acceptance of the alternative hypothesis, that the time series are stationary and have no unit root thus confirming the time series do not follow a random walk. The NSE 20 share index and the NSE ASI (both daily and weekly data) are found to not be weak-form efficient based on the ADF and Phillips-Perron unit root tests. Results of the unit root tests are reported in Table 4.3 below. For detailed results on the ADF and Phillips-Perron unit root tests, refer to tables 5 to 20 in the appendix.

TABLE 4.3: *Results of Stationarity Tests*

	ADF In levels $H0: Y_t \sim I(1)$ $H1: Y_t \sim I(0)$		Phillips-Perron In levels $H0: Y_t \sim I(1)$ $H1: Y_t \sim I(0)$	
Series (Observations)	***Intercept***	***Trend + Intercept***	***Intercept***	***Trend + Intercept***
NSE 20 Share Index: daily data	- 29.29562***	- 29.29205***	- 40.94618***	- 40.94123***
NSE 20 Share Index: weekly data	- 22.83209***	- 22.81804***	- 23.18655***	- 23.17261***
NSE AS: daily data	- 23.89800***	- 23.94337***	- 23.38092***	- 23.29334***
NSE ASI: weekly data	- 15.38453***	- 15.52423***	- 15.34235***	- 15.48951***

Notes: *,**,*** significant at 10, 5 and 1% levels, respectively.

4.2.4 Runs Test

The runs test is a non-parametric test that was conducted through the SPSS software. The cut point that was considered was the median. This test is especially suitable for this data set as it is suitable for testing non-normal data which in this study has been confirmed by the Jarque-Bera test, skewness test and the kurtosis test.

The null and alternative hypotheses for the runs tests are:

$H_0: R = E(r)$ (Successive changes in the prices of the indexes are random)

$H_a: R \neq E(r)$ (Successive changes in the prices of the indexes are not random)

The actual number of runs is symbolised by R and the expected number of runs by m. If $R \leq m$, the Z value will be negative which implies a positive serial correlation. On the other hand, if $R \geq m$, the Z value will be positive which implies a negative correlation. Positive serial correlation means there is a positive dependence of share prices indicating a violation of the RWH.

All four time series have actual number of runs that are less than the expected number of runs i.e. $R \leq m$ and the Z value of all four time-series are negative suggesting positive serial correlation with the NSE 20 share index: Daily data having a Z value of -14.647 and the NSE ASI: Weekly data having a Z value of -2.899. This means that there is positive dependence of all four times-series thus violating the random walk hypothesis. The NSE 20 share index and the NSE ASI (both daily and weekly data) are found to not be weak-form efficient based on the runs tests. Results of the runs test are reported in Table 4.4 below. For detailed results on the runs tests, refer to Tables 21 to 24 in the appendix.

TABLE 4.4: *Results of the Runs Test*

Series (Observations)	***No. of runs*** (R)	***Total Cases*** (m)	***Z statistic***
NSE 20 Share Index: Daily data	1 327	3 521	- 14.647
NSE 20 Share Index: Weekly data	297	732	- 5.178
NSE ASI: Daily data	626	1 738	- 11.709
NSE ASI: Weekly data	154	361	- 2.899

4.2.5 Variance Ratio Test

Two results are provided in the variance ratio test, the joint tests and individual tests. The joint tests provides the tests of the joint null hypothesis for all test periods while the individual tests apply to the individual test periods that have been specified.

The null hypothesis for the variance ratio test is:

$H_0 = VR(q) = 1$ (The market under the study is weak-form efficient)

$H_a \neq VR(q) \neq 1$ (The market under the study is not weak-form efficient)

The NSE 20 share index: Daily data has a test period that has a minimum of 100 and a maximum of 3 500 with a step of 100 (i.e.100 observations). The joint test of the NSE 20 share index: Daily data shows that the p-value is 0.1561 which is greater than 0.05. Therefore, we fail to reject the null hypothesis instead, we accept the null hypothesis. The individual tests of the NSE 20 share index: Daily data all fail to reject the null hypothesis, other than the first test period of 100 whose p-value is 0.0048. Results of the variance ratio test, NSE 20 share index: Daily data are reported in Table 4.5 below. For detailed results on the variance ratio test of the NSE 20 share index: Daily data, refer to Table 25 in the appendix.

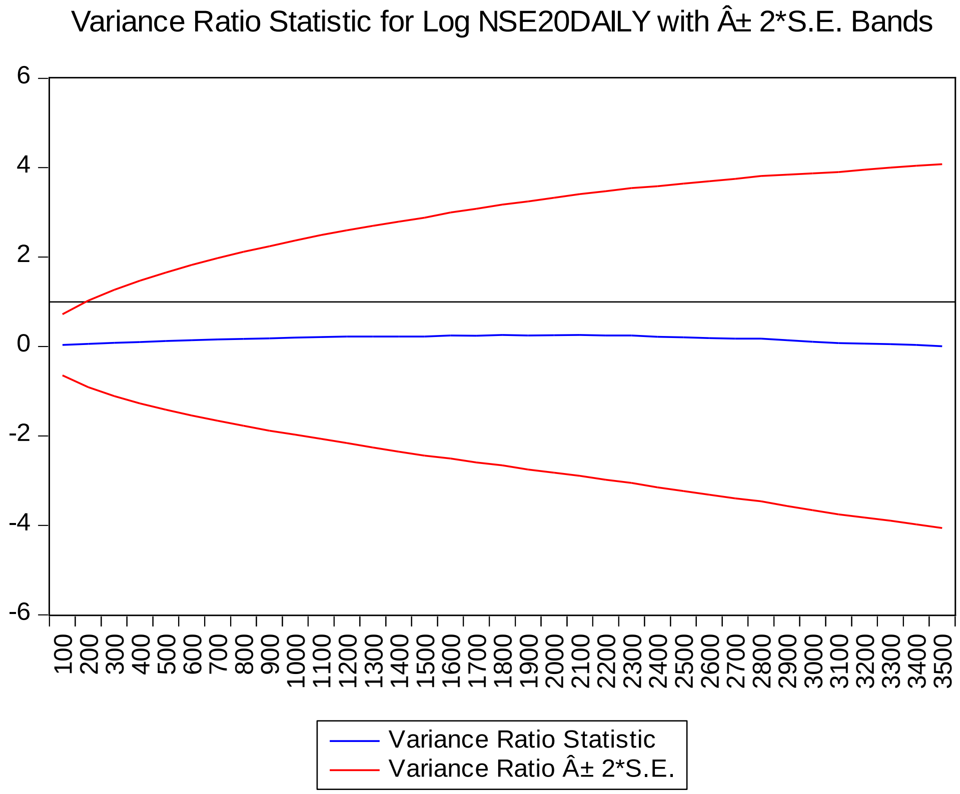
The NSE ASI: Daily data has a test period that has a minimum of 100 and a maximum of 1700 with a step of 100. The joint test of the NSE ASI: Daily data shows that the p-value is 0.4818 which is greater than 0.05, we fail to reject the null hypothesis; instead, we accept the null hypothesis. The individual tests of the NSE ASI: Daily data all fail to reject the null hypothesis, other than the first test period of 100 whose p-value is 0.0379. Results of the variance ratio test, NSE ASI: Daily data are reported in Table 4.5 below. For detailed results on the variance ratio test of the NSE ASI: Daily data, refer to Table 27 in the appendix.

TABLE 4.5: *Results of the Variance Ratio Test (*daily data*)*

Series (Observations)	**Joint tests (Values)**		**df**		**Probability**	
	Max /z/ (at period 100)*	Wald (Chi-Square)	Max /z/ (at period 100)*	Wald (Chi-Square)	Max /z/ (at period 100)*	Wald (Chi-Square)
NSE 20 Share Index (Daily data)	2.817599	34.53883	1127	35	0.1561	0.4902
NSE ASI: (Daily data)	2.075586	4.955891	579	17	0.4818	0.9979

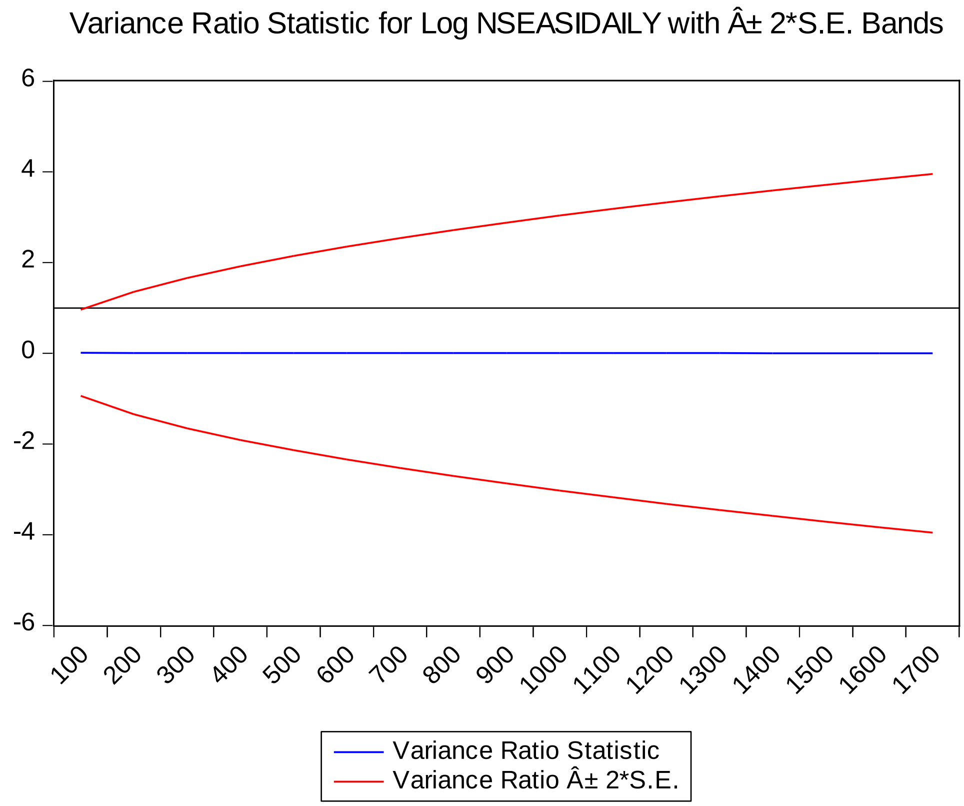
The graph of the level of efficiency of NSE 20 share index: Daily data is illustrated in Figure 4.1 below. The efficiency increased as the test periods increased.

FIGURE 4.1**:** *Graphical Illustration of the Efficiency of the NSE 20 share index* (daily data over the test periods: January 2001 to January 2015)



The graph of the level of efficiency of NSE ASI: Daily data is illustrated in Figure 4.2 below. The efficiency increased as the test periods increased.

