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An **Investigation** of the **Impact** of the **2008 Financial Crisis** and **Stock Market Automation** on **Market Efficiency**: A Case for the **Botswana Stock Exchange**

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DECLARATION

I, Ritesh Girishkumar Ambalal, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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ABSTRACT

This study investigates the effects of the 2008 financial crisis and stock market automation on the efficiency of the Botswana Stock Exchange (BSE). It makes use of the BSE All Share Index (ALSI) logged returns covering the time period 2005 – 2017. In addition, four distinct tests are employed to test for the change in market efficiency over time: runs test, unit root test, serial correlations test and variance ratio test. The study found resounding evidence to conclude that the 2008 financial crisis and stock market automation had a significant positive effect on the efficiency of the BSE. In addition, the BSE went from being inefficient to weak-form efficient due to the policies implemented by the government of Botswana and financial regulators as a direct reaction to the 2008 financial crisis, plus the continuous improvement of the Automated Trading System (ATS). To the author's knowledge, this study is the first of its kind to test the impact of the 2008 financial crisis and automation of the trading system on the weak-form market efficiency of the BSE. As a result, this study provides an original and unique testimony on the effects of the 2008 financial crisis and the ATS on the efficiency of the Botswana Stock Exchange. Moreover, it offers an updated position of the BSE's efficiency status following the recent developments to ensure that relevant legislation and effective and efficient trading systems are in place.

Keywords: Botswana Stock Exchange; Efficient Market Hypothesis; 2008 Financial Crisis; Stock Market Automation; Runs Test; Unit Root Test; Serial Correlations Test; Variance Ratio Test.

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LIST OF ABBREVIATIONS

AC	Autocorrelation
ADF	Augmented Dickey-Fuller test
ALSI	All Share Index (BSE)
ATS	Automated Trading System
BSE	Botswana Stock Exchange
BWP	Botswanan Pula
CDCB	Central Depository Company of Botswana
CSD	Central Securities Depository (of Botswana)
EMH	Efficient Market Hypothesis
ETF	Exchange Traded Funds
EU	European Union
GARCH	Generalised Autoregressive Conditional Heteroscedasticity
GDP	Gross Domestic Product
GSE	Ghana Stock Exchange
HKSE	Hong Kong Stock Exchange
JSE	Johannesburg Stock Exchange
NSE	Nairobi Securities Exchange
NYSE	New York Stock Exchange
OIC	Organisation of Islamic Conference
OLS	Ordinary Least Squares
PP	Philipps-Perron test
SETS	Stock Exchange Trading System (JSE)
SSE	Singapore Stock Exchange
T+3	Time plus 5 days
T+5	Time plus 5 days
US	United States of America

CHAPTER 1 - INTRODUCTION

1.1 Introduction

According to Fama (1970), a market is efficient if prices fully reflect all the available information. Alternatively, Fama's (1970)'s assertion is that for markets to be efficient, asset prices should follow a random walk such that the direction of future prices becomes unpredictable. Hence, it is impossible for investors to profit from information that is already available. As a result of this assertion, Fama (1970)'s argument pioneered the efficient market hypothesis (EMH) theory research. To test Fama (1970)'s EMH theory, several studies used various methods to examine whether markets are efficient or not.

Unfortunately, a review of studies testing the EMH theory shows that, so far, the results are mixed. However, some inconsistencies have also been observed in the results produced by the various methods used in previous studies. For example, the debate in prior studies shows that some methods are only suitable under certain conditions. This debate suggests that care should be taken when choosing the method to use for analysing market efficiency. In addition, a review of literature also shows that several anomalies which violate the EMH have been detected. These anomalies have been argued to distort the efficiency of the market.

Apart from the anomalies, several other determinants of market efficiency have been discussed in prior studies. Some of these are related to automation and its effect on liquidity, transaction costs and flow of information, regulation and market condition. This study argues that the determinants of market efficiency play an important role for information to be fully reflected in asset prices such that investors cannot exploit it and generate excess returns. The two important determinants discussed in this study are the condition of the economy and the automation of the operations of the stock exchange.

However, this study acknowledges that there are several other determinants that could be used to assess market efficiency. The choice of the two above is based on the location of this study and the developments that took place in the chosen location as discussed in subsequent sections of the study. This study uses Botswana as a location to empirically examine the weak-form market efficiency on the Botswana Stock Exchange (BSE).

Several developments have taken place in Botswana since the 2008 financial crisis. Due to these developments, this study seeks to investigate whether the implementation of financial regulations and stricter control policies on the BSE after the 2008 global financial crisis have had a positive impact on weak-form market efficiency. In addition, it further examines the impact of automation of the BSE in 2012, which became fully effective in 2013, on the weak-form market efficiency. This study makes use of returns of the Botswana All Share Index for the period 2005 to 2017. This study is motivated by several limitations in prior literature as discussed below.

1.2 Limitations and Motivation for the Study

A review of prior literature shows that there is a very limited number of prior studies that tests the weak-form market efficiency based on the BSE. The only well-referenced study on market efficiency is by Chiwira and Muyambiri (2012), who used market data covering the period 2004 – 2008. In their study, Chiwira and Muyambiri (2012) found that the BSE is inefficient at the weak-form and concluded that a number of improvements to market infrastructure and regulations were necessary in order to improve its efficiency.

However, the study conducted by Chiwira and Muyambiri (2012) considered a short period, that is five years, and it is also dated as a number of regulatory and market infrastructural improvements have taken place since 2008. This study tests market efficiency for a period of 12 years – between 2005 and 2017. This provides the longest period ever studied on the market efficiency of the BSE. In addition, it provides an excellent opportunity to assess whether regulatory and market infrastructural improvements have been sufficient in enabling the BSE to become more efficient, or whether additional steps need to be undertaken to make the Botswanan stock market more efficient.

Furthermore, there is no study that could be found which examines whether automation improves the weak-form market efficiency on the BSE, nor have there been studies conducted to test the effect of the 2008 financial crisis on the weak-form market efficiency on the BSE. In the same vein, there is limited research testing for weak-form market efficiency before and after the automation of trading on an exchange in developing countries, irrespective of the benefits that the automation system offers to investors relative to the manual system. A review of literature indicates that the majority of the studies regarding the effects of the crisis and automation on weak-form market efficiency are concentrated in developed markets. In addition, there is limited research that is focused on a small number of African markets. For example, there are few studies that focus on South Africa, Namibia, Kenya and Nigeria. Hence, this study provides a valuable enhancement to existing literature on the effects of a financial crisis and automation on market efficiency.

Since most young stock exchanges use an open outcry system, which slows the flow of information, it is believed that a switch to an Automated Trading System (ATS) vastly improves the processing of information which, in turn, should improve market efficiency. Therefore, an analysis that covers the period before and after automation makes it possible to conclude whether an improvement in information processing and reconciliation brought about by automation improves market efficiency as well. Botswana forms a suitable case study due to its well-structured financial sector and the fact that the BSE is considered to be the third-largest – and one of the fastest growing – stock exchange in Sub-Saharan Africa (Hoover, 2013). Furthermore, the fact that the BSE is a young stock exchange that has recently transitioned from a manual system to an automated system gives this study an opportunity to examine how efficient and effective the flow of information caused by the automation has impacted the weak-form market efficiency of the BSE.

Moreover, prior studies do not examine market efficiency before, during and after the crisis. The efficiency of the market could be different depending on whether there is a crisis or not. Botswana recovered rapidly from the crisis, with its GDP growth rate increasing from -8% to

7% in a matter of two years (African Development Bank Group, 2012). In addition, the BSE reacted swiftly to the crisis by implementing the CSD and ATS, with the aim of improving trading experience and the efficiency of the market. This provides a suitable set-up to test the impact of the 2008 financial crisis, as well as the implementation of the CSD and ATS as a response to the crisis, on the weak-form market efficiency of the BSE.

Adding to the above, previous studies do not use two complementary methods of assessing market efficiency in one study. This study follows an innovative approach of blending the 2008 financial crisis and the implementation of the ATS and assessing whether these two events impacted market efficiency on the BSE. This study observes that market efficiency is a function of a blend of factors. Therefore, in this view, an inclusion of the impact of the crisis and automation on weak-form market efficiency in one study provides this study with an additional dimension to determine the drivers of market efficiency.

All things considered, this study offers invaluable insight to domestic and foreign investors, as it provides them with an up-to-date revision of market efficiency on the BSE.

1.3 Research Objectives and Questions

The main objective of this study is to examine the impact of the 2008 financial crisis and stock market automation on weak-form market efficiency on the BSE. Specifically, the study seeks to address the following questions:

(i) Did weak-form market efficiency improve during the 2008 financial crisis?

(ii) Did the subsequent implementation of the ATS in 2012 improve weak-form market efficiency of the BSE?

1.4 Formal Statement of Hypothesis

This study seeks to test two different effects in relation to weak-form market efficiency. Thus, the study will test two hypotheses:

Hypothesis One:

H_0: Weak-form market efficiency on the BSE improved after the 2008 global financial crisis, with the implementation of the CSD

H_1: Weak-form market efficiency on the BSE did not improve after the 2008 financial crisis, with the implementation of the CSD

Hypothesis Two:

H_0: Weak-form market efficiency on the BSE improved after the implementation of the ATS in 2012.

H_1: Weak-form market efficiency on the BSE did not improve after the implementation of the ATS in 2012.

1.5 Organisation of the Study

The remainder of the study is organised as follows: Chapter 2 provides the background to the study. Chapter 3 presents a review of literature while chapter 4 describes the data and research methodologies used for the study. Thereafter, chapter 5 presents the results and a discussion of the study. Finally, the study concludes and makes final remarks in chapter 6.

CHAPTER 2 – BACKGROUND TO THE STUDY

2.1 Introduction

Botswana is Africa's economic success story—with the highest cumulative GDP growth rate in the past five decades. This is evidenced by the fact that its GDP per capita has grown at an annual average of 10.08% since it attained its independence from Britain in 1966. Numerically, GDP per capita rose from $83 in 1966 to $7153 in 2016 (World Bank, 2018). As a result, Botswana has successfully transitioned from being a low-income to an upper-middle income country in five decades (Farole, 2015). A remarkable feat of this growth is that it helped to fuel the development of Botswana's financial markets, including the stock exchange, into one of the fastest growing and most promising markets in Africa, despite the fact that they were virtually non-existent at the time of independence (Kohli, 2016). Similarly, Botswana has become the best-case scenario for stock market development and foreign investment in Sub-Saharan Africa for its relative political and economic stability, its outstanding efforts in eradicating poverty and in avoiding the resource curse which plagues most resource-rich countries in the region (Dening & Thomas, 2013:41).

However, the 2008 financial crisis was the worst economic disaster since the Great Depression of 1929. The crisis led to the collapse of large financial institutions and severely weakened the entire US financial system. The bursting of the US housing bubble sent ripples of market disturbances, leading to global financial contagion. During that time, European and American banks were highly exposed to US mortgage loans as they had bought considerable amounts of collateralised mortgage debt. When defaults rose abruptly, these banks lost billions of dollars. Banks became cash-strapped to such an extent that even the interbank lending ceased overnight as banks started pulling back their international loans. This credit crunch led to a large number of financial problems in countries that relied heavily on international borrowing and those that had current account deficits. The contagion caused a sharp drop in consumer confidence due to uncertainties regarding the state of the global economy, which led to reduced consumption as consumers were saving rather than spending. This affected businesses globally as the demand for goods and services – and their value – declined. Moreover, the demand for exports fell. As the demand for exports fell, many countries' current account balances deteriorated further. Consequently, the crisis resulted in a global downturn in economic activity, leading to an increase in unemployment, a decrease in economic profits and sharp increases in governments' budget deficits, especially for less economically-developed countries and emerging economies (Faola, 2016). By the beginning of 2009, most countries around the globe were in a recession.

Due to the interconnectedness of the global banking system, even countries that were not exposed to mortgage loans were, at least indirectly, affected by the crisis. Botswana is a prime example of a country which was greatly affected by the crisis although its banks and pension funds held minimal securities associated to US mortgage debt (Goitsemang, 2008). Real GDP decreased by 6% while the growth rate was predicted to be 3.3% in 2009. The sharp contraction in output was driven by the fact that Botswana's economy is primarily export-dependent.

The global decline in the demand for Botswana's three main exports – diamonds, copper-nickel and tourism – adversely affected its economy. In 2007, diamonds accounted for over 50% of Botswana's exports. However, the collapse in global demand for rough diamonds led to a 50% decline in diamond exports by the fourth quarter of 2008. Additionally, copper and nickel prices decreased by 80% in international markets during the same period, hence making their extraction unprofitable for Botswana's miners (Jefferis, 2008). Granted that export earnings made up 40% of Botswana's revenues, the commodity slump led to the worst current account deficit the country ever experienced since 1975. A consequence of this was that foreign exchange reserves decreased by 5.9% between 2007 and 2008 as efforts were made to stabilise the currency and fill the hole left by the widened current account deficit (Goitsemang, 2008).

A consequence of the crisis was that most companies in Botswana slowed down operations due to lack of credit lines, long-term investment opportunities funds and a steep decline in foreign direct investment. In addition, most companies in the industrial sector had postponed capital expenditure programmes to cushion operational losses (Kamidza, 2009). The closure of mines and scaling down of operations in the manufacturing sector resulted in a large-scale retrenchment of workers in the country. The consequence was a 28.6% increase in job losses between 2008 and 2010 in the mining and manufacturing sectors. Given that these two sectors employed 22% of total workers, the unemployment rate rose from 12.9% in 2008 to 17.9% in 2010 (World Bank, 2017). During the same period, poverty rates increased by 2.5% (Southern Africa Resource Watch, 2008). Based on the above discussion, it can be concluded that the financial crisis had a considerable adverse socio-economic impact in Botswana.

In addition, Botswana's stock market experienced increased volatility and negative returns due to the 2008 financial crisis. All the major indicators of stock market health were negatively affected between 2007 and 2009. The stock market index's performance declined by 18.5%, stock market capitalisation decreased by 44.7%, the P/E ratio decreased by 23% and the Price/Book ratio decreased by 35.3%. Similarly, there was a decline in the stock market liquidity over the same period. For example, the stock market turnover declined by 8% and the average daily turnover dropped by 9% (Botswana Stock Exchange [BSE], 2009).

The main contributing factor to the deterioration of the health of Botswana's stock exchange was the fact that 81% of stock market capitalisation is mostly made up of the mining and material sectors, which are highly exposed to the international markets, especially the developed economies (BSE, 2009). The sharp decline in the international prices of diamond and copper-nickel, coupled with a decline in global demand for the aforementioned commodities, steered the mining companies into enormous losses and a downscaling of operations. Naturally, as the share prices of local companies tumbled, the stock market capitalisation, and liquidity thereof, followed the same course.

Owing to the advent and resulting impact of the financial crisis, many reforms were put in place in Botswana. For example, numerous financial reforms were implemented in the banking sector and capital markets in order to improve the productivity and efficiency of these markets, and to minimise any potential contagion effect of future crises. One of the major reforms that took place was when The Board of the Bank of Botswana approved the implementation of the Basel II accords in 2016, in order to maintain close supervision of banks, ensuring that they do not take on excessive risks and to improve their disclosure policies (Bank of Botswana, 2015).

In addition, the government invested in developing the capital markets in two ways. Firstly, they established the Central Depository Company of Botswana (CDCB) during the financial crisis in order to effect the electronic settlement of BSE listed securities and to hold those listed securities in electronic form (Ntshole, 2016). Secondly, the BSE launched its automated trading system (ATS) in 2012. This replaced a manual open outcry trading system and enabled investors both from Botswana and abroad to have access to an online trading system with automatic clearing and settlement. The objective was to make the BSE more visible and transparent, and to make trading more efficient (Minney, 2012). The dematerialisation of paper certificates was aimed at reducing the risk element associated with the manual clearing and settlement process. On the impact of automation, Hiran Mendis, the CEO of the BSE, stated that the system created more liquidity and attracted more domestic and foreign investors due to its facilitation of trade.

Furthermore, the CEO of MillenniumIT, the company which installed the ATS, affirmed that their system allowed the BSE to offer more enhanced services, provide a better trading experience and, most importantly, make the stock market more efficient (MillenniumIT, 2012). The establishment of both the CDCB and ATS claimed to have improved market efficiency, which begs the question: Have they practically improved market efficiency on the BSE?

2.2 An Overview of the Botswana Stock Exchange (BSE)

The BSE was constituted as the Botswana Share Market (BSM) in 1989. Before then, there was no formal exchange in Botswana and the BSM traded as an informal market with only five listed companies and one brokerage firm, namely Edwards & Co. (Pvt) Ltd (Carana Corporation, 2003). The BSM was assisted by the Zimbabwe Stock Exchange for its listing rules, member rules and all general rules. In order to encourage foreign investment, an exchange committee was set up in 1990 with representatives from the private and public sectors which helped to formalise the stock exchange. After years of meticulous planning and deliberation, the BSM paved way for the establishment of the BSE in 1995 under the newly-formed legislation of the Botswana Stock Exchange Act (Carana Corporation, 2003).

The structure of the BSE has changed since its inception, with the number of listed companies having grown from 5 in 1989 to 44 in 2017. Furthermore, there is currently a recognisable diversification as representation on the BSE now ranges from wholesaling and retailing, financial services and insurance, banking, property, mining, security services, transport, tourism, energy and healthcare. In 2001, the BSE also introduced a Venture Capital board in order to assist companies wanting to raise start-up capital. Further developments took place on the BSE; including the listing of Botswana government bonds on the exchange in 2003 so as to develop the domestic capital market (Botswana Stock Exchange, 2017a).

Another major milestone for the BSE was the development of market infrastructure. This infrastructure was developed as a response to the 2008 financial crisis. The BSE implemented the Central Securities Depository (CSD) in 2008 in order to bring quick and efficient clearing and settlement of trades and the reduction of risks associated with the former manual process. A major benefit was that settlement time shortened from T+5 (time plus 5 days) to T+3 (time plus 3 days) to conform to international standards, which in turn helped to reduce settlement risk. Subsequent to the implementation of the CSD, the BSE successfully implemented the ATS in 2012. This was done in order to support the BSE’s marketing initiatives by making it easier for both local and foreign investors to trade on the BSE and to make the exchange more efficient. The latest developments in the BSE come from the growth of more instruments, especially alternative investments, to give investors a greater variety of exchange-listed instruments. In addition, the BSE is working on establishing a risk-free yield curve, which will serve as a benchmark for future bond issues (Botswana Stock Exchange, 2017a).

In terms of the BSE technicalities, trading is conducted from Monday to Friday between 9:00 a.m. and 4:00 p.m. The stock exchange handling fees are fixed at P15 per bought note and P10 per sold note. In terms of taxation, a 15% withholding tax is levied and there is no capital-gains tax. Settlement of transactions occur 5 days (T+5) after the transaction is completed. Moreover, no foreigner can own more than 10% of issued share capital of a publicly-listed company, and foreign ownership for the free stock of a local company may not exceed 55%. In addition, the repatriation of funds is allowed up to P100 million (Carana Corporation, 2003).

To sum up the above, the government of Botswana, financial regulators and the BSE took several steps to improve the informational efficiency of the domestic financial market. For instance, measures were taken to improve the BSE's liquidity, increasing its appeal to local and international investors, increasing trading convenience, access to alternative investment products, reduction of costs, improvement of communication between traders and brokers, centralisation of securities and decreasing trading lags. Below is a summary of some of the policies that were implemented as a result of the 2008 financial crisis, and as a drive for improvement of the ATS:

- The implementation of the CSD and the share dematerialisation for both domestic and foreign, stocks (BSE, 2009).
- The Bank of Botswana improved the risk-based regulatory and supervisory system that prevented banks from engaging in excessively risky activities (Jefferis, 2010).
- Implementation of the Basel I Banking rules in 2009 (Jefferis, 2010).
- Privatisation of financial and banking state-owned institutions such as the Botswana Savings Bank and National Development Bank (Jefferis, 2010).
- The introduction of liquid ETFs to the BSE (BSE, 2009).
- The BSE introduced ETF Investor Schemes (BSE, 2009).
- The BSE also reduced its minimum trading requirement securities from 100 units to 1 unit (BSE, 2009).
- The BSE sponsored six financial market courses, partnering with Geometric Progression CC of South Africa (BSE, 2010).
- Creation of a bond market, with 36 immediate listings (BSE, 2010).
- The introduction of the automated trading system (ATS) (BSE, 2013).
- Introduction of limit orders, market orders and stop losses (BSE, 2013).

- Extension of regular trading sessions of the BSE, from 1 hour 45 minutes to 2 hours 45 minutes (BSE, 2013).
- The BSE improved their website, introduced internet-based trading and rolled out information dissemination through data vendors (BSE, 2013).
- Implementation of the complete dematerialisation of listed securities (BSE, 2015).
- The BSE significantly progressed with the centralisation, clearing and settlement of bonds listed in the BSE (BSE, 2016). The BSE partnered with an international bank – Saxo Bank – to give local investors access to international investment products (BSE, 2016).

Overall, the above measures had to be implemented to ensure the smooth function of the BSE. The BSE plays a pivotal role in Botswana's financial system: it acts as an avenue on which government, quasi-government and private sector can raise debt and equity capital. To date, the BSE is one of Africa's best-performing stock exchanges, averaging 24% aggregate return in the past decade. This has allowed the transformation of the BSE from an informal stock exchange to the third-largest stock exchange in terms of market capitalisation in Southern Africa; behind South Africa and Namibia (Botswana Stock Exchange, 2017b).

CHAPTER 3 – LITERATURE REVIEW

3.1 Introduction

This chapter provides a review of the findings in prior literature on EMH theory. The review covers the theory of the EMH, types of market efficiency, determinants of an efficient market, market anomalies and their relationship to the EMH. It further provides a detailed discussion on empirical research on the EMH in both developed and developing markets. Empirical findings are separated in order to determine if there is any contrasting evidence on the findings between the studies conducted based on developing countries and those of their counterparts. The motivation behind this review is to envisage if country factors could be playing a role in determining the impact of the crisis and automation on weak-form market efficiency.

Owing to the broadness of the research on EMH theory, the review of literature is divided into sub-sections. Section 3.2 provides a brief overview of the EMH theory. Section 3.3 presents a review of the three different forms of the EMH. Section 3.4 reviews the determinants of an efficient capital market, while section 3.5 reviews some of the market anomalies discussed in prior studies that contradict the EMH. Section 3.6 reviews empirical evidence on the efficiency of the BSE. Section 3.7 presents a review of the effects of the 2008 financial crisis on the efficient market hypothesis, while section 3.8 reviews literature on the impact of automation on the efficiency of a stock market. Thereafter, section 3.9 presents a summary of the chapter.

3.2 Efficient Market Hypothesis (EMH) Theory

Malkiel (1992) defines an efficient market as one which fully and correctly reflects all relevant information in determining a security's price. Malkiel (2003) further asserts that when a piece of relevant information arises, the news spreads rapidly and gets immediately incorporated into the security prices. However, Reilly and Brown (2003) argued that there exist three important assumptions that should hold for a capital market to be efficient. In their study, Reilly and Brown (2003) argued that for the EMH to hold:

1. There should be a large number of profit-maximising participants who analyse and value securities independent of each other
2. New information regarding securities appears in the market in a random fashion. In addition, the timing of one announcement is independent of others
3. Profit-maximising investors adjust security prices rapidly in order to reflect the effect of new information. The market will sometimes over-adjust and at other times it will under-adjust, however the investor cannot predict which will occur at any given time (Reilly and Brown, 2003:177).

The above assumptions give rise to the idea that the EMH is associated with the concept of a "random walk," which assumes that security price changes are random and unpredictable. The logic of the random walk idea is that if the informational flow is unconstrained and stock prices immediately reflect new information, then tomorrow's price change is independent of today's price change. This is a consequence of intelligent investors competing to discover under- or over-priced stocks to buy or sell before the rest of the market becomes aware of aforementioned arbitrage opportunities (Bodie, Kane and Marcus, 2011:341). In the random walk model, the return process is illustrated by a cumulated series of independent shocks. The returns can be written as:

$$Rt = \mu + \varepsilon(t) \sim (0, \sigma 2), \tag{3.1}$$

where μ represents the expected return and ε(t) is white noise, i.e. independent distribution with mean zero and variance σ^2 (Moix, 2001:60).

The EMH began to gain popularity in the 1960s, becoming one of the most influential concepts of modern financial economics. Five decades after its inception, it remains the controlling theory of portfolio management (Sharma, 2014). Similar to other theories, the EMH theory had its share of criticism, especially from the behavioural theorists who argue that markets are inefficient and that investors do not behave rationally as assumed by the

EMH theory. In support of their argument, the behavioural theorists claim that a large number of investors display irrational behaviour. For example, Yavrumyan (2015) argues that uneven reactions by investors to new information lead to the problem of over- and under-reaction, which is inconsistent with the EMH theory.

In response to the behavioural theorists' criticism, the proponents of the EMH theory also noted some contradictions in the claim of the behavioural theorists. For example, Mahesh (2016) found that numerous conclusions drawn from behavioural finance on market efficiency contradict each other. After noting these contradictions, the proponents of the EMH theory argued that behavioural finance has been found to represent a large number of the anomalies that can be explained by the EMH.

In addition, Malkiel (2003) opined that markets cannot be perfectly efficient, or else investors would have no incentive to try and beat the market, hence, making active management obsolete. Those who support the EMH theory argue that markets are exceedingly efficient regarding the utilisation of information and, thus, market prices provide the best estimates of value. They argued that if markets are not perfectly efficient, then market prices would deviate from their true values, hence making it difficult for the valuation process to provide an estimate of the true value (Vidali, 2013). However, there are three levels of market efficiency discussed in prior studies. The next section discusses each of these levels separately, while also taking note of the difference between them.

3.3 Types of Market Efficiency

According to the EMH definition, market prices should incorporate all available information. However, a distinction is made between three levels of efficiency, as each level relates to a set of information which is increasingly more inclusive than the preceding one. The basis of the definitions for each level is the phrase "all available information." Irrespective of the common use of the phrase "all available information", each type of market efficiency is distinguished by the tests conducted on trying to prove each of them. Furthermore, the majority of empirical studies only test the weak-form of EMH due to the rarity of semi-strong and strong-form market efficiency. Before discussing the findings in past studies, it is important to provide a brief overview of each type of market efficiency.

As the discussion progresses from an explanation of one level to the next, it is also important to note that each stronger form of the EMH incorporates all the information in the previous, weaker forms of the EMH. In other words, the assumptions of the weak form are incorporated in the semi-strong form, and the assumptions of the semi strong (which incorporates those of the weak form) are also incorporated into the assumptions of strong-form EMH. The next subsections provide a brief account of each of the three forms explained above, starting with the weak form, followed by the semi-strong form and finally by the strong-form EMH.

3.3.1 Weak-Form Market Efficiency

The weak form of market efficiency affirms that stock prices already reflect all relevant past information about the stock, fully and instantaneously, when analysing market data such as past prices, trading volume or short interest. Price movements today are not correlated to yesterday's price movements, implying the absence of predictably significant price patterns. This is because the theory claims that if historical data conveyed signals about future performance, all investors would already have learned to exploit the signals. As a result, these signals lose significance as they become widely known because a sell signal, for example, would result in an immediate price decrease (Bodie, Kane and Marcus, 2011). Therefore, technical analysis – used to analyse historical price patterns – is ineffective in generating excess returns in the market (Stanculescu and Mitrica, 2012).

Empirical studies followed two different approaches in order to test if a market is weak-form efficient. The most commonly used approach tests the random walk of stock prices using statistical tools. The argument in these studies is that, if tests show that stock prices follow a random walk, then technical analysis is deemed futile in generating excess returns because the market is considered to be weak-form efficient. Conversely, if the random walk hypothesis is rejected by the tests, the market is not considered to be weak-form efficient. The most popular methodologies used in this approach are the serial correlation coefficient test, the runs test, unit root tests and the multiple variance ratio tests (Saramat and Dima, 2011). Generally, most statistical tests for weak-form efficiency support the proposition that price changes are random and historical data is ineffective in forecasting price changes profitably.

The second approach in testing the weak-form efficiency of the market is to establish whether excess returns could be generated using trading strategies based on historical data. The most renowned method for testing this approach is the filter technique introduced by Alexander (1961)'s study on price movements in speculative markets. His technique is a mechanical trading rule which tries to identify movements in stock prices in a more sophisticated manner. The filter techniques uses an x-percent factor as a filter. An x-percent filter is defined as follows: If the daily closing price of the security moves up by at least x-percent, buy and hold the security until the price moves down by at least x-percent from the subsequent high, whereby the security can be sold and held in a short position.

However, Fama and Blume (1966) criticised this approach when they argued that prices always adjust to new information, and that repeating the abovementioned filter strategy cannot generate excess returns if the market is weak-form efficient. In addition, Fama and Blume (1966) argued that Alexander (1961)'s computations included biases that seriously overstated the profitability of filters, thus making this second approach less reliable in testing weak-form efficiency. The second level of EMH theory is the semi-strong form and this is explained in the ensuing subsection.

3.3.2 Semi-Strong Form Market Efficiency

The semi-strong form of market efficiency states that share prices adjust to new publicly available information instantaneously and in an unbiased manner (Saramat and Dima, 2011). Examples of publicly available information are past prices, annual reports, financial statements, reports by the financial press, fundamental data on the firm's product line, quality of management and earnings forecast (Bodie, Kane and Marcus, 2011). The argument behind the semi strong of market efficiency is that, if all investors have access to such information, then no investor can earn excess returns from trading strategies based on any publicly available information. In essence, fundamental analysis – which uses publicly available information to estimate the intrinsic value of assets – is useless in generating excess returns if the market is semi-strong efficient.

As explained in earlier sections, the semi-strong hypothesis covers the weak-form hypothesis as all the historical data contained in the weak-form hypothesis is already considered by the semi-strong hypothesis. Thus, using fundamental analysis is equally as futile as using technical analysis in generating abnormal returns in a semi-strong efficient market (Fama, 1970).

In testing the semi-strong form of the market efficiency, Reilly and Brown (2006) divided the tests into two methods. The first method involves predicting future rates of returns using publicly available information beyond historical data. The argument is that if these predictions are consistently profitable, then the market is not semi-strong form efficient. The second method uses event studies in order to determine how fast stock prices adjust to company-specific or macroeconomic events. One example would be to test whether excess returns can be generated by investing in a security after a public announcement of a significant event, such as earnings. Thus, if excess returns are generated on a consistent basis under the event studies test, it can be concluded that the market is not semi-strong form efficient (Reilly and Brown, 2006). At the highest level is the strong form of the EMH and this is explained in the next subsection.

3.3.3 Strong-Form Market Efficiency

The strong form of market efficiency states that stock prices fully reflect all public and private information. This signifies that no investor has monopolistic access to private information relevant to the formation of prices which would allow them to outperform the market (Reilly and Brown, 2006). Therefore, no one can have an advantage in predicting securities' prices since there is no data that would add any value to investors. As a result, no investor can generate excess return using any strategy, and any form of analysis is deemed useless in a market which is strong-form efficient (Bodie, Kane and Marcus, 2011). It is important to note that strong-form efficiency also encompasses weak-form and semi-strong form efficiency.

The testing for strong-form market efficiency is important as there are groups who have access to vital private information about a company, and who can potentially trade on it. These groups include top management, investment advisors and portfolio managers. Saramat and Dima (2011) argue that if these groups earn excess returns from their trading activities, then the market is not strong-form efficient. In fact, general literature on EMH concludes that there is yet to be a market which is strong-form efficient as this version of market efficiency is quite extreme.

Barnes (2009) argues that markets are weak-form and semi-strong form efficient but cannot be strong-form efficient due to the fact that insider trading is still rampant even though it is illegal and heavily monitored by financial regulators. The author further states that testing for strong-form market efficiency has been proven to be challenging due to the secrecy of insider traders and the timing of information (Barnes, 2009). In addition to testing whether the market is efficient in the weak form or semi strong form, other studies also investigated the determinants of an efficient market. A review of these determinants is discussed below

3.4 Determinants of an Efficient Capital Market

Fama (1970) stated that market efficiency depends on the speed and accuracy with which information is incorporated into prices. Fama (1970) further postulates that there exist three conditions for a capital market to be efficient. These conditions are:

1. There are no transaction costs when trading stocks.
2. All public and private information is costlessly available to all market participants.
3. There should be an agreement on the implications of current information for the current stock price and distribution of future stock price.

Despite postulating the conditions stated above, Fama (1970) acknowledged that those conditions do not apply to markets in practice due to the existence of transaction costs, the fact that information is costly and that some private information is withheld from the public. Consequently, Fama (1970) stated that: “Fortunately, the three conditions are sufficient for market efficiency, but not necessary.” There are a number of factors that determine how efficient a market is. These determinants aim to satisfy Fama (1970)'s three conditions for an efficient capital market. For instance, there is debate in prior studies that the progression in informational and communication technology has led to the improvement in the efficiency of financial markets around the globe.

Sabate et al. (2013), for example, found that the internet leads to an improvement in market efficiency by lowering costs in obtaining and disseminating information about stock prices. In addition, the internet is argued to facilitate the acquisition of information regarding investment opportunities, which in turn, improves the allocation of resources in a capital market (Sabate et al., 2013). Consistent with Sabate et al. (2013), Mlambo and Biekpe (2003) observed that the internet has enabled the reconciliation of bulky information required for technical and fundamental analysis of stocks into a ready-to-use arrangement. Hence, making it easier to observe deviations of the stock price from its intrinsic value. In this vein, the internet is argued to minimise the chance to earn excess returns through making the markets more efficient.

Relating to the above point, Frino, McInish and Toner (1998), Hill (2000), Frino and Hill (2001) and Jiang et al. (2002) all found that increased consolidation of financial markets due to switching from open outcry systems to electronic trading systems leads to an improvement in market efficiency. Furthermore, Avolio, Gildor and Andrei (2002) argued that improving technologies has helped in reducing barriers to entry for providing financial services. They argued that the electronic trading system led to a minimisation in transaction costs due to increased competition, as well as increased processing power, which enables the extraction of more information in a shorter period of time (Avolio, Gildor and Andrei, 2002).

Consistent with Avolio, Gildor and Andrei (2002) and Goldstein, Kumar and Graves (2014) also found that technical and fundamental analyses are becoming more computerised and the information is being processed faster as computers' processing speed and power increase exponentially each year. This has especially been true since the introduction of high-frequency trading and an increase in trade automation. The increase in trade automation enables the translation of technical and fundamental analysis into an immediate trade execution call, hence resulting in increased market efficiency.

Extant literature on EMH generally agrees that financial liberalisation leads to an improvement in market efficiency. Cho (1988), for instance, found that financial liberalisation in South Korea led to a decrease in transaction and borrowing costs, thus improving informational efficiency. Similarly, Galindo, Schiantarelli and Weiss (2003) observed twelve developing countries and concluded that financial liberalisation and a relaxation of capital controls led to an improvement in the efficiency with which markets allocate resources. However, Galindo, Schiantarelli and Weiss (2003) warned that liberalisation should be balanced with financial supervision as there is a positive correlation between official supervisory power and market efficiency. They argued that supervision is vital in deterring insider trading and that information is disseminated in the least costly manner for there to be an improvement in the efficiency of markets (Galindo, Schiantarelli and Weiss, 2003).