FIGURE 4.2: *Graphical Illustration of the Efficiency of the NSE ASI* (daily data over the test periods: February 2008 to January 2015)



The NSE 20 share index: Weekly data has a test period that has a minimum of 25 and a maximum of 725 with a step of 25. The joint test of the NSE 20 share index: Weekly data shows that the p-value is 0.6401 which is greater than 0.05. Hence, we fail to reject the null hypothesis; instead we accept the null hypothesis. The individual tests of the NSE 20 share index: Weekly data all fail to reject the null hypothesis, other than the first test period of 25 whose p-value is 0.0346. Results of the variance ratio test, NSE 20 share index: Weekly data are reported in Table 4.6 below. For detailed results on the variance ratio test of the NSE 20 share index: Weekly data, refer to Table 26 in the appendix.

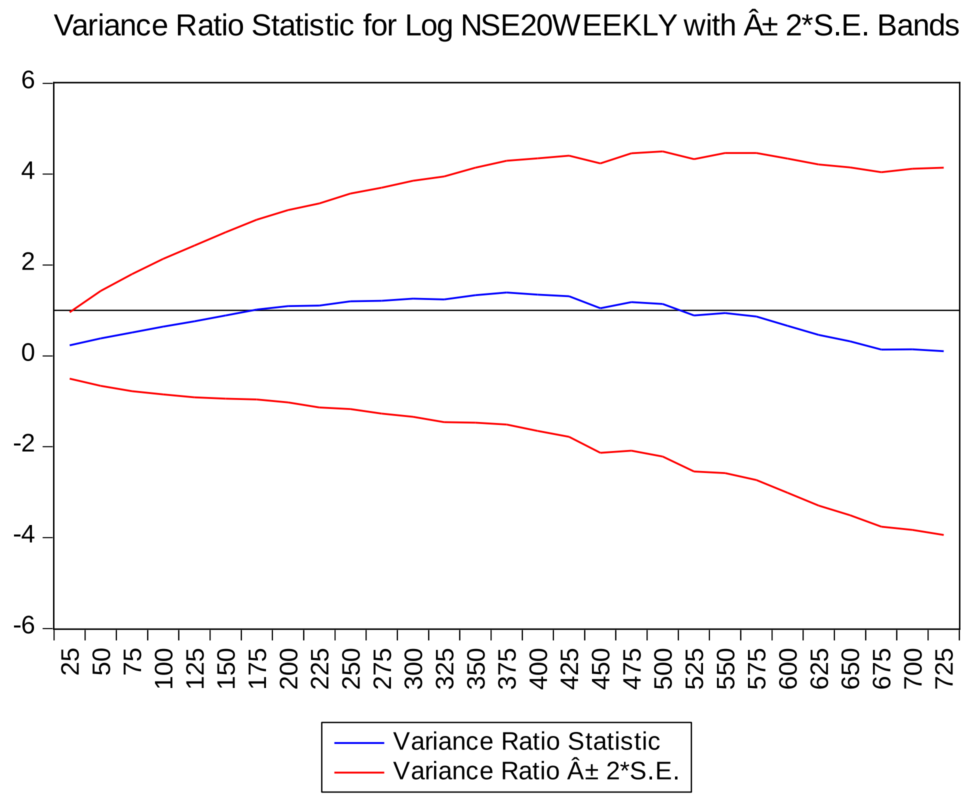
The NSE ASI: Weekly data has a test period that has a minimum of 25 and a maximum of 350 with a step of 25. The joint test of the NSE ASI: Weekly data shows that the p-value is 0.7713 which is greater than 0.05, we fail to reject the null hypothesis; instead, we accept the null hypothesis. The individual tests of the NSE ASI: Weekly data all fail to reject the null hypothesis. Results of the variance ratio test, NSE ASI: Weekly data are reported in Table 4.6 below. For detailed results on the variance ratio test of the NSE ASI: Weekly data, refer to Table 28 in the appendix.

TABLE 4.6: *Results of the Variance Ratio Test* (weekly data)

Series (Observations)	**Joint tests (Values)**		**df**		**Probability**	
	Max /z/ (at period 25)*	Wald (Chi-Square)	Max /z/ (at period 25)*	Wald (Chi-Square)	Max /z/ (at period 25)*	Wald (Chi-Square)
NSE 20 Share Index: Weekly data	2.112669	928.1357	236	29	0.6401	0.0000
NSE ASI: Weekly data	1.644742	18.29661	133	14	0.7713	0.1936

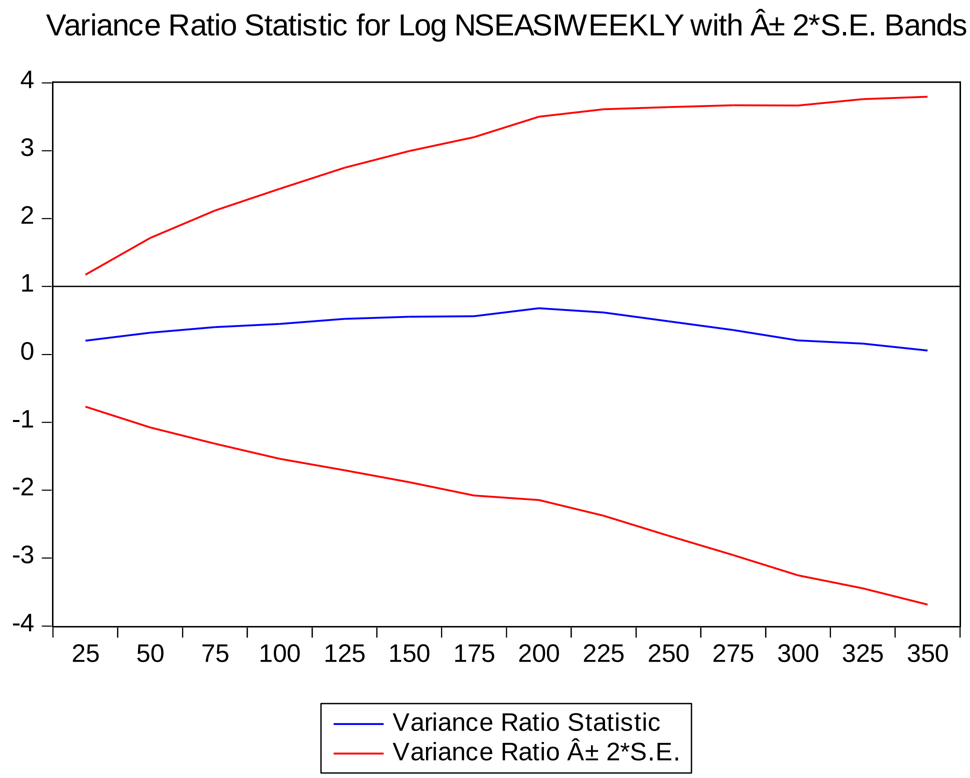
The graph of the NSE 20 share index: Weekly data is illustrated in Figure 4.3 below. The level of efficiency of the index increased over the period but declined slightly at the end of the test period.

FIGURE 4.3: *Graphical Illustration of the Efficiency of the NSE 20 share index* (weekly data over the test periods: January 2001 to January 2015)



The graph of the NSE ASI: Weekly data is illustrated in Figure 4.4 below. It shows the level of efficiency has increased but declined closer to the end of the test period.

FIGURE 4.4: *Graphical Illustration of the Efficiency of the NSE ASI* (weekly data over the test periods: February 2008 to January 2015)



The conclusion of the variance ratio test is that the NSE 20 share index and the NSE ASI fail to reject the null hypothesis. Rather, the null hypothesis will be accepted. This means that the NSE is weak-form efficient. An addition crucial finding is that the efficiency of the NSE has increased over the years as illustrated by Figures 4.1 to 4.4.

The overall results are mixed with the serial correlations test, unit root tests and runs test all indicating that the four time-series violate the RWH. This is however disputed by the more robust and recent test, the variance ratio test whose results indicate that the four time-series are in support of the RWH.

This study tested the efficiency of the NSE from the period 2001 to 2015. It found that the efficiency of the NSE has increased over the period. Figures 4.1 to 4.4 above have illustrated the change in efficiency over the period for each time series. This improvement is likely to have arisen due to the implementation of technology in the NSE in the year 2000 leading to the improvement in efficiency.

Previous studies that have been conducted on the Kenyan market have been summarised on Table 4.7 below. Most of these studies have found it to be weak-form efficient other than the study by Ngugi et al (2002) and Smith et al (2002).

Zhang et al (2012) conduct the test on efficiency of the NSE and other African exchanges using the SURKSS unit root test after the year 2000 specifically over the duration January 2000 to April 2011, and further confirm the presence of weak-form market efficiency of the Kenyan market.

The studies that used the serial correlation test and the runs test are by Mlambo and Biekpe (2007) and; Dickson and Muragu (1994) who found the Kenyan market to be weak-form efficient. Magnusson and Wydick (2002) used only the serial correlation test and found the Kenyan market is characterised by a random walk. Ngugi et al (2002) used the serial correlation test and the unit root test where weak-form efficiency of the NSE was rejected. Smith et al (2002) used an advanced form of the original variance ratio test by Lo and MacKinlay (1989) which we have used in this study known as the multiple variance ratio test of Chow and Denning (1993), and found the Kenyan market did not follow a random walk as the returns were auto-correlated.

Ngugi *et al* (2002) used the ADF and Phillips-Perron unit root test and found that the Kenyan market does not follow a random walk. This study also used the ADF and Phillips-Perron unit root tests producing a similar result.

Methods are by Zhang et al (2012) who used the SURKSS unit root test with a Fourier function, and Appiah-Kusi and Menyah (2003), who used the EGARCH-M model.

This study differs from the previous studies in that it used two indices, the NSE 20 share index and the NSE ASI with the latter initially implemented in the year 2008. In addition, it used both daily and weekly data on each of the indexes; the other studies have used daily, weekly or monthly data, individually. Therefore, a total of four time-series were analysed in this study.

Studies that used share level data of the NSE are by Mlambo and Biekpe (2007) and Dickson and Muragu (1994); those that used index level data are by Zhang et al (2012), Magnusson and Wydick (2002), Appiah-Kusi and Menyah (2003); Ngugi et al (2002) and Smith et al (2002).

The study that used daily data of the NSE is that by Mlambo and Biekpe (2007) and those that used weekly data are those by: Zhang et al (2012); Appiah-Kusi and Menyah (2003); Smith et al (2002); and Dickson and Muragu (1994). Those that used monthly data are by Magnusson and Wydick (2002) and Ngugi et al (2002).