In support of Galindo, Schiantarelli and Weiss (2003)'s argument of the importance of supervision, some studies empirically found that securities regulation is positively linked with improved market efficiency. For example, Gakeri (2011) argued that, for market efficiency to increase, the legal framework must facilitate the proper functioning of the stock market through ensuring that all relevant disclosure requirements are complied with and the necessary institutional framework for trading is put in place. In addition to the above, North and Buckley (2010) postulated that regulation can enhance the efficient operation of a market in two ways. Firstly, financial regulations can be designed in such a way that it promotes Fama (1970)'s conditions for an efficient capital market, as listed above. Secondly, regulation can help promote transparent disclosure to all parties that is clear, concise and effective. Furthermore, regulations can promote competition among companies and investors to help lower transaction costs and improve informational and allocative efficiency.

Past studies claim that stock market liquidity and market efficiency are closely linked. Chordia, Richard and Subrahmanyam (2008), for example, analysed a sample of the top 193 traded companies in the NYSE and found that increased short-term liquidity is directly linked to improved market efficiency. The rationale being that a high degree of liquidity does not allow investors to absorb the impact of price pressures due to the imbalances between buy-sell orders and large order flows. Those who can detect price deviations from their fair value may apply arbitrage which will, in turn, speed up the convergence of prices to their fair value. Thus, the result would be a low predictability of returns and a higher level of market efficiency.

Furthermore, Chung and Hrazdil (2010) sampled 4,222 companies that traded on the NYSE and determined that there is a significant positive relationship between liquidity and market efficiency in both large and small, less-traded companies. Finally, Hodrea (2015) concluded that an increase in liquidity has a positive impact on information dissemination and efficiency, thus leading to improved market efficiency. Apart from the examination of the determinants of an efficient market, other studies examined market efficiency based on certain anomalies observed in the financial markets. A stream of these studies is reviewed in the following subsection.

3.5 Market Anomalies and the Efficient Market Hypothesis

Despite the theories and notion that markets are efficient, there are a number of market anomalies which have been observed in financial markets around the globe. There have been irrefutable cases of market inefficiency, even in markets which are considered to be efficient. Two good examples are the October 1987 market crash and the internet bubble of the late 1990s. The fact that the crises occurred indicates that market participants did not act rationally and, as a result, the markets are deemed to be inefficient. These inefficiencies are argued to materialise through the different anomalies that will be discussed in this section.

The anomalies discussed in this section appear more systematically in the market and can be attributed to calendar effects, behavioural biases of firms and economic agents, fundamental factors, structural factors and unpredictable random events. The next subsection reviews three groups of anomalies, that is, those related to calendar effects, behavioural biases and finally, the fundamental anomalies.

3.5.1 The Calendar Effect

It has been observed that stock prices fluctuate in accordance with the financial calendar schedule, hence, the effect is dubbed the "Calendar Effect." Past literature dictates that since prices oscillate depending on the day or month, or any major event, investors have an opportunity to benefit from these predicable stock price movements and generate excess returns. The most common types of calendar effects are the "January effect" and the "Weekend effect."

According to Rozeff and Kinney (1976), the January effect is a seasonal anomaly where markets exhibit higher-than-average returns in the month of January. Stock prices tend to increase between the 31^{st} of December and the first week of January. Thus, investors buy low at year-end and sell high at the next year-start. Resultantly, the effect contradicts the EMH as investors can realise excess returns.

Wachtel (1942) was the main proponent of the January effect. He based his theory on three assumptions: (1) High-yielding stocks are usually the stocks whose prices have decreased, thus they are the best stocks to sell in December to obtain tax benefits, (2) individuals and corporations sell stocks for tax-saving purposes in mid-December to establish tax losses, leading to a downward pressure in prices to below their fair value, (3) the rise at the year's end is nothing more than a normal reaction from depressed levels. The first assumption implies that the January effect is primarily a small-firm phenomenon. In addition, Ligon (1997) found that the January effect exists due to the large amount of liquidity available during January. Higher trading volumes and lower interest rates in this month directly correlate with greater returns.

Kumar and Jawa (2016) observed that mean returns on Mondays are the smallest, sometimes being negative, while mean returns on Fridays are the highest compared to other days of the week. This is known as the weekend effect. Fortune (1998) attributed the weekend effect to an "information release hypothesis," whereby information released during the week tends to be positive while information released during the weekend tends to be more negative. This is because firms with good news want to get it to the public as soon as possible, while bad news will be withheld for as long as possible and only released late on Friday to avoid investor scrutiny. Alternatively, Pompian (2012) found that the weekend effect can be credited to the fact that investors feel more positive on Friday, due to the coming weekend, than on Mondays.

The next group of anomalies relates to the behaviour of market participants, that is, the investors. The argument has its origins from the behavioural theorists. The argument proffered by this group of theorists is reviewed in the next subsection.

3.5.2 Behavioural Biases

A large number of behavioural-finance supporters argue against the EMH on the basis that investors are not rational. To back this claim, they argue that investor irrationality stems from the fact that investors exhibit a large number of cognitive heuristics (Zindel, Zindel & Quirino, 2014). The most common types of heuristics are: representativeness, adjustment and anchoring, herding, overconfidence and loss aversion.

Gupta, Bedi and Lakra (2014) describe representativeness as the attempt by investors to judge the probability of uncertain events in accordance with how similar the current event is to a past event, and the degree to which it reflects the significant features of the process by which it is generated. By doing this, the investor neglects information about the unique features of the probability of the current event. Tversky and Kahneman (1974) state that representativeness can also lead to investors deducing patterns in random sequences of data, or assuming that future patterns resemble past ones. As a result, they argued that this often leads to investors making wrong conclusions about stock trends and patterns (Tversky and Kahneman, 1974).

Furthermore, Tversky and Kahneman (1974) state that investors make estimates by starting from an initial value that is adjusted in order to produce the final answer. In essence, different starting points yield different estimates which are biased towards the initial values—this is called anchoring and adjustment. In most cases, the adjustments are insufficient which yields incorrect estimates. A good example in financial markets is that past prices are likely to act as anchors for today's prices if solid technical and fundamental information is missing (Montier, 2002).

Gupta, Bedi and Lakra (2014) describe herding as a phenomenon where investors feel the need to join in groups, hence, developing herd behaviour in decision-making situations. Banerjee (1992) adds that investors and fund managers will rather copy others' decisions rather than using their own information. Consequently, they enter into risky ventures without conducting a suitable risk-reward analysis. Bikhchandani and Sharma (2001) argued that herding behaviour aggravates volatility, destabilises markets and intensifies the frailty of the financial system.

Konstantinidis et al. (2016) define overconfidence as an investor's tendency to overestimate his or her abilities or skills in the investment decision-making process. Thus, investors are argued to be too confident in their knowledge and analysis because of the information they possess. As a result of overconfidence, investors make incorrect investment decisions. Stammers (2011) argues that overconfidence stems from the fact that novice investors get lucky, as their initial stock-picking decisions usually generate large excess returns. At this point, they start believing in themselves too much, thinking that they have a magical touch and that they are smarter than all of the other investors. More often than not, subsequent stock picks perform disastrously due to lack of proper stock analysis and investor arrogance.

Barberis and Huang (2001) state that investors suffer greater disutility from a loss than utility from an equal gain in their portfolio. Accordingly, behavioural finance considers investors to be loss-averse rather than risk-averse—hence giving rise to the loss aversion heuristic. Grinblatt and Han (2005) argue that loss aversion can help explain stock momentum effects. Past winners are excessively pressured to sell, and past losers are not shunned as rapidly as they should be under the EMH. This leads to investors underreacting to public information – past winners are undervalued, and past losers are overvalued. The result is a momentum effect as the erroneous valuation reverses over time.

The last group of anomalies is based on the use of fundamental analysis to establish the intrinsic value of stocks. Several anomalies were detected in prior studies, and these are discussed in the next subsection.

3.5.3 Fundamental Anomalies

This type of market inefficiency is based on the fundamental analysis of stocks, which is used to predict the intrinsic value of stocks based on analyses of economic, financial, qualitative and quantitative factors (Vidali, 2013). Fundamental anomalies often surface during analysis, giving investors opportunities to generate excess returns. The most common types of fundamental anomalies are: small firm effect, value stock effect and the impact of earnings announcements on stock prices.

The small firm effect is a theory linking a company's size to the return on its stock. Vidali (2013) found that smaller cap stocks tend to outperform larger cap stocks because smaller firms have a greater room for growth and a more volatile business environment. This translates into smaller cap companies having lower stock prices and higher price increases than large cap companies. Malkiel (2003) stresses that this anomaly represents a predictable pattern which enables investors to generate excess returns based on the higher price appreciations of smaller stocks.

Prior literature provides convincing evidence that "value" stocks outperform "growth" stocks. These two types of stocks can be differentiated using the price-earnings multiple and price-to-book ratio. Fama and French (1998) found that firms with a lower price-earnings multiple (value stocks) outperform growth stocks in twelve out of the thirteen major global markets. In addition, Malkiel (2003) concluded that stocks with a lower price-to-book ratio (value stocks) outperform those with a higher price-to-book ratio because investors overpay for "growth" stocks which end up failing to perform as highly as expected. Fama and French (1998) state that this fundamental anomaly is heavily ingrained into almost all major financial markets, allowing investors to use the information to generate excess returns.

Elena-Dana and Ioana-Cristina (2013) found that the effects of earnings announcements on prices tend to persist even after the initial announcement, with the trend being exacerbated. As a result, positive earnings announcements are argued to generate an upward stock-price trend, while negative earnings announcements generate a downward stock-price trend (Elena-Dana & Ioana-Cristina, 2013). In addition, Elena-Dana and Ioana-Cristina (2013) argued that stocks with consistent growth continue growing above market expectations while stocks with a consistent fall in prices will fall even further, despite the fact that initial decreases were higher than expected. The argument led Elena-Dana and Ioana-Cristina (2013) to dub the effect of earnings announcements on prices as the "paradox of high-higher or low-lower."

Owing to the discussion above, the next section reviews empirical evidence on the efficiency of the BSE. The next section forms the basis on which this study was designed since it uses Botswana as its location of study. Suggestions in prior studies on the efficiency of the BSE provide valuable contributions that this study could possibly make to the existing literature. The review in the next section focuses on the efficiency of the BSE in general; thereafter, focus is also on studies that tested whether the BSE was efficient for period during the 2008 financial crisis and after the automation of the BSE. This review is presented below.

3.6 Empirical Evidence: The EMH and the Botswana Stock Exchange

Turning of the studies conducted on the efficiency of the BSE, the bulk of literature testing weak-form efficiency in the BSE suggests that stock returns in the BSE are predictable, hence violating the concept of weak-form market efficiency. Appiah-Kusi and Menyah (2003), for example, concluded that stock returns in the BSE do not follow a random walk, thus indicating that the market is not weak-form efficient. An alternative study conducted by Mlambo and Biekpe (2007) similarly found that Botswana rejected the random walk hypothesis using the runs test, implying that the BSE is weak-form inefficient.

Similarly, Chiwira and Muyambiri (2012) tested for weak-form market efficiency of the BSE for the period 2004-2008 using the Augmented Dickey-Fuller (ADF) test, autocorrelation test, Kolmogorov-Smirnov test, Runs test and Phillips Perron unit root test. Every test investigated weekly and monthly All-Share Index returns for the period 2004 to 2008. All of the tests came to a mutual conclusion that the BSE is inefficient in the weak-form. Thus, in their conclusion, Chiwira and Muyambiri (2012) suggested that a number of adjustments were required in order to improve the efficiency of the BSE. These suggestions included the implementation of more coordinated information dissemination so that information reflects on prices immediately, replacing the open outcry system with an Automated Trading System (ATS) and decreasing the settlement time from *T-5* to *T-3*.

Radikoko (2014) gives a more up-to-date revision of weak-form market efficiency in the BSE. However, the data used is still limited, as it only goes up to 2013. The study used the autocorrelations, ADF and runs test to test for weak-form efficiency in the BSE. Consistent with the aforementioned results, all of the tests conducted in the paper reject the random walk hypothesis, implying that the BSE is weak-form inefficient. Thus, prior findings show that it is possible for investors to use technical and fundamental analysis to generate excess returns on the BSE. Radikoko (2014) further states that it may still be too soon for the impact of the implementation of the CSD and ATS to be pronounced in the BSE, suggesting that future studies should be able to see a more noticeable effect of these on market efficiency.

While acknowledging the contribution of findings in past studies on weak-form efficiency of the BSE the results from these studies are now outdated, as the data which they used for the tests predate the implementation of automation in the BSE. Henceforth, this study aims to test the weak-form market efficiency on the BSE using an updated set of data, with the objective of adding noteworthy value to the general EMH literature. In addition, this study considers the recommendations suggested by Chiwira and Muyambiri (2012) and Radikoko (2014). The notable factor is that the recommendations suggested by the abovementioned researchers have been implemented by the BSE, which makes it necessary to examine if these changes have actually made the BSE efficient at least in the weak form. The expectation is that the changes should have led to an improvement in the efficiency of the BSE at least in the weak form.

However, in order to observe whether this change has actually made the BSE efficient, it would be necessary to break the entire period under study into segments. These segments are: the before, during and after financial crisis and period after automation of the BSE. Literature based on the before financial crisis and automation has already been discussed in the preceding sections, hence, the next subsections discuss EMH for the period during the 2008 financial crisis and after the automation of the stock exchange. This literature is discussed below.

3.7 Empirical Evidence: The 2008 Financial Crisis and the EMH

A review of past studies provides mixed conclusions regarding the effect of the 2008 financial crisis on market efficiency. A number of studies conclude that the crisis had a positive impact on market efficiency on various markets around the globe (Sengonul and Degirmen, 2011; Rizvi & Arshad, 2016; Arshad et al., 2016), others state that it had a negative impact (Anagnostidis, Varsakelis and Emmanouilides, 2016; Ali and Afzal, 2012; Lim et al., 2008) while a small number of studies conclude that the crisis had an insignificant effect on market efficiency (Sharma and Seth, 2011; Mahmood et al., 2010; Rizvi and Arshad, 2016).

Surprisingly, some studies show that the 2008 financial crisis proved to be especially beneficial to developing countries' market efficiency. For example, Sengonul and Degirmen (2011) used a GARCH (1,1) approach to test for market efficiency before and after the crisis on European Union countries and Turkey. In their study, Sengonul and Degirmen (2011) found that market efficiency improved post-crisis in Bulgaria, Estonia, Lithuania, Malta and Slovenia. Moreover, Turkey has been identified as the perfect definition of being in between a developing and developed country. Sengonul and Degirmen (2011) found that Turkey's market efficiency improved after the crisis.

Consistent with the results above, Rizvi and Arshad (2016) concluded that market efficiency showed significant improvement of East Asian markets' efficiency in the wake of the global crisis. However, it is important to note that the improvement in market efficiency only occurred exclusively in developing countries. They attributed this to the countries' officials' rapid reaction to the crisis when they implemented financial liberalisation policies, implementing policies which had an effect of stimulating savings and domestic investments and attracting foreign direct investment (Rizvi and Arshad, 2016).

Similarly, Arshad et al. (2016) used the Christiano-Fitzgerald filter and the Multifactural de-trended fluctuation analysis to test for the effect of the financial crisis on the top 20 countries, by market capitalisation, in the Organisation of Islamic Conference (OIC). They conclude that all 20 countries in the sample showed signs of improved efficiency after the crisis. In light of this, Arshad et al. (2016) concluded that improving efficiency is a positive omen for the development of the financial sector, as well as the growth of the economy, in these countries.

At the other end of the spectrum, Anagnostidis et al. (2016) found that the 2008 financial crisis had a significant negative impact on the stock market efficiency in most of the Eurozone capital markets. Moreover, the Eurozone stock price movements exhibited mean-reverting patterns after the crisis, indicating a drastic shifting away from market efficiency. Complementing the above results, Sengonul and Degirmen (2011) observed that EU and non-EU Eastern European countries, such as the Czech Republic and Latvia, tended to depart from weak-form efficiency after the crisis. These countries suffered from a persistence in volatility, which was greater than 1.

Stock markets in Asia have also been negatively affected by the 2008 financial crisis. Ali and Afzal (2012) concluded that the crisis had an adverse impact on stock returns and enhanced volatility of both the Indian and Pakistani stock exchanges, leading to a weakening of market efficiency in the two abovementioned markets. Lim, Brooks and Kim (2008) found that the crisis had adversely impacted the efficiency of most Asian markets significantly, with special emphasis on Hong Kong, Philippines, Malaysia, Singapore, Thailand and South Korea. The decrease in efficiency was attributed to nonlinear serial dependencies, which provided evidence of deviation from equilibrium in the markets.

Between the two extremes, some studies presented in prior literature suggest that the 2008 financial crisis had an insignificant effect on the efficiency of markets around the globe. Sharma and Seth (2011) analysed both the Bombay Stock Exchange and National Stock Exchange in India in order to determine the impact of the 2008 financial crisis on market efficiency. They used the Jarque-Bera test, runs test, unit root test and autocorrelation function on data which spanned 10 years, between 2000 and 2010. Sharma and Seth (2011) found that there were no significant differences in both markets' efficiencies when comparing the pre- and post-crisis period.

Mahmood et al., (2010) used the ADF test, runs test, Lo and MacKinlay (1988) Variance Ratio test and the Durbin-Watson test to study the impact of the 2008 financial crisis on the Chinese stock market and found that the Chinese stock market is already weak-form efficient, and that the crisis had an insignificant impact on its efficiency.

Based on the discussion above, it is worth noting that the majority of prior studies that tested the effect of the crisis on Asian markets' efficiency concluded that the effect was either positive (Sengonul and Degirmen, 2011), negative (Anagnostidis et al., 2016) or insignificant (Mahmood et al., 2010; Sharma and Seth, 2011; Rizvi and Arshad, 2016). Rizvi and Arshad (2016) concluded that the crisis did not significantly affect Indonesia's stock market efficiency because of its large population, increased savings and income from the local population.

In addition to examining the impact of financial crisis on stock market efficiency, other studies examined whether the change in systems that facilitate the operations of the stock exchange have an impact on the efficiency of the stock exchange. These studies examined periods before and after the automation of an exchange's operations to determine whether a switch from the open cry system to an automated system improves the efficiency of the stock exchange. The findings from these studies are discussed in the subsection that follows.

3.8 Empirical Evidence: Stock Market Automation and the EMH

Prior studies suggests that stock market automation has a significant positive effect on market efficiency. Dicle and Levendis (2013), for example, analysed the effect of the implementation of the SETS, the London Stock Exchange's electronic order book, on the Johannesburg Stock Exchange (JSE) in 2002. The authors found that trading activity doubled, and trading became cheaper after the implementation of the system. Moreover, after the introduction of the

SETS, the JSE became more independent and offered better diversification opportunities for domestic and international investors. As a result, the abovementioned effects were argued to have translated to significantly improved market efficiency on the JSE (Dicle and Levendis, 2013).

In Kenya, Stephen et al., (2013) studied the impact of the Nairobi Securities Exchange's (NSE) full automation in 2006 on market efficiency. Just one year after the NSE was fully automated, Stephen et al. (2013)'s study found that market efficiency on the NSE had improved significantly. Based on their findings, Stephen et al., (2013) concluded that the automated exchange became deeper and more liquid than when the NSE had an open outcry system. Still in Kenya, a more recent study by Mwangi (2015) showed that the automation of the NSE resulted in the improvement of market capitalisation, stock turnover and the total value of stocks traded. In addition, the study showed that the cost of trading decreased, and that liquidity saw an upsurge, which clearly shows that there was an improvement in the NSE's efficiency (Mwangi, 2015).

In Singapore, Naidu and Rozeff (1994) analysed the full automation of the Singapore Stock Exchange (SSE) in 1989, and its impact on market efficiency. In their study, Naidu and Rozeff (1994) examined 28 stocks, before and after automation, and concluded that automation is associated with increases in volumes traded, return volatility and liquidity (Naidu & Rozeff, 1994). In addition, their studies also observed improvements in price dissemination and a fairer matching of orders on the SSE. The aforementioned outcomes provided additional evidence of an improvement in market efficiency in the SSE.

In Hong Kong, Jiang et al. (2002) examined the effects of the switch from an open outcry system to an electronic trading system on the Hong Kong Stock Exchange's (HKSE) efficiency and found that automation led to an improvement in the pricing information collection and transmission to market participants, leading to better informational efficiency. As a result, they concluded that stock prices displayed information quicker and more effectively after automation (Jiang et al., 2002). In addition, Jiang et al. (2002) found that electronic trading led to a more transparent price discovery, reduced frauds and diminished human errors. The results after automation contrasted the findings when the HKSE had an open outcry system.

For the period before automation, that is, when the HKSE had an open outcry system, Jiang et al. (2002) found that there were different prices for the same stock, orders were not often fairly matched and there were human errors. Therefore, based on a comparison of the results for the period before and after automation, Jiang et al. (2002)'s study clearly showed that there was an improvement in the HKSE's efficiency post-automation.

However, there are a few studies that suggest that automation has had an insignificant effect on stock market efficiency. For example, Sioud and Hmaied (2003) analysed the impact of automation on liquidity, volatility and stock market efficiency on the Tunisian Stock Market. The authors concluded that, although liquidity had increased to some extent, the electronic trading mechanism did not reduce pricing error (Sioud and Hmaied, 2003). As a result, they concluded that the effect of automation on stock market efficiency was essentially insignificant (Sioud and Hmaied, 2003).

In Ghana, Mensah et al. (2014) looked at the automation of the Ghana Stock Exchange (GSE) in 2008. The study investigated the impact of the automation on GSE's efficiency using a unit root test and GARCH models. The results indicated that liquidity improved slightly and so did market capitalisation. However, the study showed that the GSE was not weak-form efficient, even after automation (Mensah et al., 2014). This suggests that automation of the GSE had an insignificant impact on market efficiency.

3.9 Summary

This chapter discussed the theory of the EMH, types of market efficiency, determinants of an efficient market and anomalies that lead to a market being inefficient. The discussion above revealed that the results in prior studies are mixed. The differences were mainly attributed to determinants of market efficiency and some of the anomalies that may lead to inefficiencies in the market.

This current study, in addition to examining the period before, during and after the 2008 financial crisis, uses a longer period after the automation of the BSE to allow for the market to adjust to changes and for the market players to understand the working of the new system. In order to facilitate the running of the tests for this study, the next chapter discusses the data used and the methodologies chosen to test the efficiency of the BSE.

CHAPTER 4 - METHODOLOGY

4.1 Introduction

The purpose of the study is to determine the effect of the 2008 financial crisis and stock market automation on stock market efficiency on the BSE. Thus, this chapter provides an explanation of the data used and a detailed account of methodologies commonly used in testing market efficiency; including what each test entails and methodological issues shown in past studies. This will be followed by a detailed explanation of the research approach that was followed.

4.2 Data Population

This study makes use of secondary financial data. The market efficiency of the BSE is analysed using the BSE All Share Index: an author-created index incorporating the BSE Domestic Company Index (DCI) and BSE Foreign Company Index (FCI). The BSE All Share Index is calculated using weighted averages of the value of stocks. In addition, the currency base is denominated in Botswanan Pula (BWP).

It is worth noting that the index data used in this study is entirely weekly. This frequency was found to be ideal; daily data contains an excessive amount of market noise which might lead to inaccurate market efficiency test results, while monthly data during the study period renders too few observations to conduct reliable tests of market efficiency. The use of weekly prices is based on the recommendations made during the presentation of the proposal for this study.

The data used for this study was collected from the INET and the Bloomberg terminals that are housed at the University of Cape Town's main library. The platforms for data collection used for this study are reliable sources of data as the organisations that collect and collate the data are globally reputable. Overall, data analysed for this study was collected for period ranging between 2005 and 2017; that is a total of 12 years. The split of the time series is indicated in table 4.1 below.

TABLE 4.1: Description of the Time Series

Test	Data	Data Period
TESTING THE EFFECTS OF THE 2008 FINANCIAL CRISIS ON MARKET EFFICIENCY		
Financial Crisis Effect on EMH (Before Crisis)	BSE All Share Index (Weekly)	Jan 2005 – Jan 2007
Financial Crisis Effect on EMH (During Crisis)	BSE All Share Index (Weekly)	Jan 2007 – Jan 2009
Financial Crisis Effect on EMH (After Crisis)	BSE All Share Index (Weekly)	Jan 2009 – Jan 2011
TESTING THE EFFECTS OF STOCK MARKET AUTOMATION ON MARKET EFFICIENCY		
Automation Effect on EMH (Pre-Automation)	BSE All Share Index (Weekly)	Jan 2010 – Jul 2013
Automation Effect on EMH (Post-Automation)	BSE All Share Index (Weekly)	Jul 2013 – Jan 2017

Raw data was collected for the time period January 2005 – January 2011 testing the effect of the 2008 financial crisis on market efficiency. The data is equally split into three parts, respectively testing for market efficiency before (January 2005 – January 2007), during (January 2007 – January 2009) and after (January 2009 – January 2011) the crisis.

Prevailing literature fixates the start of the financial crisis at August 2007 (Thakor, 2015). However, this study assumes that the financial crisis truly started materialising before then, in January 2007. Soros (2009) stated that trouble in the mortgage sector started to multiply early in 2007—On February 22, HSBC's mortgage lending business declared losses of $10.8 billion. On March 9, the biggest homebuilder in the US, DR Horton, warned of losses from subprime mortgages. On March 12, one of the biggest subprime loan lenders, New Century Financial, suspended trading of its shares due to being on the brink of bankruptcy. On April 2, New Century Financial filed for bankruptcy. On March 13, late mortgage payments and home foreclosures rose to an unprecedented high, and Accredited Home Lenders sold $2.7 billion of its subprime loan book at a heavy discount to avoid becoming insolvent (Soros, 2009).

In addition, data was collected for the time period January 2010 – January 2017 for testing the effect of stock market automation on market efficiency. The data is split in two distinct time series, respectively testing for market efficiency before (January 2010 – July 2013) and after (July 2013 – January 2017) stock market automation in the BSE.

Although the implementation of the ATS was completed in October 2012, it only became fully operational in mid-2013. This was because the BSE faced challenges in the initial implementation and rollout of the ATS. In addition, listed companies were reluctant to switch to automated systems. However, all of the listed companies had switched and were actively trading in the ATS by mid-2013. Hence, the pre-automation period stretches until July 2013.

The raw data was imported into Microsoft Excel, transformed into index returns and converted into natural logs of weekly prices of the index. The formula used for the conversion into natural logs is as follows:

$$r_t = \ln\left(\frac{P_t - P_{t-1}}{P_{t-1}}\right) \times 100, \qquad (4.1)$$

where r_t was the return on the BSE All Share Index on week t; P_t was the closing value of the index on week t; and P_{t-1} was the closing value of the index on week t-1. The price returns calculated using equation 4.1 are expressed as percentages. The data was transferred to the STATA 13 and E-Views 10 software for analysis of descriptive statistics. In addition, E-Views was used for running the serial correlations test, unit root tests and variance ratio test. The runs test was conducted using the SPSS 25 software utilising the same dataset.

4.3 Method and Model Specification

Four techniques were used to determine the effects of the 2008 financial crisis and stock market automation on BSE's market efficiency. They are as follows:

1. Runs test
2. Unit root test
3. Serial correlations test

4. Variance ratio test

- **DESCRIPTIVE STATISTICS**

In addition to the abovementioned market-efficiency tests, a summary of the following descriptive statistics was calculated for each of the five-time series: mean, median, standard deviation, maximum, minimum, skewness, kurtosis and Jarque-Bera test statistic.

Skewness is a measure of the asymmetry of a distribution. If the skewness measure is zero, the distribution is perfectly symmetrical and normally distributed. If skewness is greater than zero, then the distribution is skewed to the right and has a rightwards tail. If skewness is less than zero, then the distribution is skewed to the left and has a leftwards tail (Lovric, 2010).

Kurtosis describes the peakedness or flatness of a distribution compared to a normal distribution. A kurtosis of 3 indicates that the stock returns are normally distributed. If the value of kurtosis is greater than three, the distribution is relatively peaked and is characterised as leptokurtic. If the value of kurtosis is lower than three, the distribution is relatively flat and is characterised as platokurtic (Čisar & Čisar, 2010).

The Jarque-Bera test statistic is used to test for the normal distribution of the series. The results obtained are compared to and reinforced by the kurtosis and skewness tests. The Jarque-Bera statistic tests the null hypothesis: “the distribution is normal” and is calculated using the following formula (Abedini, 2009):

$$JB = \frac{n}{6}\left(S^2 + \frac{(K-3)^2}{4}\right) \quad (4.2)$$

where n denotes the number of observations. From here, we can calculate Skewness, measured by S and defined as the following:

$$S = \frac{\mu_3}{\sigma^3} = \frac{\mu_3}{(\sigma^3)^{3/2}} = \frac{\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x})^3}{\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x}^2)^{3/2}} \quad (4.3)$$

Furthermore, K is a measure of Kurtosis and is defined as the following:

$$K = \frac{\mu_4}{\sigma^4} = \frac{\mu_4}{(\sigma^2)^2} = \frac{\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x})^4}{\left(\frac{1}{n}\sum_{i-1}^{n}(x-\bar{x})^2\right)^2} \tag{4.4}$$

The critical value for the Jarque-Bera test at the 5% significance level is 5.99 (Abedini, 2009). Hence, if Jarque-Bera > 5.99 or if the p-value < 0.05, then the null hypothesis of normality is rejected.

- **RUNS TEST**

Vitali and Mollah (2010) describe the runs test as a non-parametric test that examines if successive price movements are independent of each other. This is done by comparing the number of runs observed in the series with the expected number if the series followed a random pattern. The test hypothesis is that if the returns in the series are random, then the observations are considered to be independent and the actual number of runs should be equal to, or at least close to, the expected number of runs. In addition, the test assumes that prices fluctuate randomly and independently (Fama, 1965).

The runs test is a fitting statistical method for testing weak-form market efficiency because the validity of the test is not dependant on the shape of the distribution of returns (Abedini, 2009). This is because it is a non-parametric test, hence returns do not need to be normally distributed. Finally, the Runs test pairs fittingly with the Serial Correlations tests as it is not affected by single outliers, while the latter is.

A run is counted every time there is a sign change in the price series, with three possible changes – positive (+), negative (-) and zero (0). Elbarghouthi, Qasim and Yassin (2012) state that a plus run of length *i* is a sequence of *i* consecutive positive, negative or zero. For example, the sequence of daily prices of (109.05, 109.38, 108.78, 108.20, 107.57, 107.01, 106.97, 107.04, 107.87, 107.87, 107.27, 106.78, 107.48, 107.53) has 6 runs (+, -, +, 0, -, +) with the lengths of (1, 6, 2, 1, 1, 2) respectively.

Fama (1965) described the runs test as examining whether the direction of one price series influences the direction taken in later observations, making it a relatively suitable test of market efficiency. The Runs test was conducted using the SPSS software

The null and alternate hypotheses for the runs tests are as follows:

H_0: R = E(r) (Successive changes in the index prices are random)

H_1: R $\neq$ E(r) (Successive changes in the index prices are not random)

The hypothesis is tested using a comparison between the observed number of runs and the expected number of runs, using the following formula:

$$m = \frac{\{N(N+1) - \sum_{i=1}^{3} n_i^2\}}{N} \quad (4.5)$$

where m is the expected number of runs; N is the total number price changes; and n_i is the number of price changes of each sign.

In addition, the standard error of the price series of runs is expressed using the following formula (Fama, 1965):

$$\sigma_m = \left\{\frac{\sum_{i=1}^{3} n_i^2\left[\sum_{i=1}^{3} n_i^2 + N(N+1)\right] - 2N\sum_{i=1}^{3} n_i^3 - N^3}{N^2(N-1)}\right\}^{1/2} \quad (4.6)$$

The significance of the runs test is determined through calculating the difference between the actual number of runs, R, and expected number of runs, m. This difference is expressed by the means of a standardised variable. This is represented using the following formula:

$$Z = \frac{R \pm 0.5 - m}{\sigma_m} \quad (4.7)$$

The null hypothesis of independence is rejected if the z-value is greater than the critical value, implying that returns are not independent of each other. In addition, the sample cannot be independent if it contains too many or too few runs. A positive z-value is obtained if the actual runs are greater than the expected runs, while a negative z-value is attained if the actual returns are less than expected returns.

A significant difference between actual and expected returns is indicative that returns are not random, giving rise to the opportunity of investors earning excess returns. A scenario where the actual number of runs is significantly less than the expected values means that market participants overreacted to information, while a higher actual number of runs indicates a lagged response to information.

If the Z-value is greater than the absolute value of 2.576, the null hypothesis is rejected at the 1% significance level (Elbarghouthi, Qasim and Yassin, 2012), indicating a violation of the EMH – returns are not independent of each other and the market is not weak-form efficient.

- **UNIT ROOT TEST**

The EMH states that price movements need to be random (non-stationary), which is characterised by the presence of a unit root. In light of this, the unit root test examines whether the stock price time series are stationary or non-stationary. However, it is important to note that Gilmore and McManus (2003) state that a unit root is a necessary but not sufficient condition for a random walk in a price series. They go on to state that the presence of a unit root itself is not sufficient to imply weak-form market efficiency; the returns must also be serially uncorrelated. Hence, the unit root test should ideally be paired with a serial correlations test in order to give a more accurate representation of market efficiency.

The null and alternate hypotheses for the unit root test are as follows:

H_0: A unit root is present in the time series. $(b = 0)$

H_1: A unit root is not present in the time series. $(|b| > 0)$

The null hypothesis above is tested using an Augmented Dickey-Fuller (ADF) test. This builds up from the standard Dickey-Fuller test by accounting for higher order auto-regression through a parametric correction of adding *l*-lagged difference terms of the dependent variable to the right-hand side of the equation (Setyawan, 2010). The equation for the ADF is as follows:

$$\Delta y_1 = \mu + \gamma_t + by_{t-1} + \sum_{j=1}^{k-1} \beta_j \Delta y_{t-j} + \mu_t \quad (4.8)$$

where y_t is the time series to be tested for the unit root, Δ is the difference operator, t is the time trend and μ_t is the white-noise term error – the aforementioned parametric correction. The ADF test statistic is the ratio of the estimated *b* value to its standard error obtained from the OLS regression (Buguk and Brorsen, 2003).

The Phillips-Perron (PP) test is another unit root test which, in this study, is used as a control test in order to ensure that the ADF results are accurate in representing the level of stationarity of the time series. The PP test similarly checks whether a time series is stationary or non-stationary. In addition, it tests for the same null and alternate hypothesis as the ADF, making it an ideal control for unit root tests (Imam, Habiba and Atanda, 2016).

The null hypothesis, for both the ADF and PP test, is rejected at the 1% significance level if the observed absolute quasi t-statistic is greater than the absolute critical value of 2.576. This would indicate that a unit root is not present in the time series, signifying that there is no evidence of randomness and that future price movements can be predicted using past price patterns. In this scenario, investors will be able to generate excess returns, indicating that the market is not weak-form efficient.

- **SERIAL CORRELATIONS TEST**

Vitali and Mollah (2010) describe the serial correlations test as a parametric test used to examine the absence of auto-correlation between a time-series variable and its lagged values. In essence, the test evaluates the independence of variables with their lagged values.