TABLE 4.7: *Previous Studies that have tested the Efficiency of the NSE*

Findings: Stock market efficiency (Weak-form) for the Kenyan market					
Author Name	***Year***	***Objective***	***Variables Used***	***Tests Used***	***Results***
Zhang, Wu, Chang and Lee	2012	To examine evidence for mean reversion in stock prices for five African countries (Egypt, Kenya, Morocco, South Africa and Tunisia)	Weekly stock market index of the Kenya National stock exchange index. The sampling period is from January 2000 to April 2011.	Seeming unrelated regression of the Kapetanious-Shin-Snell (SURKSS) unit root test with a Fourier function.	Presence of weak-form market efficiency for the Kenyan market.
Magnusson and Wydick	2002	To test whether the eight largest African stock markets meet the criterion of weak-form stock market efficiency with returns characterised by a random walk.	Monthly data for the eight African markets listed in the International Finance Corporation (IFC) index.	Serial correlation test.	The hypothesis that the Kenyan market it is characterised by a random walk cannot be rejected.
Mlambo and Biekpe	2007	To study the weak-form efficiency of ten African markets.	Daily closing stock prices and volume traded for individual stocks. The sampling period for the Kenyan market is 02 January 1997 to 31 May 2002.	Serial correlation test and Runs test.	The Kenyan market is found to be weak-form efficient since a significant number of stocks conformed to the random walk.
Appiah-Kusi and Menyah	2003	To model weekly index returns adjusted for thin trading as a non-linear autoregressive process with conditional heteroscedasticity to investigate the weak-form pricing efficiency of 11 African stock markets.	Weekly index data obtained directly from the various stock exchanges.	EGARCH-M model.	The Kenyan market is found to be weak-form efficient.
Ngugi, Murinde and Green	2002	To investigate if the revitalisation process enhanced the stock market micro-structure of the NSE. One of the parameters that was tested was market efficiency.	Monthly data for the NSE 20 Index from January 1970 to December 1999.	Serial correlation test and unit root test.	Weak-form efficiency of the NSE is rejected.

TABLE 4.7: *Previous studies that have tested the efficiency of the NSE* (contd)

Findings: Stock market efficiency (Weak-form) for the Kenyan market					
Author Name	***Year***	***Objective***	***Variables Used***	***Tests Used***	***Results***
Smith, Jefferis and Ryoo	2002	To test the hypothesis that a stock market price index follows a random walk for South Africa, Egypt, Kenya, Morocco, Nigeria, Zimbabwe, Botswana and Mauritius.	Weekly data of the NSE 20 Index from the third week of January 1990 to the last week of August 1998.	Multiple variance ratio test of Chow and Denning.	The hypothesis that stock market price index follows a random walk is rejected as returns are auto-correlated.
Dickson and Muragu	1994	To investigate whether the behaviours of the price series in the Kenya market were consistent with the weak-form of the EMH.	Weekly data of 30 most actively traded equity securities listed on the Kenyan market over the duration of 1979 to 1988.	Serial correlation test and Runs test.	The Kenyan market provides empirical results consistent with weak-form efficiency.

4.3 SUMMARY

This chapter discussed the results of the tests of market efficiency of the NSE. These results are of the serial correlations test, unit root tests, runs test and variance ratio test. A discussion of the previous studies on the market efficiency on the NSE and their relation to the results of this study finalise the chapter. Chapter five will discuss the recommendations and conclusion of the study.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter will state the findings of the study in addition to the contributions of the study. Suggestions of future research will be provided. Finally, the recommendations and conclusion of the study will be discussed.

5.2 SUMMARY OF FINDINGS

Based on the descriptive statistics that were conducted, the NSE 20 share index and the NSE ASI, both daily and weekly data respectively, are found to be non-normal since the four time-series are positively skewed, leptokurtic and the Jarque-Bera statistic confirms that the time series have non-normal distributions.

The serial correlation test conducted via E-views, shows that the auto-correlation test of the four times-series are not equal to 0, and the p-values of the Q-statistics are equal to 0, both indicating that the time series are stationary and do not follow the RWH.

The ADF test and the Phillips-Perron test both indicate that the four time-series are significant at 10%, 5% and 1% levels respectively for both intercept, and intercept and trend respectively. Both the stationarity tests indicate the time series are stationary and have no unit root.

The runs test results indicate that the four time-series all have actual number of runs that are less than the expected number of runs leading to a negative Z-value and a positive serial correlation. This confirms that there is positive dependence hence, the time series do not follow the RWH.

The variance ratio test results are contrary to the prior tests. The p-value of the joint tests of the four time-series, are all greater than 0.05 this means that the time series all follow a RWH. In addition, the graphs that illustrate the efficiency of the time-series as per the variance ratio test all show an increase in efficiency over the test periods.

The NSE 20 share index and the NSE ASI (both daily and weekly data) are found to not be weak-form efficient based on the serial correlation test, unit root tests and the runs test. On the contrary, the more robust variance ratio test finds these indexes to be weak-form efficient. Furthermore, the variance ratio test finds that the efficiency of the NSE has increased over the years.

Generally the NSE is found to be weak-form efficient and its efficiency has increased over the years.

Some of the steps that have been undertaken to improve informational efficiency of the NSE are as follows:

1. The NSE is set to launch its derivatives market in 2015. Trading is set to launch with equity, fixed income and foreign exchange based futures derivatives contracts (African Securities Exchanges Association Year Book 2015).
2. In 2014, the NSE undertook demutualisation, self-listed and commenced to trade the NSE shares at the bourse, becoming the second self-listed bourse in Africa after the JSE (African Securities Exchanges Association Year Book 2015).
3. Also in 2014, the NSE launched the T+0 trading settlement cycle for Government bonds in order to increase the liquidity of the Fixed Income Securities Market Segment (African Securities Exchanges Association Year Book 2015).
4. In 2006, live trading on the automated trading systems was implemented at the NSE. In 2012, the exchange started operations with a system capable of facilitating internet trading. Later in 2014, it also launched a system that enabled online trading of debt securities such as corporate bonds and Government of Kenya Treasury bonds (NSE 2015b).
5. The NSE in partnership with FTSE International officially introduced the FTSE NSE Kenya 15 index and the FTSE NSE Kenya 25 index (FTSE 2012) which are aimed to enhance the depth of available information and also be the underpinning for exchange traded funds and other index-linked products (NSE 2012a).

6. The NSE provides real time (live) data in five different categories: real time listed debt securities data, real time listed equity securities data, NSE live ticker on company website, FTSE NSE equity indices, FTSE NSE bond index (NSE 2016).

Based on the Capital Market Master Plan, 2014 - 2023, the CMA aims to improve the infrastructure of the markets by enabling for deeper, more liquid domestic markets, international standard market infrastructure and coming up with institutional and capacity building initiatives (Capital Market Authority 2014). This will improve the actual operation and infrastructure of Kenyan capital market so as to increase product supply and trading activity of existing markets, add new markets and products, and bring infrastructure up to international best practice standards to improve the security and risk management of the markets, and to attract more international players. This will ensure the accelerated development of the securities markets through sophistication of the securities trading arrangements as well as spot and derivatives markets. Key to the development of the country's market infrastructure is the development of the depository and clearing infrastructure to ensure efficient and reliable post trade process meeting international standards, the post trade infrastructure is critical in attracting international investments. The derivatives markets will provide a secure and efficient platform to manage risks and ensure efficiency is a major prerequisite. Therefore, it needs a robust and secure central counter party clearing house to offer innovative services meeting international standards.

According to the Section 22A - Directions to a securities exchange and a derivative exchange of The Capital Market Act, Chapter 485A of the Laws of Kenya (Capital Market Authority 2000:49), the CMA endeavours to ensure:

1. The fair, transparent and efficient operation of a securities market or derivatives market,
2. The fair, transparent and effective clearing and settlement of transactions in exchange-traded derivative contracts or securities transactions,
3. The integrity and proper management of systematic risks in securities markets or derivatives markets, or

4. A fair and proper governance structure of the securities exchange or derivatives exchange.

5.3 SUMMARY OF CONTRIBUTIONS

This study tested the market-efficiency of the NSE using two indexes, the NSE 20 share index, and the NSE ASI. The latter has not been used as data for any prior study on the NSE. Preceding studies have used either the NSE 20 share index or share prices of individual shares.

This study also conducted one of the longest studies on the NSE that has ever been conducted, as the sample period was from January 2001 to January 2015 for the NSE 20 share index which is over a period of fourteen years. While for the NSE ASI the study was from when the index was initiated in February 2008 to January 2015 which is a period of approximately seven years. The other studies on the NSE that covered a long duration were by Ngugi et al (2002) who's study was over the period January 1970 to December 1999; and Zhang et al (2012) who's study was over the period January 2000 to April 2011.

Earlier studies have used the serial correlation test, unit root tests, runs test, E-GARCH M model and variance ratio test. This study departs from prior studies in that it used four methods in one study of the NSE, which is more than any other study has undertaken.

In terms of the theoretical contribution, this study has established that the efficiency of the NSE has increased from the year 2000, which could be attributed to increased technology development from that time.

5.4 SUGGESTIONS OF FUTURE RESEARCH

The securities exchanges in East Africa have been poorly researched. Therefore, the market efficiency of the other East Africa countries should also be tested so as to determine how informational efficient they are, and what steps need to be undertaken to ensure that they are efficient if they are currently not. In addition, market efficiency studies should also be extended to other African stock markets that have not been well researched.

Prior studies on efficiency of African stock markets should be re-visited using more robust methods of testing market efficiency such as the joint sign test (Wright 2000); the wild bootstrap test (Kim 2006); and the automatic variance ratio test (Kim 2009). These methods will enable the African stock markets to determine whether there is a change in efficiency over the years. In turn, they can take correctional measures to improve market efficiency, if necessary.

5.5 RECOMMENDATIONS

Availability of data was a critical issue as the data that was derived from the NSE needed to be purchased which is a huge impediment for any researcher. It would be beneficial for the researcher if the market data was easily accessible.

The efficiency of the NSE should be tested on the individual shares that are listed on the exchange and ranked from the most efficient to the least efficient using relative efficiency. This can be conducted using the most recent variance ratio methods such as the joint sign test (Wright 2000), wild bootstrap test (Kim 2006); and the automatic variance ratio test (Kim 2009); as used in the study on determining the efficiency and relative predictability of African stock markets (Smith and Dyakova 2014).

5.6 Conclusion

The main aim of this study was to determine the current level of efficiency of the NSE using both daily and weekly data of the NSE 20 share index and the NSE ASI. Results of the efficiency of the NSE are mixed because the serial correlation test, unit root tests and the runs test fail to support the EMH. However, these results are disputed by the variance ratio test which supports the EMH. Since the variance ratio test is more powerful than the prior tests and its results are much more precise as stated by Mobarek and Fiorante (2014), we can conclude that the NSE supports the EMH and is weak-form efficient.