This test is considered to be ideal to test for weak-form market efficiency because the relationship between price series in the current period with values in the previous periods is measured using auto-correlation (Abedini, 2009). In addition, the serial correlations test complements the unit root test. As aforementioned, the presence of a unit root is not a sufficient condition to imply market efficiency: the price changes need to be serially uncorrelated as well.

If the serial correlations test presents evidence of auto-correlation in the series, then the returns are not independent, showing that they do not follow a random walk. The consequence being that markets are inefficient, and it would be possible to make predictions about price future movements based on past price movements and use such information to generate excess returns (Kumar and Kumar, 2015).

The null and alternate hypothesis for serial correlation tests are as follows:

> H_0: $P_k = 0$ (There is an absence of serial correlation between price changes over successive q time lags – price changes are independent)
> H_1: $P_k \neq 0$ (There is positive or negative serial correlation between price changes over successive time lags – price changes are not independent)

The Ljung and Box (1978) Q-statistic is used to test for serial correlation in the data series. It follows the approach of using a first-difference correlogram test in the EViews software to extrapolate the Q-statistic. In addition, the test was conducted on level data with 36 lags.

The Ljung and Box (1978) test provides an ideal measure of serial correlation in a dataset of stock returns as it tests overall randomness based on a number of lags rather than testing randomness at each specific lag, which is usually observed in the Durbin-Watson test. In addition, the Ljung and Box (1978) is an improved and refined version of the original general-purpose tests as it is more suitable for smaller sample sizes, where the datasets are usually not normally distributed (Wheeler et al., 2002).

The Ljung and Box (1978) Q-statistic follows a chi-square distribution with k-degrees of freedom and is represented by the following equation:

$$Q_{LB} = N(N+2)\sum_{j=1}^{k}\frac{\rho_j^2}{N-j} \tag{4.9}$$

where N = number of observations, ρ_j = the j^{th} auto-correlation and k = number of auto-correlations.

A high Q-statistic, regardless of its sign, indicates the presence of correlation between the current stock price and the previous stock price—which provides evidence that the market is not weak-form efficient. Conclusively, if the absolute Q-statistic value is greater than or equal to the critical value at the chi-squared 1% critical level, the null hypothesis is rejected, and it can be concluded that there is significant statistical evidence of autocorrelation, signifying that the market is not efficient at the weak-form.

- **VARIANCE RATIO TEST**

Lo and MacKinlay (1988) mention that variance ratio tests are more powerful and accurate than alternative tests, such as the runs test and unit root tests, for examining the random walk hypothesis. In addition, Cochrane (1988) affirmed that variance ratio statistics are useful in computing the persistence of real output. Furthermore, Christiano and Eichenbaum (1990) showed that slight changes in parametric assumptions yield dramatically different conclusions about persistence and randomness in the Augmented Dickey-Fuller and Ljung-Box tests for market efficiency, while the variance ratio tests do not.

Complementing the above, Füss (2005) stated that the traditional random walk tests, such as runs and serial correlation tests, are highly susceptible to errors caused by non-synchronous and low volume trading; a major characteristic in developing markets. In retrospect, the variance ratio statistics are immune to this problem as they rely on short-horizon autocorrelations to infer long-run events. These are useful in investigating stock returns that do not usually follow a normal distribution.

Lo and MacKinlay (1988) developed a martingale difference hypothesis, tested using the variance ratio test in order to examine the existence of random walks in stock price time series under the assumptions of homoscedasticity and heteroscedasticity of the random error term. The variance ratio test examines whether returns are serially correlated with each other or not.

The null and alternate hypothesis for the variance ratio test are (Patel, Radadia and Dhawan, 2012):

H_0: VR(q) = 1 (The BSE is weak-form efficient)

H_1: VR(q) $\neq$ 1 (The BSE is not weak-form efficient)

The null hypothesis postulates that returns are not serially correlated, and the market is weak-form efficient. However, if the null hypothesis fails to hold, then the returns are positively or negatively serially correlated. This leads to a rejection of the random walk hypothesis and the conclusion that the market is not weak-form efficient, as investors have the opportunity of generating excess returns (Patel, Radadia and Dhawan, 2012).

Lo and MacKinlay (1988) and Charles and Darné (2009) state that if a price series follows a random walk with uncorrelated increments in p_t, the variance of its q-differences would be q times the variance of its first differences as follows:

$$Var(p_t - p_{t-q}) = qVar(p_t - p_{t-1}) \tag{4.10}$$

where q is a positive integer; p_t and p_{t-q} are the natural logarithm of prices at t and t-q respectively. Var(…) are the variances. Hence, the variance ratio, VR(q) is defined as:

$$VR_{(q)} = \frac{\frac{1}{q}Var(p_t - p_{t-p})}{Var(p_t - p_{t-1})} = \frac{\sigma^2(q)}{\sigma^2(1)} \tag{4.11}$$

where $\sigma^2(q)$ is 1/q times the variance of $(p_t - p_{t-q})$. and $\sigma^2(1)$ is the variance of $(p_t - p_{t-1})$. The equations used to calculate $\sigma^2(q)$ and $\sigma^2(1)$ are as follows:

$$\sigma^2(q) = \frac{\sum_{t=q}^{nq}(p_t - p_{t-q} - q\mu)^2}{h} \tag{4.12}$$

where

$$h = q(nq + 1 - q)(1 - \frac{q}{nq}) \tag{4.13}$$

and

$$\mu = \frac{1}{nq}\sum_{t=1}^{nq}(p_t - p_{t-1}) = \frac{1}{nq}\left(p_{nq} - p_0\right) \tag{4.14}$$

and

$$\sigma^2(1) = \frac{\sum_{t=1}^{nq}(p_t - qp_{t-1} - \mu)^2}{(nq-1)} \tag{4.15}$$

Two test statistics, Z(q) and Z*(q), are estimated by Lo and MacKinlay (1988) using an asymptotic distribution of the estimated variance ratio above. The two test statistics are estimated under the null hypothesis of homoscedastic and heteroscedastic increments of the random walk, respectively. This is described as follows:

$$Z(q) = \frac{VR(q)-1}{[\emptyset(q)]^{1/2}} \approx N(0,1) \tag{4.16}$$

$$Z^*(q) = \frac{VR(q)-1}{[\emptyset^*(q)]^{1/2}} \approx N(0.1) \tag{4.17}$$

where:

$$\emptyset(q) = \frac{2(2q-1)(q-1)}{3q(nq)} \tag{4.18}$$

$$\emptyset^*(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2_{\partial(j)} \tag{4.19}$$

where δ(j) is the term describing heteroscedasticity in the model – a consistent estimator. It is calculated using the following formula:

$$\partial(j) = \frac{\sum_{t=j+1}^{nq}(p_t - p_{t-1} - \mu)^2\left(p_{t-j} - p_{t-j-1} - \mu\right)^2}{\sum_{t=1}^{nq}\left(p_t - p_{t-1\hat{\mu}}\right)^2} \tag{4.20}$$

When the null hypothesis holds, Z(q) and Z*(q) have an asymptomatic standard distribution with mean zero and a standard deviation of 1. In addition, the nature of the variance ratio tests suggests that there exists different critical values for each individual test. Hence, the p-value is used to determine the significance of the tests—a p-value less than 0.01 would constitute a rejection of the null hypothesis at the 1% confidence interval (Chen, 2008; N'Dri, 2015). If the null hypothesis is rejected, it is conclusive that returns are serially correlated, and the market is not weak-form efficient. If the p-value is greater than 0.01, the null hypothesis is not rejected, and it confirms that the market is at least weak-form efficient.

In addition to Lo and MacKinlay (1988)'s original data tests, the bootstrap signs tests are used as a complement and consistency measure to the original data tests in order to reinforce the results of the latter. The bootstraps signs test aid in guarding against small sample bias – which suits this study, as it is divided into segments made up of a few years – hence if the change and magnitude of the results of the two tests over relevant time periods are similar, it strengthens the results and conclusion of the variance-ratio tests.

The null and alternate hypothesis tested by both the bootstrap signs tests are the same as the original data tests:

H_0: VR(q) = 1 (The BSE is weak-form efficient)

H_1: VR(q) $\neq$ 1 (The BSE is not weak-form efficient)

The results are considered to be statistically significant at the 1% if the p-value exceeds 0.01. Therefore, if the p-values of the tests exceed 0.01, the BSE ALSI returns would be considered to follow a random walk and an index containing a martingale. Thus, the conclusion in that case, would be that the null hypothesis is not rejected and that the BSE is weak-form efficient.

4.4 Summary

This chapter began by describing the data used in the study. A discussion was held on tests of market efficiency, and selected estimation models, and thereafter the research approach followed for this study was explained. The next chapter discusses the results obtained from the runs test, serial correlations test, unit root test and variance ratio tests. Since the entire period is split into segments, the results from the tests conducted for each segment are discussed separately.

CHAPTER 5 – ANALYSIS OF RESULTS

5.1 Introduction

This chapter discusses the findings of the study. Since the study uses a multitude of methods to test the market efficiency of the BSE over a period that is also segmented into defined time frames, the analysis of results follows the same procedure so that each test and the associated segments are discussed separately from the other tests and their associated segments.

To ensure coherence in the discussion of results, section 5.2 provides a discussion on the descriptive statistics, while section 5.3 presents an analysis of results based on the Runs Test. Section 5.4 presents an analysis of results based on the Unit Root Test. Section 5.5 provides an analysis of results based on the Serial Correlations Test while section 5.6 presents the analysis of results based on the Variance Ratio Test. Thereafter, section 5.7 presents overall discussion of results and the conclusion of the study. The aforementioned procedure for analysis is presented in the subsequent sections.

5.2 Descriptive Statistics

Table 5.1 presents the descriptive statistics for all five time series: the first three time series test the effect of the financial crisis on market efficiency on the BSE; the last two time series test the effect of automation on market efficiency on the BSE.

The results in Table 5.1 show that, for the pre-, during and post-financial crisis period, the BSE ALSI had the highest mean (0.7896%) for the pre-crisis period (2005-2007). This result is expected because Botswana's economy and the BSE ALSI were at their peak performance prior to the financial crisis. However, since the crisis, Botswana's economy and the BSE ALSI have not been able to return to the pre-crisis levels of economic performance. This is evidenced by the fact that the BSE ALSI had the lowest mean (-0.0225%) for the post-crisis period (2009-2011). Similarly, the BSE ALSI had the highest median (0.7896%) for the pre-crisis period (2005-2007) and the lowest median (0.0003%) for the post-crisis period (2009-2011). This result also confirms the better performance of the economy prior to the financial crisis relative to the crisis and post-crisis periods.

Still on the pre-, during and post-financial crisis, for the period between 2005 – 2007 (pre-crisis), the BSE ALSI recorded a maximum value of 7.7218% in the pre-crisis period while a minimum value of -1.6756% was achieved for the same period. For the period between 2007-2009 (financial crisis period) the maximum value was 3.8134% while the minimum was -4.3354%. For the period between 2009-2011 (post crisis), the maximum value was 3.5928% while the minimum was -5.4006%. This analysis also confirms that Botswana's financial market had not fully recovered from the 2007-2009 recession leading up to 2011.

However, for the pre-automation period (2010-2013) the BSE ALSI achieved a maximum of 2.5653% and a minimum of -5.4006%, while the post-automation period (2013-2017) had a maximum of 2.9293% and a minimum of -1.9116%. Overall, the results show that the pre-crisis period (2005-2007) had the highest maximum value while the pre-automation period (2010-2013) had the lowest maximum value. As for the minimum values, the pre-crisis period (2005-2007) had the lowest minimum followed by the post-automation period (2013-2017). However, the results show that the maximum value has been improving since the pre-automation period (2010-2013) although the maximum value is still below the pre-crisis period (2005-2007). A glance at both the minimum and maximum values, show that, overall, the BSE was on a recovery path since the pre-automation period (2010-2013).

In addition to the recovery of the BSE performance, the post-automation period (2013-2017) recorded the lowest volatility as it had the lowest standard deviation. The results in Table 4.1 show that financial crisis period (2007-2009) had the highest standard deviation of 1.5329% while the post-automation period (2013-2017) had the lowest standard deviation of 0.5700%.

The previous chapter defined that a normal distribution has a skewness of zero: a right-tailed distribution has positive skewness and a left-tailed distribution has negative skewness. The skewness of the BSE ALSI is positive for the pre-crisis (2005-2007) and pre-automation periods

(2010-2013), indicating that these distributions have a right tail. The rest of the time series have negative skewness, indicating that the distributions have a left tail. The pre-crisis period (2005-2007) has the highest skewness at 2.2073, while the pre-automation period (2010-2013) has the lowest skewness at-1.5409.

All of the concerned time series have a kurtosis greater than 3, the highest being the pre-automation period (2010-2013) with 14.4875 and the lowest being the financial crisis period (2007-2009) with 3.8558. This suggests that the density functions have a higher and sharper peak than a normal distribution and are known to be leptokurtic. It is worth noting that the financial crisis period (2007-2009) is the closest representative to a normally distributed density function, having skewness close to zero and kurtosis close to 3.

The Jarque-Bera statistic tests for normal distribution were also conducted to validate the skewness and kurtosis tests of tails and peakedness of the distribution. It is worth restating that the 5% critical value for the Jarque-Bera test is 5.99. Therefore, the null hypothesis cannot be rejected if the Jarque-Bera statistic is 5.99 and below. Table 5.1 shows that the financial crisis period (2007-2009) has a Jarque-Bera statistic less than 5.99. This means that the null hypothesis is not rejected, leading to a conclusion that the time series is normally distributed. The result is further confirmed by the fact that the time series in question has a skewness level close to zero and kurtosis of around 3.

The remaining four time series – the before- and after-crisis, and the pre- and post-automation series – have Jarque-Bera test statistics which are significantly greater than 5.99, with the highest being the pre-automation period (2010-2013), containing a test statistic of 1079.6380. This signifies that the null hypothesis of a normal distribution is rejected, and it can be concluded that the time series before- and after-crisis and the pre- and post-automation are not normally distributed. The outcome is confirmed by the results of the skewness and kurtosis tests which conclude that the distributions of the aforementioned four time series have a significant right or left tail and are leptokurtic.

For a detailed account on the descriptive statistics and the data series' distributions, refer to Figures 7.1 to 7.5 in the appendix.

TABLE 5.1: Summary of the Descriptive Statistics for the five time series.

Data Series	N	Mean	Median	Minimum	Maximum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera Statistic (probability)
BSE ALSI 2005 - 2007 (Pre-Crisis)	103	0.7896%	0.4673%	-1.6756%	7.7218%	1.2599%	2.2073	11.5265	395.6472 (<0.0001)
BSE ALSI 2007 - 2009 (Crisis)	104	0.0363%	0.0054%	-4.3354%	3.8134%	1.5329%	-0.2975	3.8558	4.7079 (0.0949)
BSE ALSI 2009 - 2011 (Post-Crisis)	105	-0.0225%	0.0003%	-5.4006%	3.5928%	1.1431%	-0.7290	7.4426	95.6488 (<0.0001)
BSE ALSI 2010 - 2013 (Pre-Automation)	183	0.0945%	0.0831%	-5.4006%	2.5653%	0.8203%	-1.5409	14.4875	1078.6380 (<0.0001)
BSE ALSI 2013 - 2017 (Post-Automation)	183	0.0369%	0.0504%	-1.9116%	2.9293%	0.5700%	0.3335	6.6751	106.3783 (<0.0001)

5.3 Runs Test

The first test of the weak-form market efficiency was conducted using the runs test. The runs tests were conducted using the SPSS 25 software. The median was selected as an ideal cut-point measure since the distributions are predominantly non-symmetrical and the data points are continuous. In addition, the runs test is appropriate for testing randomness in these data sets as the distributions are predominantly non-normal and the test is non-parametric. Five individual runs tests were conducted: the first three testing the weak-form efficiency of the BSE before, during and post the 2008 financial crisis, and the last two testing the weak-form efficiency of BSE pre and post the automation of the BSE.

The null and alternate hypotheses for the runs tests are as follows:

H_0: R = E(r) (Successive changes in the index prices are random)

H_1: $R \neq E(r)$ (Successive changes in the index prices are not random)

If the Z-value is greater than or equal to the absolute value of 2.576, the null hypothesis is rejected at the 1% significance level. Such a result would indicate that the returns are not independent of each other and the BSE is not weak-form efficient.

Table 5.2 below illustrates the evolution of weak-form efficiency of the BSE between 2005 and 2007. The Z statistic for the runs test before the crisis is -2.2430, which is lower than the critical value of -2.576. Thus, the runs test show that the BSE was weak-form efficient prior to the crisis. Nevertheless, market efficiency broke down during the financial crisis. The Z statistic for the financial crisis period (2007-2009) is -7.2920. The Z statistic is greater than the critical value, meaning that the BSE was not weak-form efficient during the crisis.

In addition, the runs test show that the BSE did not manage to regain its pre-crisis efficiency even after the crisis. The Z statistic for the post-crisis period (2009-2011) is -5.0010. This means that the prices changes on the BSE ALSI were still not random. Hence, the BSE was not weak-form efficient even after the crisis. However, a distinction between the during and the post-crisis periods is that the Z statistic for the post-crisis period is lower than that of the financial crisis period. This shows that the weak-form efficiency of the BSE improved slightly after the crisis – evidenced by a decline in the Z value from -7.292 for the crisis period to -5.0010 for post crisis period.

TABLE 5.2: Results of Runs Tests between 2005 and 2011

Data Series	Number of Runs (R)	Total Cases (m)	Z statistic	p-value
BSE ALSI 2005 - 2007 (Pre-Crisis)	38	103	-2.2430	0.0250
BSE ALSI 2007 - 2009 (Crisis)	16	104	-7.2920	0.0000
BSE ALSI 2009 - 2011 (Post-Crisis)	28	105	-5.0010	0.0000

Further tests based on the runs test were also conducted to examine if the changes made to the BSE through automation have had an impact on its efficiency. The runs test results for the pre- and post-automation periods are shown in Table 5.3 below. Table 5.3 show that the Z statistic was -3.7800 for the pre-automation period (2010-2013) and -4.6700 for the post-automation period (2013-2017). These statistics show that the BSE was not weak-form efficient over the pre- and post-automation periods. What is surprising to note is that the Z statistic for the post-automation period is even greater than the pre-automation period. This finding is contrary to the expectation because it shows that the BSE became less efficient after automation despite the numerous advantages that automation is perceived to bring to improving the efficiency of the market.

TABLE 5.3: Results of Runs Tests between 2010 and 2017

Data Series	Number of Runs (R)	Total Cases (m)	Z statistic	p-value
BSE ALSI 2010 - 2013 (Pre-Automation)	67	183	-3.7800	0.0000
BSE ALSI 2013 - 2017 (Post-Automation)	61	183	-4.6700	0.0000

Refer to Tables 7.1 to 7.5 in the appendix for more detailed results on the runs tests.

However, given that the runs test results in a type 1 error rate if it is used to investigate the independence of errors in time-series regression models and that it is not robust to slight differences between data sets which might arise due to rounding errors, other methods were also conducted to validate the findings. The next test that was conducted to validate the runs tests was the Unit Root test. The results from Unit Root test are discussed below.

5.4 Unit Root Test

The unit root test checks for the presence of a unit root in the time series, with its presence indicating that the time series is non-stationary. A non-stationary time series implies that the index follows a random walk and that the market is weak-form efficient. In contrast, the absence of a unit root is evidence of serial correlation in the data series, which would signify that the market is not weak-form efficient.

Two unit root tests were selected for this study: the main one being the Augmented Dickey-Fuller (ADF) Test and the control being the Philipps-Perron (PP) Test. In addition, the tests were conducted using the SPSS 25 software. These tests are especially suitable for testing for the presence of a unit root using the data series utilised in this study due to their predominantly non-normal nature.

As shown in the methodology section, the null and alternate hypotheses for the unit root tests are as follows:

H_0: A unit root is present in the time series. (The time series is non-stationary)

H_1: A unit root is not present in the time series. (The time series is stationary)

The null hypothesis cannot be rejected if the computed p-value is greater than the significance level alpha (herein, 1%, 5% or 10%). The results in Table 5.4 show that the ADF unit root tests for pre-, during- and post-financial crisis period are all significant at 1%. This means that the computed p-values are not greater than the significance level, thus the null hypothesis cannot be rejected for all the three series. Since the null hypothesis cannot be rejected, it can be concluded that the BSE was not weak-form efficient before, during or after the financial crisis period. However, a closer look at the 1st differences values for the ADF test shows that the 1st difference value for the pre-crisis period was the highest while that of the post-crisis period was the lowest. This finding shows that, even though the BSE was not weak-form efficient, there are signs that there was an improvement during the crisis which is also shown through after the crisis period. For example, the ADF 1st difference value changed from 4.489312 before crisis to 3.663734 during crisis and then to 3.062434 post-crisis. The improvement of market efficiency over a crisis period is surprising since crises are assumed to distort the operations of the markets.

Similarly, the PP test, which is used as a control test, also confirms that the BSE was not weak-form efficient for all the series discussed above. Therefore, consistent with the ADF, the PP test further confirms that the BSE's efficiency improved slightly during and post-crisis when compared to the pre-crisis period. This is supported by the change in the PP's 1st difference test statistic from -14.69624 to -14.20310.

TABLE 5.4: Results of Unit Root Tests between 2005 and 2009

Data Series	Augmented Dickey-Fuller (ADF) Test		Philipps-Perron (PP) Test	
	Level	1st Difference	Level	1st Difference
BSE ALSI 2005 - 2007 (Pre-Crisis)	-12.66104***	4.489312***	-17.61090***	-14.69624***
BSE ALSI 2007 - 2009 (Crisis)	-9.225601***	3.663734***	-14.31918***	-14.07386***
BSE ALSI 2009 - 2011 (Post-Crisis)	-10.79009***	3.062434***	-14.54665***	-14.20310***

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

Similar tests were also conducted for the pre- and post-automation periods. These results are shown in Table 5.5. A glance at the results show that both test statistics for the ADF unit root tests are significant at 1% level. Therefore, the null hypothesis is rejected, leading to the conclusion that the BSE was not weak-form efficient pre- and post-automation periods.

The finding is also confirmed by the PP unit root tests, as can be seen in Table 5.5. Evidence shows that the 1st difference ADF test statistic decreased from 3.783901 to 3.629652. In addition, the PP 1st difference test statistic also decreased from -18.16145 to -17.49226. Therefore, these results show that the 1st difference values for both the ADF and PP tests improved post the automation period.

Interestingly, the pre-automation period had a 1st difference value greater than the during-crisis and after-crisis periods. This shows that some of the improvements the BSE made over the period between the during the crisis and just after the crisis period were lost over the period leading to the automation of the BSE. However, some of the lost improvements were then regained post-automation as the 1st difference value of the ADF is lower than the during the crisis albeit being still slightly higher than the post-crisis period. This finding provides further confirmation that the weak-form efficiency of the BSE improved marginally after the crisis period as compared to the before and during the crisis periods.

TABLE 5.5: Results of Unit Root Tests between 2010 and 2017

Data Series	Augmented Dickey-Fuller (ADF) Test		Philipps-Perron (PP) Test	
	Level	1st Difference	Level	1st Difference
BSE ALSI 2010 - 2013 (Pre-Automation)	-14.17171***	3.783901***	-19.31328***	-18.16145***
BSE ALSI 2013 - 2017 (Post- Automation)	-10.46073***	3.629652***	-17.71279***	-17.49226***

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

For a more detailed analysis of the ADF and PP unit root tests, refer to tables 7.6 to 7.15 in the appendix.

In keeping with the validating of results of the unit root tests, further tests were conducted based on the serial correlation test using correlograms in order to determine the presence of autocorrelation within the time series. A correlogram is fitting since it tests the main theory backing the EMH, namely the random walk hypothesis, and assumes that prices follow a random pattern. The results of this test are presented in Table 5.6 in the next section.

5.5 Serial Correlations Test

The serial correlations test was used to complement the unit root tests in order to determine the level of efficiency of the BSE. The reason is that, for a time series to follow a random walk, it is not enough that it contains a unit root, it must also be serially uncorrelated. In total, the data series in the correlogram were tested with 36 lags.

The null and alternate hypotheses for the serial correlations tests are as follows:

> H_0: P_k (AC) = 0 (There is an absence of serial correlation between price changes over successive q time lags – price changes are independent)
> H_1: P_k (AC) $\neq$ 0 (There is positive or negative serial correlation between price changes over successive time lags – price changes are not independent)

The results of the correlogram shown in Table 5.6 show that the autocorrelation (AC) test of all three time series, at greater than 50% of the lags, are not equal to 0. In addition, the Q-statistic is greater than the 1% critical value of 2.576 at all points. The latter lags of the 2009 – 2011 time series show a p-value higher than 0.05, which would normally indicate that we do not reject the null hypothesis. However, the BSE is still considered not weak-form efficient because the initial lags contain p-values lower than 0.01. In addition, the AC measure for the latter lags are rarely close to 0 and the Q-statistics are nowhere near the absolute critical value of 2.576, hence, violating the null hypothesis principle of independent price changes. Therefore, the time series are not stationary and price changes are not independent.

TABLE 5.6: Results of the Serial Correlations Tests between 2005 and 2011

	BSE ALSI (2005 – 2007) Pre-Crisis				BSE LSI (2007 – 2009) Crisis				BSE ALSI (2009 – 2011) Post-Crisis			
Lag	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	-0.378	-0.378	14.989	0.000	-0.335	-0.335	11.903	0.001	-0.335	-0.335	12.004	0.001
2	-0.212	-0.414	19.770	0.000	-0.085	-0.222	12.680	0.002	-0.137	-0.281	14.039	0.001
3	0.271	0.001	27.630	0.000	-0.118	-0.270	14.195	0.003	0.017	-0.166	14.070	0.003
4	-0.196	-0.195	31.792	0.000	0.016	-0.203	14.223	0.007	0.030	-0.083	14.171	0.007
5	-0.116	-0.267	33.264	0.000	0.107	-0.041	15.496	0.008	-0.053	-0.110	14.479	0.013
6	0.215	-0.101	38.382	0.000	0.044	0.039	15.707	0.015	-0.051	-0.149	14.767	0.022
7	-0.064	-0.077	38.834	0.000	-0.123	-0.085	17.407	0.015	-0.015	-0.166	14.791	0.039
8	-0.102	-0.146	40.002	0.000	0.001	-0.049	17.407	0.026	0.078	-0.061	15.495	0.050
9	0.140	-0.085	42.230	0.000	-0.051	-0.114	17.700	0.039	-0.122	-0.205	17.235	0.045
10	-0.103	-0.180	43.466	0.000	0.156	0.052	20.524	0.025	0.067	-0.111	17.762	0.059
11	0.092	0.051	44.444	0.000	-0.084	-0.056	21.351	0.030	0.061	-0.049	18.203	0.077
12	-0.047	-0.120	44.698	0.000	-0.099	-0.163	22.514	0.032	-0.055	-0.104	18.561	0.100
13	-0.041	-0.097	44.896	0.000	0.129	0.049	24.507	0.027	0.138	0.111	20.863	0.076
14	0.068	-0.069	45.451	0.000	-0.097	-0.103	25.658	0.029	-0.072	0.024	21.496	0.090
15	-0.081	-0.147	46.259	0.000	0.111	0.011	27.161	0.027	-0.048	-0.014	21.780	0.114

16	0.072	-0.015	46.896	0.000	0.032	0.091	27.289	0.038	-0.042	-0.088	22.002	0.143
17	0.061	0.007	47.353	0.000	-0.194	-0.134	32.029	0.015	-0.001	-0.092	22.002	0.185
18	-0.102	-0.043	48.671	0.000	0.168	0.089	35.628	0.008	0.072	0.002	22.667	0.204
19	-0.011	-0.072	48.685	0.000	-0.121	-0.100	37.508	0.007	0.006	0.051	22.671	0.252
20	-0.027	-0.238	48.778	0.000	0.030	-0.105	37.626	0.010	-0.111	-0.070	24.288	0.230
21	0.043	-0.071	49.025	0.000	0.121	0.105	39.571	0.008	0.157	0.083	27.578	0.153
22	0.002	-0.154	49.026	0.001	-0.177	-0.129	43.759	0.004	-0.153	-0.118	30.716	0.102
23	0.157	0.144	52.348	0.000	0.152	0.086	46.898	0.002	0.109	0.026	32.336	0.093
24	-0.212	-0.174	58.446	0.000	-0.160	-0.121	50.402	0.001	0.054	0.086	32.738	0.110
25	0.035	-0.114	58.613	0.000	0.045	-0.080	50.680	0.002	-0.041	0.067	32.972	0.132
26	0.052	-0.153	58.995	0.000	0.032	-0.060	50.826	0.003	-0.091	-0.058	34.132	0.132
27	0.013	0.044	59.017	0.000	-0.011	-0.040	50.843	0.004	0.004	-0.051	34.134	0.162
28	0.027	0.064	59.123	0.001	0.012	-0.055	50.864	0.005	-0.072	-0.171	34.886	0.173
29	-0.056	-0.026	59.582	0.001	0.043	0.034	51.128	0.007	0.128	-0.014	37.298	0.139
30	-0.003	-0.054	59.584	0.001	-0.069	0.026	51.826	0.008	-0.092	-0.092	38.570	0.136
31	0.010	0.075	59.597	0.002	0.104	-0.000	53.436	0.007	0.112	0.001	40.461	0.119
32	0.006	0.009	59.602	0.002	-0.198	-0.115	59.408	0.002	0.004	-0.001	40.464	0.145
33	-0.141	-0.199	62.649	0.001	0.199	0.083	65.512	0.001	-0.055	-0.012	40.936	0.161
34	0.213	-0.020	69.751	0.000	-0.076	-0.079	66.423	0.001	-0.042	-0.151	41.218	0.184
35	-0.042	0.111	70.024	0.000	-0.064	-0.055	67.079	0.001	0.076	-0.020	42.148	0.189
36	-0.133	-0.001	72.870	0.000	0.133	0.018	69.940	0.001	0.084	0.084	43.297	0.188

The results for the pre- and post-automation periods show a similar finding. The correlogram shown in Table 5.7 indicate that the autocorrelation (AC) test of the two time series, at greater than 50% of the lags, is not equal to 0. In addition, the Q-statistic is greater than the 1% absolute critical value of 2.576 at all points. Resultantly, it can be postulated that the time series pre- and post-automation are not stationary and price changes are not independent. Refer to Table 5.6 and table 5.7 for evidence of serial correlation in the series for before, during, and after financial crisis and those for pre- and post-automation respectively.

For more detailed results of the autocorrelation tests, refer to tables 7.16 to 7.20 in the appendix.

TABLE 5.7: Results of the Serial Correlations Tests between 2010 and 2017

BSE ALSI (2010 – 2013) Pre-Automation						BSE ALSI (2013 – 2017) Post-Automation			
Lag	AC	PAC	Q-Stat	Prob		AC	PAC	Q-Stat	Prob
1	-0.299	-0.299	16.498	0.000		-0.264	-0.264	12.873	0.000
2	-0.156	-0.270	21.054	0.000		-0.176	-0.264	18.646	0.000
3	0.053	-0.103	21.571	0.000		-0.033	-0.186	18.844	0.000
4	-0.095	-0.183	23.261	0.000		-0.035	-0.184	19.068	0.001
5	-0.015	-0.147	23.302	0.000		0.115	-0.007	21.584	0.001
6	-0.002	-0.147	23.304	0.001		-0.068	-0.094	22.451	0.001
7	0.030	-0.083	23.476	0.001		-0.105	-0.170	24.553	0.001
8	0.007	-0.072	23.486	0.003		0.021	-0.132	24.638	0.002
9	0.004	-0.050	23.490	0.005		0.125	0.018	27.642	0.001
10	-0.101	-0.178	25.469	0.005		-0.106	-0.143	29.819	0.001
11	0.063	-0.082	26.252	0.006		0.061	-0.002	30.550	0.001
12	0.059	-0.021	26.940	0.008		-0.009	-0.020	30.567	0.002
13	-0.004	0.008	26.943	0.013		-0.029	-0.049	30.738	0.004
14	-0.047	-0.066	27.378	0.017		-0.075	-0.186	31.855	0.004
15	-0.073	-0.157	28.460	0.019		0.132	0.058	35.374	0.002
16	0.043	-0.101	28.840	0.025		-0.051	-0.070	35.901	0.003
17	-0.042	-0.158	29.203	0.033		0.034	0.011	36.131	0.004
18	0.177	0.086	35.564	0.008		-0.137	-0.193	39.968	0.002
19	-0.086	-0.066	37.079	0.008		0.056	-0.017	40.615	0.003
20	-0.071	-0.130	38.114	0.009		0.119	-0.023	43.558	0.002
21	0.107	-0.014	40.517	0.006		-0.089	-0.073	45.200	0.002
22	-0.070	-0.048	41.557	0.007		0.047	0.016	45.667	0.002
23	0.027	0.007	41.714	0.010		-0.029	0.026	45.848	0.003
24	0.010	-0.034	41.736	0.014		0.016	-0.043	45.899	0.005
25	-0.022	-0.068	41.840	0.019		-0.030	-0.050	46.090	0.006
26	-0.080	-0.163	43.216	0.018		-0.052	-0.116	46.666	0.008
27	0.120	0.025	46.325	0.012		0.022	-0.038	46.771	0.010
28	-0.141	-0.168	50.660	0.005		0.108	0.014	49.301	0.008
29	0.136	-0.005	54.685	0.003		-0.124	-0.100	52.673	0.005
30	0.017	-0.093	54.749	0.004		0.058	0.004	53.422	0.005
31	-0.014	0.018	54.792	0.005		0.006	-0.040	53.431	0.007
32	0.030	0.038	54.992	0.007		0.073	0.058	54.607	0.008
33	-0.085	-0.003	56.634	0.006		-0.050	-0.001	55.176	0.009
34	0.044	0.013	57.071	0.008		-0.156	-0.152	60.712	0.003
35	0.002	0.029	57.072	0.011		0.069	-0.079	61.807	0.003
36	-0.082	-0.101	58.619	0.010		0.096	0.010	63.942	0.003

The finding that prices changes are not independent requires the use of an approach that considers the trading mechanisms and the specific and common components of information. In the case of the weekly prices, this study proposes that the statistical properties of price changes rely on the interaction between the spread effects and the effects due to the gradual incorporation of common information.

Therefore, unlike prior studies on the BSE, this study's contribution is that it provides an innovative test procedure that minimises potential biases that arise from unwanted factors. Therefore, the variance ratio test is considered as the main and appropriate test to assess the weak-form efficiency of the BSE given the observed serial correlation in the series. In addition, the variance ratio test is considered is sensitive to serial correlation, is robust to time-varying volatilities and deviations to normality. Moreover, the variance ratio test is considered to be volatility-based compared to the runs tests and the unit root test. This feature makes the variance ratio test important in that most securities' returns often display volatility and deviations from normality (Belaire-Franch et al., 2007).

Thus, the variance ratio test, which is robust to heteroscedasticity and non-normality becomes important for this study compared to the runs test and the unit root test methods. The use of the variance ratio test is motivated by the finding in Poterba and Summers (1988)'s study which examined the power of the different random walk tests. It found that the variance ratios are amongst the most powerful tests, and that they are even more powerful than the Fama and French (1988)'s regression procedure.