The NSE has become more efficient from the year 2000 onwards as illustrated by the Figures 4.1 to 4.4 of the results of the variance ratio test in Chapter 4. This increase in market efficiency can be attributed to the improvement in technology that enhances the speedy impounding of information on the share prices mainly due to high speed internet, mobile technologies and world-wide broadcasting systems (Yang et al 2008). Accordingly, increased automation has enabled market players to be able to process information and trade at a much faster rate as inferred by Tóth and Kertész (2006), this by reducing the execution time for market orders (Hendershott and Moulton 2011). This has led to a more accurate price discovery than before the year 2 000 (Ciner 2002).

5.7 Summary

This chapter indicated the summary of findings, contributions to the study and suggestions of future research. Finally, recommendations and conclusions were discussed.

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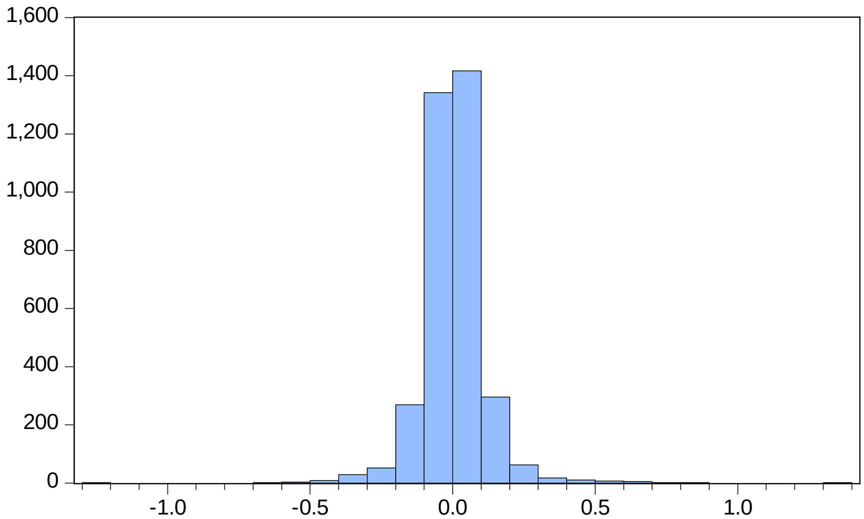
APPENDIX

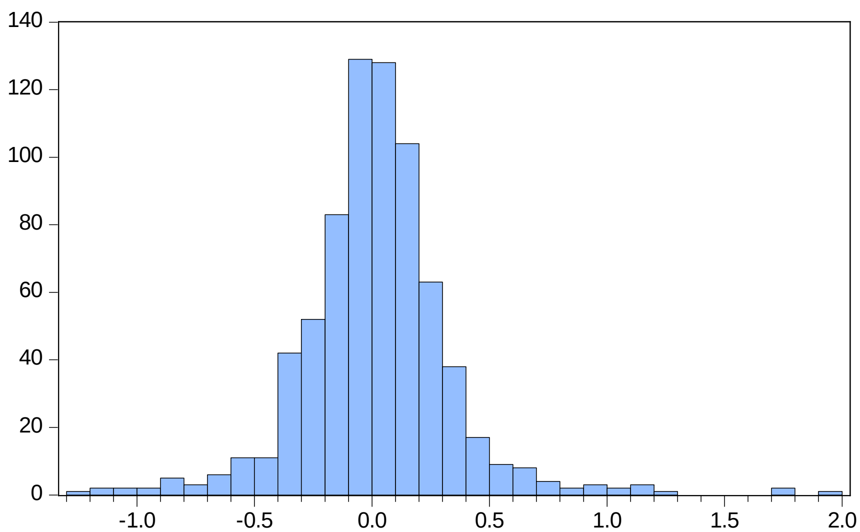
Figure 1: Descriptive Statistics of the NSE 20 share index (daily data)



Series: NSE20DAILY
Sample 1/02/2001 7/02/2014
Observations 3521

Mean	0.003612
Median	0.001321
Maximum	1.313339
Minimum	-1.262414
Std. Dev.	0.109775
Skewness	0.547178
Kurtosis	19.85817
Jarque-Bera	41869.89
Probability	0.000000

Figure 2: Descriptive Statistics of the NSE 20 share index (weekly data)



Series: NSE20WEEKLY
Sample 1/05/2001 1/30/2015
Observations 734

Mean	0.017900
Median	0.011458
Maximum	1.963580
Minimum	-1.274222
Std. Dev.	0.322315
Skewness	0.640592
Kurtosis	8.699999
Jarque-Bera	1043.853
Probability	0.000000

Figure 3: Descriptive Statistics of the NSE ASI (daily data)

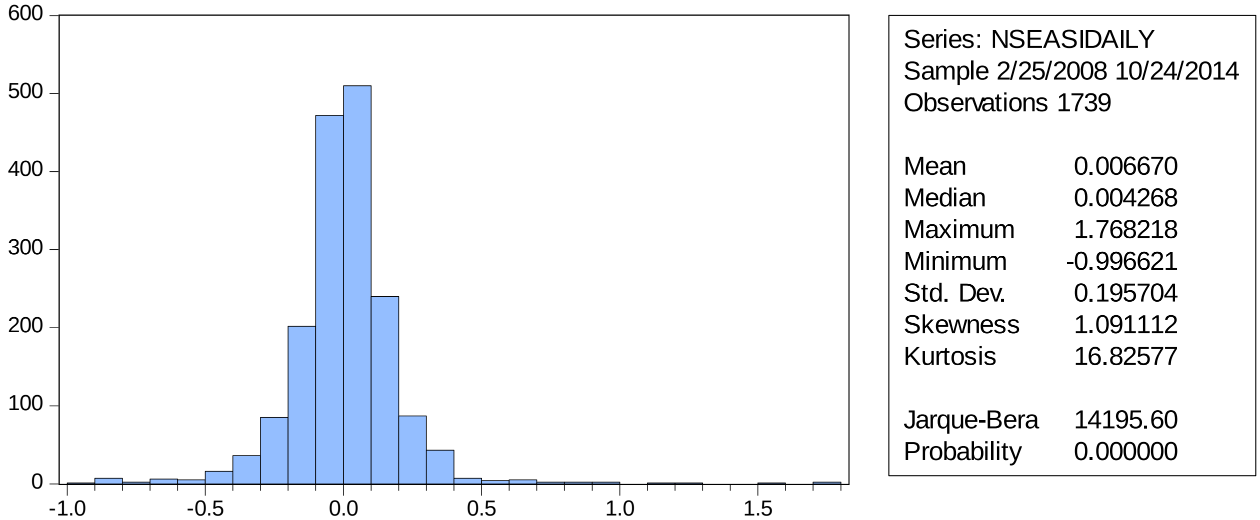


Figure 4: Descriptive Statistics of the NSE ASI (weekly data)

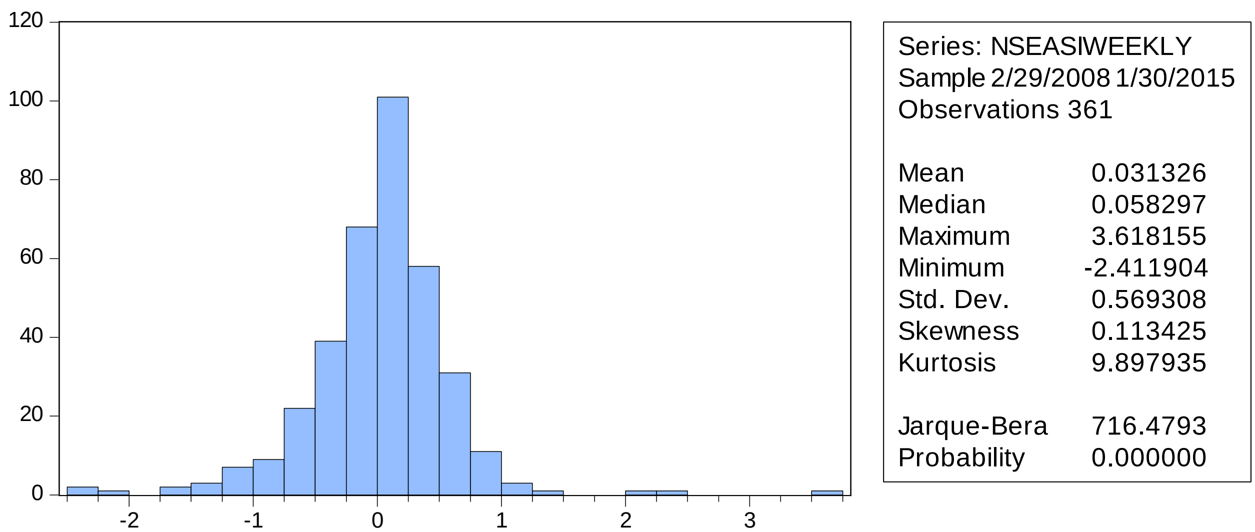


Table 1: Correlogram Test of the NSE 20 share index (daily data)

Date: 05/04/15 Time: 12:12

Sample: 1/02/2001 - 7/02/2014

Included observations: 3521

Auto-correlation	***Partial Correlation***		***AC***	***PAC***	***Q-Stat***	***Prob***
|*** |	|*** |	1	0.369	0.369	478.62	0.000
|** |	|* |	2	0.246	0.128	692.60	0.000
|* |	| |	3	0.119	- 0.009	742.41	0.000
| |	| |	4	0.031	- 0.043	745.80	0.000
| |	| |	5	0.022	0.012	747.49	0.000
| |	| |	6	- 0.032	- 0.044	751.20	0.000
| |	| |	7	- 0.017	0.005	752.28	0.000
| |	| |	8	- 0.009	0.009	752.59	0.000
| |	| |	9	0.031	0.045	755.99	0.000
| |	| |	10	0.030	0.007	759.12	0.000
| |	| |	11	0.028	0.003	761.82	0.000
| |	| |	12	0.026	0.005	764.22	0.000
| |	| |	13	0.022	0.008	765.99	0.000
| |	| |	14	0.041	0.029	771.80	0.000
| |	| |	15	0.032	0.011	775.50	0.000
| |	| |	16	0.024	0.001	777.53	0.000
| |	| |	17	0.012	- 0.005	778.03	0.000
| |	| |	18	- 0.008	- 0.018	778.28	0.000
| |	| |	19	- 0.025	- 0.022	780.41	0.000
| |	| |	20	- 0.023	- 0.003	782.35	0.000
| |	| |	21	- 0.028	- 0.010	785.11	0.000
| |	| |	22	- 0.015	0.005	785.92	0.000
| |	| |	23	- 0.012	- 0.004	786.45	0.000
| |	| |	24	- 0.011	- 0.008	786.90	0.000
| |	| |	25	0.005	0.010	786.97	0.000
| |	| |	26	0.022	0.022	788.73	0.000
| |	| |	27	0.029	0.014	791.73	0.000
| |	| |	28	0.060	0.046	804.65	0.000
| |	| |	29	0.049	0.010	813.02	0.000
| |	| |	30	0.062	0.030	826.81	0.000
| |	| |	31	0.030	- 0.014	829.99	0.000
| |	| |	32	0.017	- 0.001	831.07	0.000
| |	| |	33	0.017	0.012	832.08	0.000
| |	| |	34	0.029	0.031	835.06	0.000
| |	| |	35	0.033	0.016	838.84	0.000
| |	| |	36	0.020	- 0.002	840.32	0.000