Prior studies by Poterba and Summers (1988), Fama and French (1988), Lo and MacKinlay (1988), Cochrane (1988) and Mobarek and Fiorante (2014) also argue that the unit root test has a very low power against stationary alternatives and that it is difficult to reject the null hypothesis of random walk. Therefore, the variance ratio tests are considered to be reliable in testing the random walk hypothesis and existence of a martingale in the BSE ALSI returns. Based on the above argument, below is an analysis of results based on the variance ratio test.

5.6 Variance Ratio Test

The weak-form market efficiency of the BSE is investigated by testing the random walk or martingale difference hypothesis using Lo and MacKinlay's (1988) variance ratio tests. This study compares the variance ratios between different periods in order to determine the effects of the 2008 financial crisis and stock market automation on BSE's efficiency. Two styles of variance ratio tests were employed in this study:

1. Original Data Test – testing for a random walk in the BSE ALSI returns
2. Bootstrap Signs Test – testing for the presence of a martingale in the BSE ALSI returns

The bootstrap signs tests are used as a complement and consistency measure to the original data tests in order to reinforce the results of the latter. The bootstraps signs test aid in guarding against small sample bias – which suits this study, as it is divided into segments made up of a few years – hence if the change and magnitude of the results of the two tests over relevant time periods are similar, it strengthens the results and conclusion of the variance-ratio tests.

The null and alternate hypothesis tested by both the original data and bootstrap signs tests are:

H_0: VR(q) = 1 (The BSE is weak-form efficient)

H_1: VR(q) $\neq$ 1 (The BSE is not weak-form efficient)

The results are considered to be statistically significant at the 1% if the p-value exceeds 0.01. Therefore, if the p-values of the tests exceed 0.01, the BSE ALSI returns would be considered to follow a random walk and an index containing a martingale. Thus, the conclusion in that case, would be that the null hypothesis is not rejected and that the BSE is weak-form efficient.

Table 5.8 below presents the variance ratio test statistics and p-values for the individual tests with the aim of formulating a conclusion of the effects of the 2008 financial crisis on BSE's weak-form efficiency. For the pre-crisis period, the original data test shows a p-value of

0.0032. This shows that the null hypothesis should be rejected, leading to the conclusion that the BSE was not weak-form efficient prior to the 2008 financial crisis. However, step increments of 5 in both variance ratio tests indicate that small sample bias may be present in the BSE ALSI returns. As a consequence of that finding, the bootstrap signs test statistic becomes more reliable in this case. The bootstrap signs test clearly indicates that the BSE ALSI was weak-form market efficient prior to the crisis, as the p-value of 0.0190 exceeds the 0.01 threshold. Moreover, the BSE remained weak-form efficient even during the crisis, as indicated by the bootstrap test's p-value of 0.0191.

The tests also indicate that the BSE became more efficient post-crisis. The results in Table 5.8 show that the efficiency on the BSE strengthened after the crisis as the p-values of both the original data and bootstrap signs tests exceed 0.01, at 0.0174 and 0.0400 respectively. The p-values are significantly higher after the crisis compared to before the crisis. In addition, despite the differences in the p-values of both tests, the changes in direction and strength are similar across the test period between the two tests. Hence, it can be concluded that the aftermath of the 2008 financial crisis had a significant positive effect on BSE's weak-form market efficiency.

TABLE 5.8: Results of the Variance Ratio Test between 2005 and 2011

Data Series	Test	Maximum VR(q)*	Maximum Z(q)*	Probability at Maximum Z(q)*
BSE ALSI 2005 - 2007 (Pre-Crisis)	Original Data	0.626003	3.777183***	0.0032
	Signs (Bootstrap)	0.764706	2.376354**	0.0190
BSE ALSI 2007 - 2009 (Crisis)	Original Data	0.672246	3.326339***	0.0083
	Signs (Bootstrap)	0.679612	3.251587***	0.0191
BSE ALSI 2009 - 2011 (Post-Crisis)	Original Data	0.672420	3.340674***	0.0174
	Signs (Bootstrap)	0.788462	2.157277**	0.0400

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

Graphically, Figures 5.1, 5.2 and 5.3 below show the evolution of weak-form market efficiency transitioning between the pre-, during- and post-crisis periods, with the x-axis representing the number of weeks. For instance, Figure 5.1 shows that market efficiency decreased and remained relatively stable over the pre-crisis period. This is likely due to the financial crisis beginning to unfold before turning into a full-blown crisis.

Figure 5.2 illustrates that market efficiency in the BSE dropped significantly during the crisis. This can be attributed to the decrease in liquidity and trading volume on the BSE. It can also be attributed to the substantial downturn experienced by the Botswana economy during the crisis. However, market efficiency began to recover towards the end of the financial crisis once stricter financial regulations were put into place.

Finally, Figure 5.3 depicts a significant increase in market efficiency after the crisis. Stricter regulations, and increased liquidity and trading volume due to the implementation of the CSD contributed to this increase. The conclusion that can be drawn from these figures is that the aftermath of the financial crisis led to a significant increase in BSE's weak-form market efficiency.

FIGURE 5.1: Graphical Illustration of the Efficiency of the BSE ALSI Weekly Index between 2005 and 2007

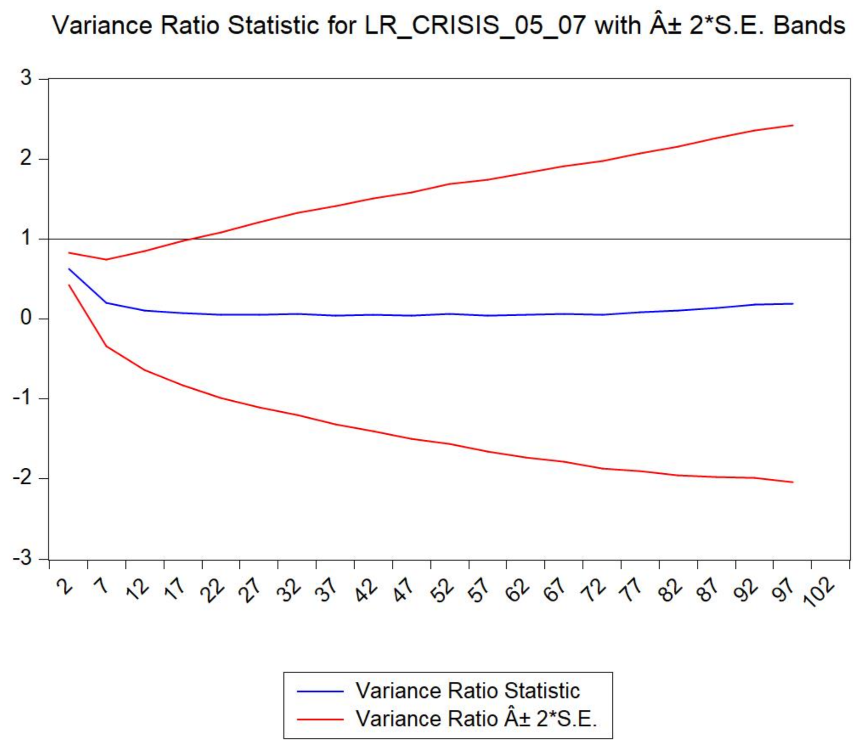


FIGURE 5.2: Graphical Illustration of the Efficiency of the BSE ALSI Weekly Index between 2007 and 2009

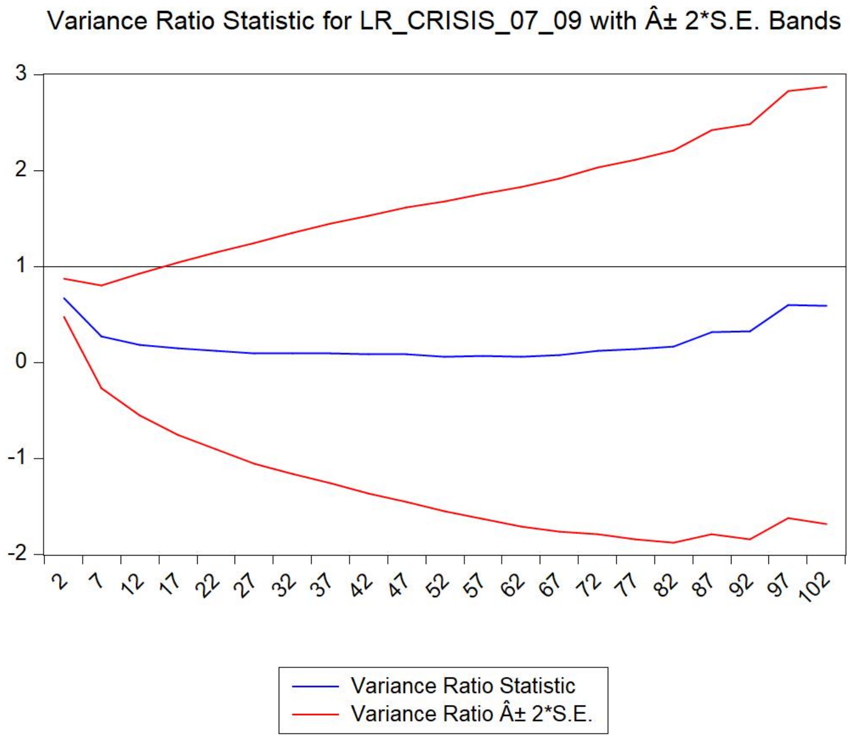
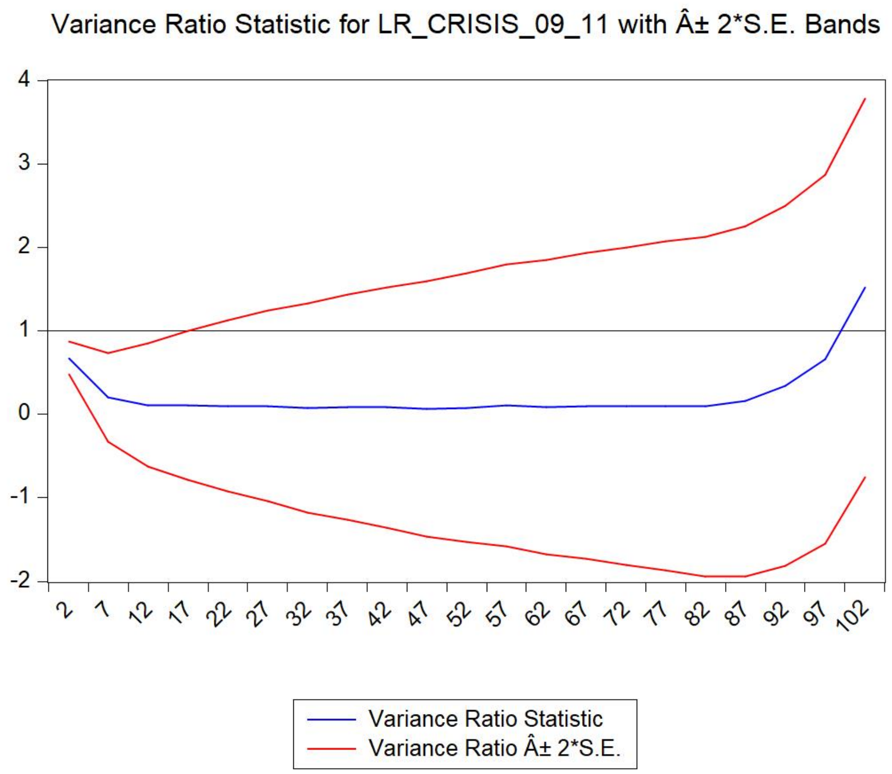


FIGURE 5.3: Graphical Illustration of the Efficiency of the BSE ALSI Weekly Index between 2009 and 2011



Next is an analysis of results based on the pre- and post- the automation of the BSE. Table 5.9 presents the results grounded on the variance ratio tests on weak-form efficiency pre- and post-automation of the BSE. Results in Table 5.9 show the variance ratios, test statistics and p-values for the individual tests with the aim of generating a conclusion of the effects of stock-market automation on BSE's weak-form efficiency. Both the original data and bootstrap signs variance ratio tests for the time period 2010 to 2013 produced p-values of 0.0195 and 0.0110, respectively. Thus, both tests produced p-values above 0.01 and, as a result, the null hypothesis is not rejected, and it can be concluded that the BSE was already weak-form efficient prior to its automation.

However, it is also vital to note that the original data and bootstrap signs variance ratio tests increased substantially in the post-automation period of 2013 to 2017, jumping from 0.0195 to 0.0228 and from 0.0110 to 0.0300, respectively. As a result, the null hypothesis is not rejected, and it can be concluded that the BSE remained weak-form efficient post-automation. As expected, an analysis of the variance ratios, critical values and p-values indicate that efficiency improved substantially after the introduction of the ATS to the BSE. Based on these findings, it can be concluded that the automation of the BSE had a significant positive effect on the BSE's weak-form efficiency. It is also important to note that both tests changed equally in direction and magnitude when comparing the pre- and post-automation period.

For more detailed results of the original data and bootstrap signs variance ratio tests, refer to tables 7.21 to 7.30 in the appendix.

TABLE 5.9: Results of the Variance Ratio Test between 2010 and 2017

Data Series	Test	Maximum VR(q)*	Maximum Z(q)*	Probability at Maximum Z(q)*
BSE ALSI 2010 - 2013 (Pre-Automation)	Original Data	0.182776	3.265309**	0.0195
	Signs (Bootstrap)	0.747253	3.409747**	0.0110
BSE ALSI 2013 - 2017 (Post-Automation)	Original Data	0.193883	3.220929**	0.0228
	Signs (Bootstrap)	0.813187	2.520248**	0.0300

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

Graphically, Figures 5.4 and 5.5 below illustrate the developments in the weak-form market efficiency of the BSE before and after automation, with the x-axis representing the number of weeks. Figure 5.4 indicates that BSE's efficiency was relatively stable throughout the pre-automation period. However, market efficiency registered a spike at the end of this period. This spike coincides with the implementation and initial rollout of the ATS. Thus, it is apparent that the introduction of the ATS had a positive impact on BSE's weak-form efficiency.

Figure 5.5 exhibited a consistent increase in BSE's market efficiency throughout the period between 2013–2017. The observed increase in market efficiency could, amongst other factors, be attributed to the steady improvements of the ATS over the years, which in turn could have led to a further increase in market efficiency. This is evidenced by the spike at the far-right side of the graphical presentation in Figure 5.4. The evolution of market efficiency illustrated by Figures 5.4 and 5.5 yields a clear conclusion that the automation of the BSE had a significant, continuous positive effect on BSE's weak-form efficiency.

FIGURE 5.4: Graphical Illustration of the Efficiency of the BSE ALSI Weekly Index between 2010 and 2013

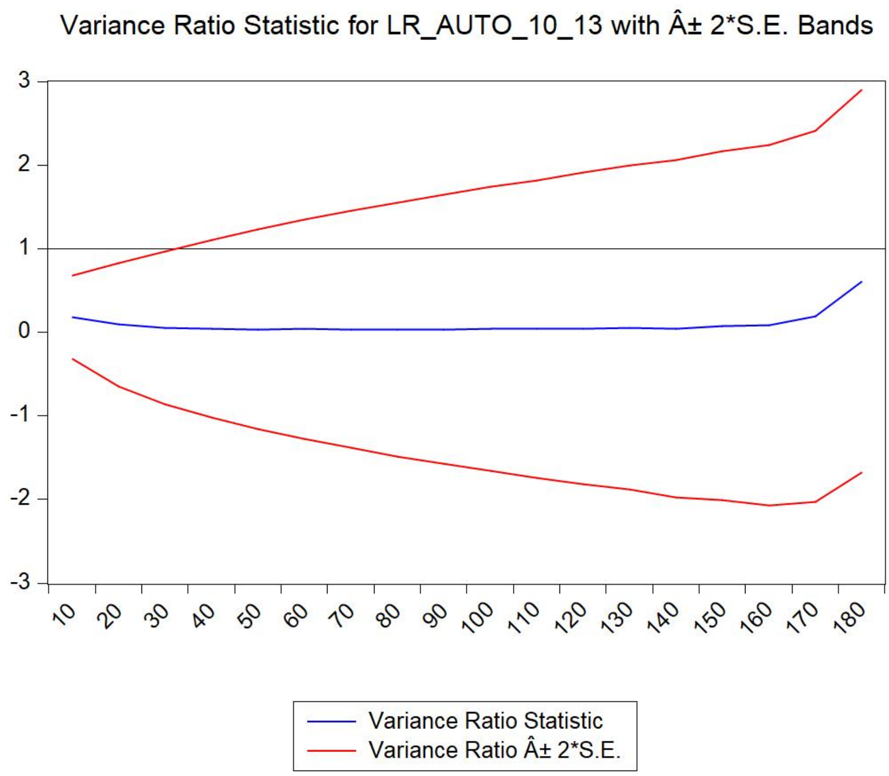


FIGURE 5.5: Graphical Illustration of the Efficiency of the BSE ALSI Weekly Index between 2013 and 2017

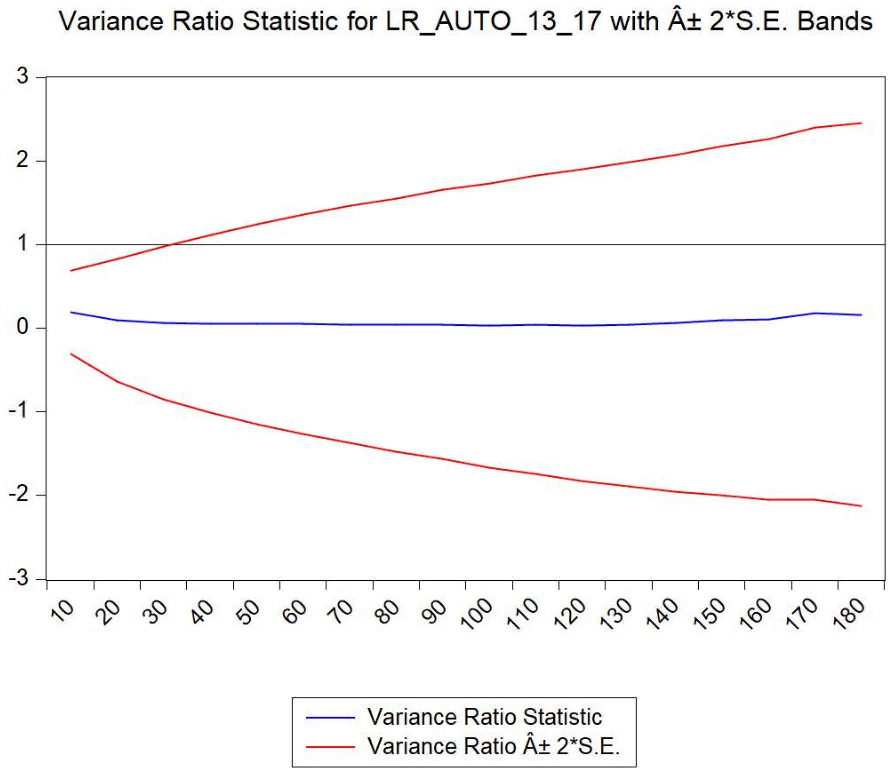


TABLE 5.10: Consolidation of results across the different market efficiency tests

Market Efficiency Test	The Effect of the Following Event on BSE's Market Efficiency	
	2008 Financial Crisis	**Stock Market Automation**
Runs tests	Negative	Negative
Unit Root test	Positive	Positive
Serial Correlations test	Positive	Positive
Variance Ratio tests	Positive	Positive

5.7 Discussion of Results Based on the Variance Ratio Tests

Owing to the above view, the remaining sections of this chapter focus on a summary of the findings discussed using the tests conducted based on the variance ratio test.