Table 2 Correlogram Test of the NSE 20 share index (weekly data)

Date: 05/04/15 Time: 11:54
Sample: 1/05/2001 - 1/30/2015
Included observations: 1739

Auto-correlation	***Partial Correlation***		***AC***	***PAC***	***Q-Stat***	***Prob***
|* |	|* |	1	0.168	0.168	20.687	0.000
|* |	|. |	2	0.078	0.052	25.212	0.000
|. |	|. |	3	0.055	0.035	27.447	0.000
|. |	|. |	4	- 0.018	- 0.038	27.694	0.000
|. |	|. |	5	- 0.008	- 0.005	27.743	0.000
|* |	|* |	6	0.083	0.089	32.838	0.000
|* |	|* |	7	0.119	0.100	43.373	0.000
|. |	|. |	8	0.015	- 0.031	43.536	0.000
|. |	|. |	9	0.024	0.004	43.971	0.000
|. |	|. |	10	0.019	0.011	44.228	0.000
|. |	|. |	11	0.018	0.024	44.460	0.000
.|. |	|. |	12	0.069	0.060	47.972	0.000
|. |	|. |	13	0.064	0.026	51.071	0.000
|. |	|. |	14	0.011	- 0.023	51.165	0.000
|. |	|. |	15	0.067	0.063	54.523	0.000
|. |	|. |	16	0.040	0.020	55.703	0.000
|. |	|. |	17	0.072	0.062	59.644	0.000
|. |	|. |	18	0.058	0.019	62.144	0.000
|. |	|. |	19	0.052	0.015	64.189	0.000
|. |	|. |	20	0.018	- 0.004	64.438	0.000
|. |	|. |	21	0.014	0.006	64.586	0.000
|. |	|. |	22	0.031	0.015	65.338	0.000
|. |	|. |	23	- 0.020	- 0.040	65.630	0.000
|. |	|. |	24	0.054	0.040	67.840	0.000
|. |	|. |	25	0.059	0.033	70.473	0.000
|. |	|. |	26	0.035	0.014	71.432	0.000
|. |	|. |	27	0.009	- 0.018	71.489	0.000
|. |	|. |	28	0.015	- 0.003	71.669	0.000
|. |	|. |	29	0.047	0.044	73.335	0.000
|. |	|. |	30	0.008	- 0.012	73.383	0.000
|. |	|. |	31	0.004	- 0.025	73.397	0.000
|. |	|. |	32	0.010	- 0.012	73.481	0.000
*|. |	*|. |	33	- 0.070	- 0.080	77.238	0.000
|. |	|. |	34	- 0.048	- 0.035	79.017	0.000
|. |	|. |	35	0.026	0.038	79.557	0.000
|. |	|. |	36	- 0.013	- 0.030	79.691	0.000

Table 3: Correlogram Test of the NSE 20 share index (daily data)

Date: 05/04/15 Time: 12:15

Sample: 2/25/2008 - 10/24/2014

Included observations: 1739

Auto-correlation	***Partial Correlation***		***AC***	***PAC***	***Q-Stat***	***Prob***
|**** |	|**** |	1	0.506	0.506	445.48	0.000
|** |	| |	2	0.275	0.026	577.04	0.000
|* |	| |	3	0.122	- 0.035	603.05	0.000
| |	*| |	4	- 0.015	- 0.094	603.47	0.000
| |	| |	5	- 0.043	0.005	606.68	0.000
| |	| |	6	- 0.035	0.012	608.88	0.000
| |	| |	7	- 0.033	- 0.010	610.80	0.000
| |	| |	8	- 0.018	- 0.001	611.36	0.000
| |	| |	9	0.014	0.029	611.70	0.000
| |	| |	10	0.017	- 0.002	612.19	0.000
| |	| |	11	0.017	0.000	612.70	0.000
| |	| |	12	0.023	0.012	613.64	0.000
| |	| |	13	0.025	0.014	614.75	0.000
| |	| |	14	0.007	- 0.015	614.85	0.000
| |	| |	15	-0.030	- 0.044	616.44	0.000
| |	| |	16	-0.040	- 0.008	619.31	0.000
| |	| |	17	- 0.055	- 0.022	624.59	0.000
| |	| |	18	- 0.042	0.005	627.70	0.000
| |	| |	19	- 0.027	- 0.003	629.00	0.000
| |	| |	20	- 0.015	- 0.001	629.42	0.000
| |	| |	21	- 0.038	- 0.046	631.91	0.000
| |	| |	22	- 0.031	- 0.002	633.65	0.000
| |	| |	23	- 0.006	0.024	633.71	0.000
| |	| |	24	0.046	0.064	637.44	0.000
|* |	| |	25	0.079	0.035	648.40	0.000
|* |	| |	26	0.099	0.035	665.60	0.000
|* |	| |	27	0.110	0.040	686.85	0.000
|* |	| |	28	0.092	0.017	701.73	0.000
| |	| |	29	0.065	0.006	709.10	0.000
| |	| |	30	0.043	0.011	712.36	0.000
| |	| |	31	0.024	0.008	713.38	0.000
| |	| |	32	0.018	0.010	713.93	0.000
| |	| |	33	0.032	0.028	715.76	0.000
| |	| |	34	0.034	0.010	717.77	0.000
| |	| |	35	0.041	0.020	720.74	0.000
| |	| |	36	0.048	0.015	724.88	0.000

Table 4: Correlogram Test of the NSE ASI (weekly data)

Date: 05/04/15 Time: 12:16

Sample: 2/29/2008 - 1/30/2015

Included observations: 361

<table>
<tr><th>Auto-correlation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>|* |</td><td>|* |</td><td>1</td><td>0.206</td><td>0.206</td><td>15.492</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>2</td><td>0.062</td><td>0.020</td><td>16.891</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>3</td><td>- 0.010</td><td>- 0.027</td><td>16.924</td><td>0.001</td></tr>
<tr><td>*|. |</td><td>*|. |</td><td>4</td><td>- 0.103</td><td>- 0.101</td><td>20.808</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|* |</td><td>5</td><td>0.055</td><td>0.103</td><td>21.931</td><td>0.001</td></tr>
<tr><td>|* |</td><td>|* |</td><td>6</td><td>0.171</td><td>0.159</td><td>32.741</td><td>0.000</td></tr>
<tr><td>|* |</td><td>|. |</td><td>7</td><td>0.132</td><td>0.062</td><td>39.185</td><td>0.000</td></tr>
<tr><td>|* |</td><td>|. |</td><td>8</td><td>0.077</td><td>0.012</td><td>41.373</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>9</td><td>- 0.003</td><td>- 0.015</td><td>41.377</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>10</td><td>- 0.022</td><td>0.011</td><td>41.561</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|* |</td><td>11</td><td>0.061</td><td>0.074</td><td>42.950</td><td>0.000</td></tr>
<tr><td>|* |</td><td>|* |</td><td>12</td><td>0.145</td><td>0.106</td><td>50.857</td><td>0.000</td></tr>
<tr><td>|* |</td><td>|. |</td><td>13</td><td>0.081</td><td>- 0.009</td><td>53.298</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>14</td><td>0.007</td><td>- 0.049</td><td>53.316</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>15</td><td>0.004</td><td>0.021</td><td>53.323</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>16</td><td>- 0.076</td><td>- 0.054</td><td>55.512</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>17</td><td>- 0.020</td><td>- 0.017</td><td>55.671</td><td>0.000</td></tr>
<tr><td>|* |</td><td>|* |</td><td>18</td><td>0.127</td><td>0.096</td><td>61.806</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>19</td><td>0.062</td><td>- 0.010</td><td>63.264</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>20</td><td>0.015</td><td>- 0.038</td><td>63.347</td><td>0.000</td></tr>
<tr><td>|. |</td><td>*|. |</td><td>21</td><td>- 0.067</td><td>- 0.071</td><td>65.061</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|* |</td><td>22</td><td>- 0.005</td><td>0.076</td><td>65.071</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>23</td><td>- 0.004</td><td>- 0.007</td><td>65.078</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>24</td><td>0.031</td><td>- 0.015</td><td>65.456</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>25</td><td>0.068</td><td>0.022</td><td>67.254</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>26</td><td>0.026</td><td>0.011</td><td>67.517</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>27</td><td>0.050</td><td>0.071</td><td>68.508</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>28</td><td>- 0.011</td><td>- 0.006</td><td>68.556</td><td>0.000</td></tr>
<tr><td>|* |</td><td>|* |</td><td>29</td><td>0.076</td><td>0.095</td><td>70.852</td><td>0.000</td></tr>
<tr><td>|* |</td><td>|. |</td><td>30</td><td>0.099</td><td>0.038</td><td>74.703</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>31</td><td>0.039</td><td>- 0.007</td><td>75.319</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>|. |</td><td>32</td><td>0.032</td><td>0.015</td><td>75.720</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>*|. |</td><td>33</td><td>- 0.101</td><td>- 0.120</td><td>79.786</td><td>0.000</td></tr>
<tr><td>*|. |</td><td>|. |</td><td>34</td><td>- 0.103</td><td>- 0.064</td><td>84.071</td><td>0.000</td></tr>
<tr><td>|. |</td><td>|. |</td><td>35</td><td>0.006</td><td>0.029</td><td>84.084</td><td>0.000</td></tr>
<tr><td>|. |</td><td>*|. |</td><td>36</td><td>- 0.035</td><td>- 0.080</td><td>84.567</td><td>0.000</td></tr>
</table>

Table 5: ADF Test of the NSE 20 share index (daily data with intercept)

Null Hypothesis: NSE20DAILY has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag = 29)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 29.29562	0.0000
Test critical values:	1% level	- 3.432021	
	5% level	- 2.862164	
	10% level	- 2.567146	

****MacKinnon (1996) one-sided p-values.***

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSE20DAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:25

Sample (adjusted): 1/05/2001 - 7/02/2014

Included observations: 3519 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20DAILY(- 1)	- 0.550610	0.018795	- 29.29562	0.0000
(NSE20DAILY(- 1))	- 0.127900	0.016725	- 7.647360	0.0000
C	0.001979	0.001708	1.158373	0.2468

R-squared	0.326870	Mean dependent variance	1.40E-05
Adjusted R-squared	0.326487	S.D. dependent variance	0.123378
S.E. of regression	0.101253	Akaike info criterion	- 1.741528
Sum squared residual	36.04692	Schwarz criterion	- 1.736272
Log likelihood	3067.219	Hannan-Quinn criterion	- 1.739653
F-statistic	853.6793	Durbin-Watson statistic	1.997711
Prob (F-statistic)	0.000000		

Table 6: ADF Test of the NSE 20 share index (daily data with intercept and trend)

Null Hypothesis: NSE20DAILY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag = 29)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 29.29205	0.0000
Test critical values:	1% level	- 3.960648	
	5% level	- 3.411083	
	10% level	- 3.127363	

**** MacKinnon (1996) one-sided p-values.***

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSE20DAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:26

Sample (adjusted): 1/05/2001 - 7/02/2014

Included observations: 3519 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20DAILY(-1)	- 0.550630	0.018798	- 29.29205	0.0000
D(NSE20DAILY(-1))	- 0.127890	0.016727	- 7.645633	0.0000
C	0.002477	0.003419	0.724604	0.4687
@TREND("1/02/2001")	- 2.83E-07	1.68E-06	- 0.168373	0.8663

R-squared	0.326875	Mean dependent variance	1.40E-05
Adjusted R-squared	0.326301	S.D. dependent variance	0.123378
S.E. of regression	0.101267	Akaike info criterion	- 1.740968
Sum squared residual	36.04663	Schwarz criterion	- 1.733959
Log likelihood	3067.234	Hannan-Quinn criterion	- 1.738468
F-statistic	568.9717	Durbin-Watson statistic	1.997709
Prob (F-statistic)	0.000000		

Table 7: Phillips-Perron Test of the NSE 20 share index (daily data with intercept)

Null Hypothesis: DNSE20DAILY has a unit root

Exogenous: Constant

Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 40.94618	0.0000
Test critical values:	1% level	- 3.432021	
	5% level	- 2.862164	
	10% level	- 2.567146	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.010412
HAC corrected variance (Bartlett kernel)	0.011315

Phillips-Perron Test Equation

Dependent Variable: D(NSE20DAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:29

Sample (adjusted): 1/04/2001 - 7/02/2014

Included observations: 3520 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20DAILY(-1)C	- 0.631456	0.015672	- 40.29291	0.0000
C	0.002259	0.001721	1.312628	0.1894
R-squared	0.315766	Mean dependent variance		- 1.48E-05
Adjusted R-squared	0.315572	S.D. dependent variance		0.123372
S.E. of regression	0.102066	Akaike info criterion		- 1.725829
Sum squared residual	36.64856	Schwarz criterion		- 1.722325
Log likelihood	3039.458	Hannan-Quinn criterion		- 1.724579
F-statistic	1623.519	Durbin-Watson statistic		2.093972
Prob (F-statistic)	0.000000			

Table 8: Phillips-Perron Test of the NSE 20 share index (daily data with intercept and trend)

Null Hypothesis: NSE20DAILY has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 40.94123	0.0000
Test critical values:	1% level	- 3.960647	
	5% level	- 3.411082	
	10% level	- 3.127362	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.010411
HAC corrected variance (Bartlett kernel)	0.011315

Phillips-Perron Test Equation

Dependent Variable: D(NSE20DAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:29

Sample (adjusted): 1/04/2001 - 7/02/2014

Included observations: 3520 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20DAILY(-1)	- 0.631471	0.015674	- 40.28777	0.0000
C	0.002802	0.003444	0.813513	0.4160
@TREND("1/02/2001")	- 3.08E-07	1.69E-06	- 0.181846	0.8557
R-squared	0.315773	Mean dependent variance		- 1.48E-05
Adjusted R-squared	0.315384	S.D. dependent variance		0.123372
S.E. of regression	0.102080	Akaike info criterion		- 1.725270
Sum squared residual	36.64822	Schwarz criterion		- 1.720015
Log likelihood	3039.475	Hannan-Quinn criterion		- 1.723395
F-statistic	811.5529	Durbin-Watson statistic		2.093957
Prob (F-statistic)	0.000000			

Table 9: ADF Test of the NSE 20 share index (weekly data with intercept)

Null Hypothesis: NSE20WEEKLY has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag = 19)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 22.83209	0.0000
Test critical values:	1% level	- 3.439044	
	5% level	- 2.865267	
	10% level	- 2.568811	

****MacKinnon (1996) one-sided p-values.***

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSE20WEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 11:56

Sample (adjusted): 1/19/2001 - 1/30/2015

Included observations: 733 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20WEEKLY(-1)	- 0.832432	0.036459	- 22.83209	0.0000
C	0.015166	0.011768	1.288783	0.1979

R-squared	0.416276	Mean dependent variance	0.000394
Adjusted R-squared	0.415478	S.D. dependent variance	0.416101
S.E. of regression	0.318126	Akaike info criterion	0.549987
Sum squared residual	73.98028	Schwarz criterion	0.562530
Log likelihood	- 199.5702	Hannan-Quinn criterion	0.554825
F-statistic	521.3045	Durbin-Watson statistic	2.017413
Prob (F-statistic)	0.000000		

Table 10: ADF Test of the NSE 20 share index (weekly data with intercept and trend)

Null Hypothesis: NSE20WEEKLY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag = 19)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 22.81804	0.0000
Test critical values:	1% level	- 3.970621	
	5% level	- 3.415959	
	10% level	- 3.130252	

****MacKinnon (1996) one-sided p-values.***

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSE20WEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 13:15

Sample (adjusted): 1/19/2001 - 1/30/2015

Included observations: 733 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20WEEKLY(-1)	- 0.832495	0.036484	- 22.81804	0.0000
C	0.019355	0.023602	0.820052	0.4125
@TREND("1/05/2001")	- 1.14E-05	5.56E-05	- 0.204779	0.8378

R-squared	0.416310	Mean dependent variance	0.000394
Adjusted R-squared	0.414711	S.D. dependent variance	0.416101
S.E. of regression	0.318335	Akaike info criterion	0.552658
Sum squared residual	73.97603	Schwarz criterion	0.571473
Log likelihood	- 199.5491	Hannan-Quinn criterion	0.559916
F-statistic	260.3316	Durbin-Watson statistic	2.017397
Prob (F-statistic)	0.000000		

Table 11: Phillips-Perron Test of the NSE 20 share index (weekly data with intercept)

Null Hypothesis: NSE20WEEKLY has a unit root

Exogenous: Constant

Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 23.18655	0.0000
Test critical values:	1% level	- 3.439044	
	5% level	- 2.865267	
	10% level	- 2.568811	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.100928
HAC corrected variance (Bartlett kernel)	0.117294

Phillips-Perron Test Equation

Dependent Variable: D(NSE20WEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 11:57

Sample (adjusted): 1/19/2001 - 1/30/2015

Included observations: 733 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20WEEKLY(-1)	- 0.832432	0.036459	- 22.83209	0.0000
C	0.015166	0.011768	1.288783	0.1979
R-squared	0.416276	Mean dependent variance		0.000394
Adjusted R-squared	0.415478	S.D. dependent variance		0.416101
S.E. of regression	0.318126	Akaike info criterion		0.549987
Sum squared residual	73.98028	Schwarz criterion		0.562530
Log likelihood	- 199.5702	Hannan-Quinn criterion		0.554825
F-statistic	521.3045	Durbin-Watson statistic		2.017413
Prob (F-statistic)	0.000000			

Table 12: Phillips-Perron Test of the NSE 20 share index (weekly data with intercept and trend)

Null Hypothesis: NSE20WEEKLY has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 23.17261	0.0000
Test critical values:	1% level	-3.970621	
	5% level	- 3.415959	
	10% level	- 3.130252	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.100922
HAC corrected variance (Bartlett kernel)	0.117248

Phillips-Perron Test Equation

Dependent Variable: D(NSE20WEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 11:57

Sample (adjusted): 1/19/2001 - 1/30/2015

Included observations: 733 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSE20WEEKLY(-1)	- 0.832495	0.036484	- 22.81804	0.0000
C	0.019355	0.023602	0.820052	0.4125
@TREND("1/05/2001")	- 1.14E-05	5.56E-05	- 0.204779	0.8378
R-squared	0.416310	Mean dependent variance		0.000394
Adjusted R-squared	0.414711	S.D. dependent variance		0.416101
S.E. of regression	0.318335	Akaike info criterion		0.552658
Sum squared residual	73.97603	Schwarz criterion		0.571473
Log likelihood	- 199.5491	Hannan-Quinn criterion		0.559916
F-statistic	260.3316	Durbin-Watson statistic		2.017397
Prob (F-statistic)	0.000000			

Table 13: ADF Test of the NSE ASI (daily data with intercept)

Null Hypothesis: NSEASIDAILY has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag = 24)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 23.89800	0.0000
Test critical values:	1% level	- 3.433910	
	5% level	- 2.862999	
	10% level	- 2.567594	

MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSEASIDAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:41

Sample (adjusted): 2/27/2008 - 10/24/2014

Included observations: 1738 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIDAILY(-1)	- 0.494274	0.020683	- 23.89800	0.0000
C	0.003507	0.004050	0.865984	0.3866
R-squared	0.247545	Mean dependent variance		0.000228
Adjusted R-squared	0.247112	S.D. dependent variance		0.194470
S.E. of regression	0.168740	Akaike info criterion		- 0.719762
Sum squared residual	49.42963	Schwarz criterion		- 0.713478
Log likelihood	627.4729	Hannan-Quinn criterion		- 0.717438
F-statistic	571.1146	Durbin-Watson statistic		2.024969
Prob (F-statistic)	0.000000			

Table 14: ADF Test of the NSE ASI (daily data with intercept and trend)

Null Hypothesis: NSEASIDAILY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag = 24)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 23.94337	0.0000
Test critical values:	1% level	- 3.963332	
	5% level	- 3.412397	
	10% level	- 3.128142	

****MacKinnon (1996) one-sided p-values.***

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSEASIDAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:42

Sample (adjusted): 2/27/2008 - 10/24/2014

Included observations: 1738 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIDAILY(-1)	- 0.495984	0.020715	- 23.94337	0.0000
C	- 0.006136	0.008109	- 0.756721	0.4493
@TREND("2/25/2008")	1.11E-05	8.08E-06	1.372608	0.1701
R-squared	0.248361	Mean dependent variance		0.000228
Adjusted R-squared	0.247495	S.D. dependent variance		0.194470
S.E. of regression	0.168697	Akaike info criterion		- 0.719696
Sum squared residual	49.37601	Schwarz criterion		- 0.710271
Log likelihood	628.4160	Hannan-Quinn criterion		- 0.716211
F-statistic	286.6447	Durbin-Watson statistic		2.023662
Prob (F-statistic)	0.000000			

Table 15: Phillips-Perron Test of the NSE ASI (daily data with intercept)

Null Hypothesis: NSEASIDAILY has a unit root

Exogenous: Constant

Bandwidth: 16 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 23.38092	0.0000
Test critical values:	1% level	- 3.433910	
	5% level	- 2.862999	
	10% level	- 2.567594	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.028441
HAC corrected variance (Bartlett kernel)	0.025993

Phillips-Perron Test Equation

Dependent Variable: D(NSEASIDAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:43

Sample (adjusted): 2/27/2008 - 10/24/2014

Included observations: 1738 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIDAILY(-1)	- 0.494274	0.020683	- 23.89800	0.0000
C	0.003507	0.004050	0.865984	0.3866

R-squared	0.247545	Mean dependent variance	0.000228
Adjusted R-squared	0.247112	S.D. dependent variance	0.194470
S.E. of regression	0.168740	Akaike info criterion	- 0.719762
Sum squared residual	49.42963	Schwarz criterion	- 0.713478
Log likelihood	627.4729	Hannan-Quinn criterion	- 0.717438
F-statistic	571.1146	Durbin-Watson statistic	2.024969
Prob (F-statistic)	0.000000		

Table 16: Phillips-Perron Test of the NSE ASI (daily data with intercept and trend)

Null Hypothesis: NSEASIDAILY has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 17 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 23.29334	0.0000
Test critical values:	1% level	- 3.963332	
	5% level	- 3.412397	
	10% level	- 3.128142	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.028410
HAC corrected variance (Bartlett kernel)	0.025335

Phillips-Perron Test Equation

Dependent Variable: D(NSEASIDAILY)

Method: Least Squares

Date: 05/04/15 Time: 12:43

Sample (adjusted): 2/27/2008 - 10/24/2014

Included observations: 1738 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIDAILY(-1)	- 0.495984	0.020715	- 23.94337	0.0000
C	- 0.006136	0.008109	- 0.756721	0.4493
@TREND("2/25/2008")	1.11E-05	8.08E-06	1.372608	0.1701
R-squared	0.248361	Mean dependent variance		0.000228
Adjusted R-squared	0.247495	S.D. dependent variance		0.194470
S.E. of regression	0.168697	Akaike info criterion		- 0.719696
Sum squared residual	49.37601	Schwarz criterion		- 0.710271
Log likelihood	628.4160	Hannan-Quinn criterion		- 0.716211
F-statistic	286.6447	Durbin-Watson statistic		2.023662
Prob (F-statistic)	0.000000			

Table 17: ADF Test of the NSE ASI (weekly data with intercept)

Null Hypothesis: NSEASIWEEKLY has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag = 16)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 15.38453	0.0000
Test critical values:	1% level	- 3.448312	
	5% level	- 2.869351	
	10% level	- 2.570999	

****MacKinnon (1996) one-sided p-values.***

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSEASIWEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 12:50

Sample (adjusted): 3/14/2008 - 1/30/2015

Included observations: 360 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIWEEKLY(-1)	- 0.793668	0.051589	- 15.38453	0.0000
C	0.022708	0.029413	0.772043	0.4406
R-squared	0.398000	Mean dependent variance		- 0.002451
Adjusted R-squared	0.396318	S.D. dependent variance		0.717158
S.E. of regression	0.557210	Akaike info criterion		1.673792
Sum squared residual	111.1530	Schwarz criterion		1.695382
Log likelihood	- 299.2826	Hannan-Quinn criterion		1.682376
F-statistic	236.6839	Durbin-Watson statistic		1.975715
Prob (F-statistic)	0.000000			

Table 18: ADF Test of the NSE ASI (weekly data with intercept and trend)

Null Hypothesis: NSEASIWEEKLY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag = 16)

		t-Statistic	***Prob.****
Augmented Dickey-Fuller test statistic		- 15.52423	0.0000
Test critical values:	1% level	- 3.983755	
	5% level	- 3.422356	
	10% level	- 3.134036	

MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(NSEASIWEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 12:53

Sample (adjusted): 3/14/2008 - 1/30/2015

Included observations: 360 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIWEEKLY(-1)	- 0.803097	0.051732	- 15.52423	0.0000
C	- 0.066128	0.059058	- 1.119704	0.2636
@TREND("2/29/2008")	0.000491	0.000283	1.733050	0.0840
R-squared	0.403022	Mean dependent variance		- 0.002451
Adjusted R-squared	0.399678	S.D. dependent variance		0.717158
S.E. of regression	0.555658	Akaike info criterion		1.670970
Sum squared residual	110.2257	Schwarz criterion		1.703354
Log likelihood	- 297.7746	Hannan-Quinn criterion		1.683846
F-statistic	120.5060	Durbin-Watson statistic		1.973241
Prob (F-statistic)	0.000000			

Table 19: Phillips-Perron Test of the NSE ASI (weekly data with intercept)

Null Hypothesis: NSEASIWEEKLY has a unit root

Exogenous: Constant

Bandwidth: 5 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 15.34235	0.0000
Test critical values:	1% level	- 3.448312	
	5% level	- 2.869351	
	10% level	- 2.570999	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.308758
HAC corrected variance (Bartlett kernel)	0.300277

Phillips-Perron Test Equation

Dependent Variable: D(NSEASIWEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 12:53

Sample (adjusted): 3/14/2008 - 1/30/2015

Included observations: 360 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIWEEKLY(-1)	- 0.793668	0.051589	- 15.38453	0.0000
C	0.022708	0.029413	0.772043	0.4406
R-squared	0.398000	Mean dependent variance		-0.002451
Adjusted R-squared	0.396318	S.D. dependent variance		0.717158
S.E. of regression	0.557210	Akaike info criterion		1.673792
Sum squared residual	111.1530	Schwarz criterion		1.695382
Log likelihood	-299.2826	Hannan-Quinn criterion		1.682376
F-statistic	236.6839	Durbin-Watson statistic		1.975715
Prob (F-statistic)	0.000000			

***Table 20**:* Phillips-Perron Test of the NSE ASI (weekly data with intercept and trend)

Null Hypothesis: NSEASIWEEKLY has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 6 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	***Prob.****
Phillips-Perron test statistic		- 15.48951	0.0000
Test critical values:	1% level	- 3.983755	
	5% level	- 3.422356	
	10% level	- 3.134036	

MacKinnon (1996) one-sided p-values.

Residual variance (no correction)	0.306183
HAC corrected variance (Bartlett kernel)	0.299009

Phillips-Perron Test Equation

Dependent Variable: D(NSEASIWEEKLY)

Method: Least Squares

Date: 05/04/15 Time: 12:54

Sample (adjusted): 3/14/2008 - 1/30/2015

Included observations: 360 after adjustments

Variable	***Coefficient***	***Std. Error***	***t-Statistic***	***Prob.***
NSEASIWEEKLY(-1)	- 0.803097	0.051732	- 15.52423	0.0000
C	- 0.066128	0.059058	- 1.119704	0.2636
@TREND("2/29/2008")	0.000491	0.000283	1.733050	0.0840
R-squared	0.403022	Mean dependent variance		- 0.002451
Adjusted R-squared	0.399678	S.D. dependent variance		0.717158
S.E. of regression	0.555658	Akaike info criterion		1.670970
Sum squared residual	110.2257	Schwarz criterion		1.703354
Log likelihood	- 297.7746	Hannan-Quinn criterion		1.683846
F-statistic	120.5060	Durbin-Watson statistic		1.973241
Prob (F-statistic)	0.000000			

Table 21 : NSE 20 share index (daily data)

Runs Test

	Price returns
Test Value[a]	.0013210190850228
Cases < Test Value	1760
Cases >= Test Value	1761
Total Cases	3521
Number of Runs	1327
Z	- 14.647
Asymp. Sig. (2-tailed)	.000

a. Median

Table 22: NSE 20 share index (weekly data)

Runs Test

	Price returns (%)
Test Value[a]	.0106603262448119
Cases < Test Value	366
Cases >= Test Value	366
Total Cases	732
Number of Runs	297
Z	- 5.178
Asymp. Sig. (2-tailed)	.000

a. Median

Table 23: NSE ASI (daily data)

Runs Test

	-0.32805224401 463229
Test Value[a]	.004310096036 5436
Cases < Test Value	869
Cases >= Test Value	869
Total Cases	1738
Number of Runs	626
Z	- 11.709
Asymp. Sig. (2-tailed)	.000

a. Median

Table 24: NSE ASI (weekly data)

Runs Test

	Price returns
Test Value[a]	.058297099608 0568
Cases < Test Value	180
Cases >= Test Value	181
Total Cases	361
Number of Runs	154
Z	- 2.899
Asymp. Sig. (2-tailed)	.004

a. Median

Table 25: Variance Ratio Test of the NSE 20 share index (daily data)

Null Hypothesis: Log NSE20DAILY is a random walk

Date: 05/04/15 Time: 12:37

Sample: 1/02/2001 - 7/02/2014

Included observations: 1127 (after adjustments)

Standard error estimates assume no heteroscedasticity

Use biased variance estimates

Lags specified as grid: min = 100, max = 3500, step = 100

Joint Tests

	Value	Df	Probability
Max |z| (at period 100)*	2.817599	1127	0.1561
Wald (Chi-Square)	34.53883	35	0.4902

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
100	0.038131	0.341379	-2.817599	0.0048
200	0.057888	0.484608	-1.944072	0.0519
300	0.080496	0.594266	-1.547293	0.1218
400	0.098861	0.686629	-1.312410	0.1894
500	0.120741	0.767963	-1.144924	0.2522
600	0.140637	0.841472	-1.021262	0.3071
700	0.160014	0.909056	-0.924020	0.3555
800	0.171797	0.971952	-0.852102	0.3942
900	0.181187	1.031019	-0.794179	0.4271
1000	0.199701	1.086880	-0.736327	0.4615
1100	0.213885	1.140007	-0.689570	0.4905
1200	0.220760	1.190766	-0.654402	0.5129
1300	0.220338	1.239448	-0.629040	0.5293
1400	0.222083	1.286289	-0.604776	0.5453
1500	0.220975	1.331484	-0.585080	0.5585
1600	0.246982	1.375193	-0.547572	0.5840

Table 25: Variance Ratio Test of the NSE 20 share index (daily data) (contd)

Period	Var. Ratio	Std. Error	z-Statistic	Probability
1800	0.259052	1.458689	-0.507955	0.6115
1900	0.247033	1.498693	-0.502416	0.6154
2000	0.252111	1.537657	-0.486382	0.6267
2100	0.257693	1.575658	-0.471109	0.6376
2200	0.246548	1.612763	-0.467181	0.6404
2300	0.246949	1.649034	-0.456662	0.6479
2400	0.218570	1.684524	-0.463888	0.6427
2500	0.205924	1.719282	-0.461865	0.6442
2600	0.188398	1.753351	-0.462886	0.6434
2700	0.173723	1.786770	-0.462442	0.6438
2800	0.176282	1.819575	-0.452698	0.6508
2900	0.137975	1.851800	-0.465507	0.6416
3000	0.107148	1.883473	-0.474045	0.6355
3100	0.075843	1.914623	-0.482684	0.6293
3200	0.067138	1.945273	-0.479553	0.6315
3300	0.052864	1.975448	-0.479454	0.6316
3400	0.034112	2.005169	-0.481699	0.6300
3500	0.008605	2.034456	-0.487302	0.6260

*Probability approximation using studentised maximum modulus with parameter value 35 and infinite degrees of freedom

Test Details (Mean = - 0.0280903565088)

Period	Variance	Var. Ratio	Obs.
1	2.25984	--	1127
100	0.08617	0.03813	911
200	0.13082	0.05789	867
300	0.18191	0.08050	842
400	0.22341	0.09886	785
500	0.27285	0.12074	777
600	0.31782	0.14064	754
700	0.36160	0.16001	734
800	0.38823	0.17180	692
900	0.40945	0.18119	651

Table 25: Variance Ratio Test of the NSE 20 share index (daily data) (contd)

Test Details (Mean = - 0.0280903565088) (contd)

Period	Variance	Var. Ratio	Obs.
1000	0.45129	0.19970	650
1100	0.48334	0.21388	632
1200	0.49888	0.22076	591
1300	0.49793	0.22034	546
1400	0.50187	0.22208	513
1500	0.49937	0.22098	479
1600	0.55814	0.24698	499
1700	0.54939	0.24311	463
1800	0.58541	0.25905	465
1900	0.55825	0.24703	421
2000	0.56973	0.25211	408
2100	0.58234	0.25769	397
2200	0.55716	0.24655	364
2300	0.55806	0.24695	349
2400	0.49393	0.21857	297
2500	0.46535	0.20592	269
2600	0.42575	0.18840	237
2700	0.39258	0.17372	209
2800	0.39837	0.17628	204
2900	0.31180	0.13797	154
3000	0.24214	0.10715	115
3100	0.17139	0.07584	79
3200	0.15172	0.06714	67
3300	0.11946	0.05286	52
3400	0.07709	0.03411	32
3500	0.01945	0.00860	8

Table 26: Variance Ratio Test of the NSE 20 share index (weekly data)

Null Hypothesis:	Log NSE20WEEKLY is a random walk
Date:	05/04/15 Time: 11:59
Sample:	1/05/2001 - 1/30/2015
Included observations:	236 (after adjustments)

Standard error estimates assume no heteroscedasticity

Use biased variance estimates

Lags specified as grid: min = 25, max = 725, step = 25

Joint Tests

	Value	df	Probability
Max |z| (at period 25)*	2.112669	236	0.6401
Wald (Chi-Square)	928.1357	29	0.0000

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
25	0.229871	0.364529	-2.112669	0.0346
50	0.384185	0.523515	-1.176309	0.2395
75	0.513389	0.644431	-0.755102	0.4502
100	0.643621	0.746006	-0.477716	0.6329
125	0.759463	0.835322	-0.287958	0.7734
150	0.887653	0.915970	-0.122653	0.9024
175	1.017651	0.990072	0.017828	0.9858
200	1.092268	1.059001	0.087127	0.9306
225	1.108636	1.123710	0.096676	0.9230
250	1.200656	1.184891	0.169346	0.8655
275	1.215180	1.243064	0.173105	0.8626
300	1.257951	1.298634	0.198633	0.8426
325	1.244503	1.351922	0.180856	0.8565
350	1.338166	1.403187	0.240998	0.8096
375	1.391763	1.452645	0.269690	0.7874
400	1.347587	1.500473	0.231652	0.8168
425	1.310041	1.546823	0.200437	0.8411
450	1.050601	1.591824	0.031788	0.9746

Table 26: Variance Ratio Test of the NSE 20 share index (weekly data) (contd)

Period	Var. Ratio	Std. Error	z-Statistic	Probability
475	1.185661	1.635588	0.113513	0.9096
500	1.142321	1.678210	0.084805	0.9324
525	0.892326	1.719777	-0.062610	0.9501
550	0.941672	1.760362	-0.033134	0.9736
575	0.866269	1.800033	-0.074294	0.9408
600	0.661600	1.838848	-0.184028	0.8540
625	0.460089	1.876860	-0.287667	0.7736
650	0.320661	1.914118	-0.354910	0.7227
675	0.139242	1.950664	-0.441264	0.6590
700	0.144795	1.986538	-0.430500	0.6668
725	0.100262	2.021775	-0.445024	0.6563

*Probability approximation using studentised maximum modulus with parameter value 29 and infinite degrees of freedom

Test Details (Mean = 0.124544003781)

Period	***Variance***	***Var. Ratio***	***Obs.***
1	1.89651	--	236
25	0.43595	0.22987	205
50	0.72861	0.38418	198
75	0.97364	0.51339	186
100	1.22063	0.64362	181
125	1.44033	0.75946	170
150	1.68344	0.88765	166
175	1.92998	1.01765	162
200	2.07149	1.09227	152
225	2.10253	1.10864	139
250	2.27705	1.20066	136
275	2.30460	1.21518	125
300	2.38571	1.25795	119
325	2.36021	1.24450	108
350	2.53784	1.33817	108
375	2.63949	1.39176	105

Table 26: Variance Ratio Test of the NSE 20 share index (weekly data) (contd)

Test Details (Mean = 0.124544003781) (contd)

Period	***Variance***	***Var. Ratio***	***Obs.***
400	2.55571	1.34759	95
425	2.48450	1.31004	88
450	1.99247	1.05060	66
475	2.24861	1.18566	70
500	2.16642	1.14232	64
525	1.69230	0.89233	48
550	1.78589	0.94167	48
575	1.64288	0.86627	42
600	1.25473	0.66160	31
625	0.87256	0.46009	21
650	0.60814	0.32066	14
675	0.26407	0.13924	6
700	0.27460	0.14479	6
725	0.19015	0.10026	4

Table 27: Variance Ratio Test of the NSE ASI (daily data)

Null Hypothesis: Log NSEASIDAILY is a random walk

Date: 05/04/15 Time: 12:45

Sample: 2/25/2008 - 10/24/2014

Included observations: 579 (after adjustments)

Standard error estimates assume no heteroscedasticity

Use biased variance estimates

Lags specified as grid: min = 100, max = 1700, step = 100

Joint Tests	***Value***	***df***	***Probability***
Max |z| (at period 100)*	2.075586	579	0.4818
Wald (Chi-Square)	4.955891	17	0.9979

Individual Tests

Period	***Var. Ratio***	***Std. Error***	***z-Statistic***	***Probability***
100	0.011447	0.476277	-2.075586	0.0379
200	0.006102	0.676103	-1.470038	0.1416
300	0.005331	0.829093	-1.199706	0.2303
400	0.004753	0.957955	-1.038930	0.2988
500	0.004930	1.071428	-0.928733	0.3530
600	0.004914	1.173985	-0.847614	0.3967
700	0.004962	1.268275	-0.784560	0.4327
800	0.004608	1.356025	-0.734051	0.4629
900	0.005022	1.438432	-0.691711	0.4891
1000	0.004510	1.516367	-0.656497	0.5115
1100	0.003957	1.590487	-0.626250	0.5312
1200	0.003792	1.661304	-0.599654	0.5487
1300	0.002955	1.729223	-0.576586	0.5642
1400	0.002443	1.794574	-0.555874	0.5783
1500	0.001615	1.857627	-0.537452	0.5910
1600	0.000927	1.918609	-0.520728	0.6026
1700	0.000310	1.977711	-0.505478	0.6132

* Probability approximation using studentised maximum modulus with parameter value 17 and infinite degrees of freedom

Table 27: Variance Ratio Test of the NSE ASI (daily data) (contd)

Test Details (Mean = - 0.00474601465735)

Period	***Variance***	***Var. Ratio***	***Obs.***
1	1.66976	--	579
100	0.01911	0.01145	438
200	0.01019	0.00610	404
300	0.00890	0.00533	388
400	0.00794	0.00475	349
500	0.00823	0.00493	324
600	0.00821	0.00491	289
700	0.00828	0.00496	260
800	0.00769	0.00461	228
900	0.00838	0.00502	219
1000	0.00753	0.00451	197
1100	0.00661	0.00396	163
1200	0.00633	0.00379	141
1300	0.00493	0.00295	107
1400	0.00408	0.00244	84
1500	0.00270	0.00162	52
1600	0.00155	0.00093	29
1700	0.00052	0.00031	10

Table 28: Variance Ratio Test of the NSE ASI (weekly data)

Null Hypothesis: Log NSEASIWEEKLY is a random walk

Date: 05/04/15 Time: 12:55

Sample: 2/29/2008 - 1/30/2015

Included observations: 133 (after adjustments)

Standard error estimates assume no heteroscedasticity

Use biased variance estimates

Lags specified as grid: min = 25, max = 350, step = 25

Joint Tests	***Value***	***df***	***Probability***
Max |z| (at period 25)*	1.644742	133	0.7713
Wald (Chi-Square)	18.29661	14	0.1936

Individual Tests

Period	***Var. Ratio***	***Std. Error***	***z-Statistic***	***Probability***
25	0.201344	0.485582	-1.644742	0.1000
50	0.318766	0.697363	-0.976871	0.3286
75	0.402133	0.858434	-0.696462	0.4861
100	0.450372	0.993740	-0.553090	0.5802
125	0.521149	1.112715	-0.430344	0.6669
150	0.556304	1.220146	-0.363642	0.7161
175	0.561252	1.318854	-0.332673	0.7394
200	0.678242	1.410674	-0.228088	0.8196
225	0.617204	1.496871	-0.255731	0.7982
250	0.485876	1.578369	-0.325731	0.7446
275	0.356961	1.655860	-0.388341	0.6978
300	0.204900	1.729884	-0.459626	0.6458
325	0.157887	1.800867	-0.467615	0.6401
350	0.055307	1.869157	-0.505411	0.6133

*Probability approximation using studentised maximum modulus with parameter value 14 and infinite degrees of freedom

Table 28: Variance Ratio Test of the NSE ASI (weekly data) (contd)

Test Details (Mean = 0.125130019781)

Period	***Variance***	***Var. Ratio***	***Obs.***
1	2.26119	--	133
25	0.45528	0.20134	120
50	0.72079	0.31877	106
75	0.90930	0.40213	94
100	1.01838	0.45037	87
125	1.17842	0.52115	77
150	1.25791	0.55630	71
175	1.26910	0.56125	62
200	1.53363	0.67824	63
225	1.39561	0.61720	50
250	1.09866	0.48588	36
275	0.80716	0.35696	24
300	0.46332	0.20490	13
325	0.35701	0.15789	9
350	0.12506	0.05531	3