5.7.1 A Discussion of the Impact of 2008 Financial Crisis on BSE's Efficiency

Using the bootstrap signs, this study found that the BSE was weak-form efficient prior to and during the crisis. In addition the bootstraps sign tests indicated that the BSE became more efficient post-crisis when compared to the pre-crisis period.

The findings of an improvement in BSE's efficiency post-crisis are consistent with the findings of Sengonul and Degirmen (2011) and Rizvi and Arshad (2016). However, the findings are contrary to those of Anagnostidis et al., (2016), Ali and Afzal (2012) and Lim et al., (2008) who found that the crisis had a negative impact on market efficiency. These results are also contrary to the Sharma and Seth (2011) study which found no difference in market efficiency before and after the crisis. Prior studies on the weak-form efficiency of BSE did not segment the entire period into pre-, during and post-crisis periods. Hence, a comparison could not be made in that regard.

However, the improvement on the BSE's efficiency post-crisis is likely to have been caused by the immediate and effective regulatory response by the government of Botswana and financial regulators to the 2008 financial crisis. The response was aimed at improving and strengthening Botswana's entire financial sector so as to prevent future exogenous shocks from negatively impacting the economy. The increased regulation was also aimed at promoting the active improvement of the BSE's attractiveness to domestic and foreign investors, its operations and efficiency. The CSD was implemented in 2008 and share dematerialisation for domestic and foreign stocks was advancing at a satisfactory pace (BSE, 2009). The major advantage of the CSD was that the trade settlement time shortened from T+5 to T+3. This enabled the BSE to conform to international standards which, in turn, aided in reducing settlement risk. As a result, BSE's efficiency registered an improvement.

In addition, the Bank of Botswana enhanced the risk-based regulatory and supervisory system that prevented banks from engaging in excessively risky activities which exposed them to exogenous global shocks. The enhancements of these systems were supported by the implementation of the Basel I Banking rules in 2009 (Jefferis, 2010). Another measure that was taken was the privatisation of financial and banking state-owned institutions, such as the Botswana Savings Bank and National Development Bank (Jefferis, 2010).

Furthermore, the introduction of exchange traded funds (ETF) to the BSE in 2009 led to a noteworthy increase in market liquidity, enhancing the depth and breadth of the market (BSE, 2009). In addition, ETF listing fees on the BSE were competitive compared to the JSE, hence reducing costs of trading and improving market efficiency. The BSE also reduced its minimum trading requirement securities from 100 units to 1 unit and introduced ETF Investor Schemes which allowed retail investors to also participate in ETF investments. These policies led to a considerable increase in trading volume and improved market efficiency (BSE, 2009).

In 2010, the BSE sponsored 6 financial market courses by partnering with Geometric Progression CC of South Africa. The objective was to increase the level of knowledge and understanding of BSE financial market participants. The course covered the following topics: equities, debt, derivatives and ETFs (Botswana Stock Exchange [BSE], 2010). These courses enabled greater information proliferation to the BSE, thereby improving its efficiency.

The bond market also materialised in the second quarter of 2010 and there were already 36 bonds listed on the BSE, most of which were government bonds. The addition of new financial instruments on the BSE attracted risk-averse investors who wanted to invest on the BSE. Thus, the increase in dynamism of the BSE led to an increase in market participants, trading volumes and, ultimately, an improvement in market efficiency.

5.7.2 A Discussion of the Impact of Automation on BSE's Efficiency

The findings from the variance ratio tests show that the introduction of automation on the BSE in mid-2012, and its effective functioning in mid-2013, led to an improvement of BSE's efficiency. This falls in line with the aforesaid conclusion that the BSE became weak-form efficient following the 2008 financial crisis, with its efficiency being higher than before the crisis. The introduction of the ATS further supported the continuous increase of BSE's efficiency. The finding that the BSE's efficiency improved further as a result of automation are consistent with those of Dicle and Levendis (2013), Stephen et al., (2013), Mwangi (2015), Naidu and Rozeff (1994) and Jiang et al., (2002), but contrary to studies by Sioud and Hmaied (2003) and Mensah et al., (2014) whose studies found an insignificant impact.

However, numerous reasons could be proffered regarding automation's role in the improvement of the weak-form efficiency of the BSE. For example, it could be argued that the improvement could have been a result of the ATS's guarantee of an average order latency of 5 milliseconds, which is magnitudes lower than the open-floor trading system. Additionally, this could have been because of the ATS's automated order submission interface and its guarantee of a peak order rate of 150 orders per second—amounting to 200,000 orders and 20,000 trades per day. Moreover, the orders and trades can be executed on a number of financial instruments—equities, bonds and ETFs (Botswana Stock Exchange [BSE], 2013). Finally, the ATS enabled the dissemination of real-time market data to brokers and investors, and more effective and efficient communication between brokers and investors. This led to more effective information dissemination, an increase in informed trading decisions, faster trades and instant settlements.

Thus, the above factors aided in enhancing the BSE's efficiency. For example, ATS facilitated the access to different order types available in the BSE, therefore adding a layer of convenience to brokers and investors. This was done through the introduction of limit orders, market orders and stop losses (BSE, 2013). Facilitation of trade enabled market participants to broaden the scope of possible entry strategies into the BSE, thus attracting more domestic and foreign investors. As a result, trading volume and liquidity increased, leading to an improvement in BSE's efficiency. Liquidity and stock market turnover increased by 5.9% to 10.6% one year after the implementation of the ATS, respectively.

Market efficiency further improved in 2013 due to an extension of regular trading sessions of the BSE, from 1 hour 45 minutes to 2 hours 45 minutes. In addition, the BSE improved their website, introduced internet-based trading and rolled out information dissemination through data vendors. The policies led to increased market participants as the number of account openings in the CSD was 20,027 in 2013 compared to 17,368 in 2012, translating to a 13.55% increase (BSE, 2013). Hence, the increase in the number of traders and brokers in the BSE subsequently led to increased market turnover and liquidity.

In 2015, the BSE put into effect the complete dematerialisation of listed securities. The advantages of such a policy lie in the reduction of risk of physical stock certificate fraud, ensuring that information is readily available to market participants. This enables investors to trade anytime and from anywhere by communicating with their brokers, as full dematerialisation would nullify the need to deposit certificates at the CSD. Dematerialisation further reduces inefficiencies as it does away with the dual-trading system in which two separate share registers have to be maintained: one for the dematerialised securities and one for the physical stock certificates (Botswana Stock Exchange [BSE], 2015).

In 2016, the BSE significantly progressed with the centralisation, clearing and settlement of bonds listed in the BSE. This plan was set forth in order to improve market efficiencies, reduce costs and improve the attractiveness of the domestic bond market to foreign investors. In addition, the BSE progressed with the development of new products created to promote liquidity and depth of the BSE. The BSE partnered with an international bank, namely Saxo Bank, in order to provide local investors access to international investment products (Botswana Stock Exchange [BSE], 2016). This, in turn, attracted investors, improved trading volume, increased liquidity and generated improved price discovery. The result was a compounding improvement of the efficiency of the BSE.

The introduction of the ATS and its continuous enhancements led to an improvement of the efficiency of the BSE. The following results were achieved in the BSE between 2012 and 2016, which provides a background for the observed increased efficiency as a direct, and potentially indirect, result of the ATS:

- Yearly Account Openings increased from 17,638 to 78,837.
- Equity Market Capitalisation increased from P412,349m to P421,313m.
- Average Daily Turnover increased from P894.7m to P2,541.2m.
- Turnover/Market Cap increased from an index of 0.79 to 1.47.
- Number of Shares Traded increased from 409.9m to 778.2m.
- Units of ETFs Traded increased from 0.223m to 1.020m.

CHAPTER 6 – CONCLUSION

6.1 Introduction

This chapter will begin by providing a summary of the findings of this study. In addition, this study's relevant contributions to literature concerning the BSE, 2008 financial crisis and ATS will be stated. Finally, the limitations of the study and recommendations for future researchers will be discussed.

6.2 Summary of Results

In summary, the runs tests indicate that the BSE was weak-form efficient prior to the crisis but that it lost its weak-form efficiency during the crisis and recovered some of it post-crisis. On net, the runs tests indicate that the BSE's efficiency was negatively affected by the 2008 financial crisis. In addition, the runs tests also show that the introduction of the ATS had a negative effect on the efficiency of the BSE, as it decreased post-automation.

As for the unit root tests, both the ADF and PP tests demonstrate that BSE was not efficient before or after the financial crisis. However, it clearly shows that BSE became more efficient post-crisis. Hence, the unit root tests conclude that the 2008 financial crisis had a positive effect on BSE's efficiency. Moreover, both the ADF and PP tests indicate that the BSE became more efficient after the introduction of the ATS. Hence, the unit root tests suggest that BSE's efficiency improved as a result of its automation.

The serial correlations tests suggest that market efficiency significantly improved after the crisis. The findings based on this test correlate to the unit root tests. The serial correlations tests indicate that BSE's efficiency improved as a result of the 2008 financial crisis. Additionally, the serial correlations tests indicate that BSE's efficiency improved considerably after the ATS was introduced. Likewise, the serial correlations tests and the unit root tests follow the same pattern. Resultantly, the serial correlations tests show that BSE's efficiency improved as a direct result of its automation.

The variance ratio tests, using the bootstrap signs test, suggest that market efficiency improved significantly after the crisis. In addition, the variance ratio tests demonstrated that the BSE became more efficient after the introduction of the ATS. These results correspond to the results obtained by the unit root and serial correlations tests. Hence, the overall results provide overwhelming evidence that the introduction of the numerous regulations aimed at mitigating the effect of the 2008 financial crisis, and the automation of the BSE, had a significant positive effect on BSE's efficiency.

The only contradicting result comes from the runs test, which states that both the 2008 financial crisis and stock market automation significantly decreased the BSE's efficiency. The unit roots tests, serial correlations tests and variance ratio tests all agree that the 2008 financial crisis and automation significantly improved BSE's efficiency.

However, since past literature argue that the variance ratio tests is the best model for testing the EMH at its weak-form, this study uses the variance ratio tests' results as a basis for the discussion on the magnitude of the effect of the 2008 financial crisis and stock market automation on the BSE's market efficiency.

It is important to note that, owing to serial correlation in the data and the shortcoming of the runs test, and unit root test under such situations, this study presented the results based on the runs test and unit root tests as sanity checks for the variance ratio tests. As explained in other sections of the study, the runs test, for example, is not robust to slight differences between data sets due to the high incidence of rounding errors associated with this type of test. Below is a table that summarises the finds from all the tests conducted.

6.3 Summary of Contributions to Literature

The sole publicly available study testing market efficiency on the BSE was conducted by Chiwira and Muyambiri (2012). Even so, the data employed in their studies only spanned for a period of four years, from 2004 to 2008. Hence, this study offers an updated status of BSE's efficiency by using data stretching through 2017.

Moreover, this study is the longest conducted on the BSE, as the sample period was from January 2005 to January 2017, a total of twelve years. Even when splitting the study into its individual components, the two distinct experiments remain the longest studies ever conducted on the BSE: between 2005 and 2011 for testing the effects of the 2008 financial crisis on BSE's efficiency, a total of 6 years; and between 2010 and 2017 for testing the effects of stock market automation on BSE's efficiency, a total of 7 years.

In addition, Chiwira and Muyambiri's (2012) study used the runs test, unit root test and serial correlations test for analysing market efficiency on the BSE. This study uses all tests employed by Chiwira and Muyambiri's (2012) study, but also adds the variance ratio tests, which is considered to be more accurate than the first three tests. Hence, this study employed more tests than any previous studies have done, therefore improving the certainty of results.

This study is one of a kind as it is the only study testing for the effects of the 2008 financial crisis on market efficiency on the BSE. In addition, it is the only study testing for the effects of the introduction of the ATS on market efficiency on the BSE. Finally, this study provides a unique approach by combining the 2008 financial crisis and automation, not as mutually exclusive events, but with automation being a response to the crisis.

This study adds theoretical value to existing literature regarding the BSE, the 2008 financial crisis and stock market automation. This study has established that BSE's efficiency has significantly increased over time. In addition, this study answers research questions not answered in prior literature: the 2008 financial crisis and stock market automation had a significant positive effect on market efficiency on the BSE.

6.4 Recommendations for Future Studies

Most of the studies on weak-form market efficiency focus on the entire market over the entire period under consideration without any segmentation, although the economy grows in cycles. The fact that the economy is affected by business cycles means that each cycle might affect the efficiency of the market differently. Furthermore, business cycles might affect different industries and sectors differently. Owing to this argument, future studies should consider testing the impact of the 2008 financial crisis and stock market automation on indexes created based on individual industries or sectors of the BSE. By focusing on individual industries or sectors, future studies would be able determine which of the industries or sectors were affected by the crisis the most and which benefitted the most from automation. Botswana's financial regulators can then use this information to implement policies to cushion future financial crises. In addition, they can use the information to aid sectors which have not significantly benefitted from automation to absorb more of its positive impacts.

Since further improvements, such as the development of an integrated data analysis and reporting system and centralisation of trading, clearing and settlement of bonds at the BSE are being made to the BSE ATS, such policies are likely to theoretically lead to increased efficiency of a stock market. Consequently, future research should look at replicating tests conducted in this study, using a much longer sample period—possibly also using daily and monthly data in addition to weekly data, in order to determine whether the ATS policies will have a significant positive effect on the efficiency of the BSE. Furthermore, future studies will be in a much better position to use a longer sample period to obtain more accurate results and also to allow for learning effects as the market and its participants adjust to the new policy and regulation changes.

Automated trading systems theoretically cushion the effects of GDP volatility on stock market returns. Given the recent history of considerable fluctuations of Botswana's GDP, future researchers should consider testing the effect of the ATS as a cushion to GDP fluctuations on the BSE. This can be done by testing the correlation between GDP fluctuations and the BSE ALSI fluctuations to the introduction of the ATS, and the same test for the period after the introduction of the ATS.

In addition, a review of literature on weak-form efficiency on the stock exchanges in sub-Saharan Africa, with the exception of South Africa and Nigeria, show that these exchanges have been poorly researched. Furthermore, the existing studies are also outdated, and usually do not correspond to evolving market conditions and new policy regulations. Therefore, market efficiency of poorly researched sub-Saharan African countries should be tested with more recent data to determine the progression of market efficiency over time. In addition, more accurate tests, such as the Lo and MacKinlay (1988) variance ratio test, should be employed to give more robust conclusions regarding market efficiency. These results can enable future researchers to postulate steps and policies required to be undertaken in order to improve the informational efficiency of the markets in question.

6.5 Conclusion

The principal aim of this study was to investigate and determine the impact of the 2008 financial crisis and stock market automation on market efficiency on the BSE. This study used the runs test, unit root test, serial correlations test and variance ratio test using the BSE ALSI weekly data for the period 2005 - 2017. The results of the tests overwhelmingly agree that the BSE became more informationally efficient subsequent to the crisis and following the introduction of the ATS.

In addition, prior literature asserts that the variance ratio test is the most powerful tool that can be used for testing for the EMH. Therefore, using the variance ratio tests as the basis for conclusion, this study concludes that the BSE became more informationally efficient over time, and evolved from not being efficient into being weak-form efficient.

The increase in efficiency could be attributed to the effective policy responses by the government of Botswana and financial regulators to the 2008 financial crisis. One of the policies called for automation of the BSE. The introduction of the ATS to the BSE had a significant positive impact on BSE's efficiency due to an increase in market participants, improved information dissemination, improved price discovery, improved trading volume and liquidity due to faster trading and improved communication. Furthermore, the continuous policies aimed at improving the ATS, such as increasing trading time from 1 hour and 45 minutes to 2 hours and 45 minutes, together caused the BSE to become all the more efficient over time.

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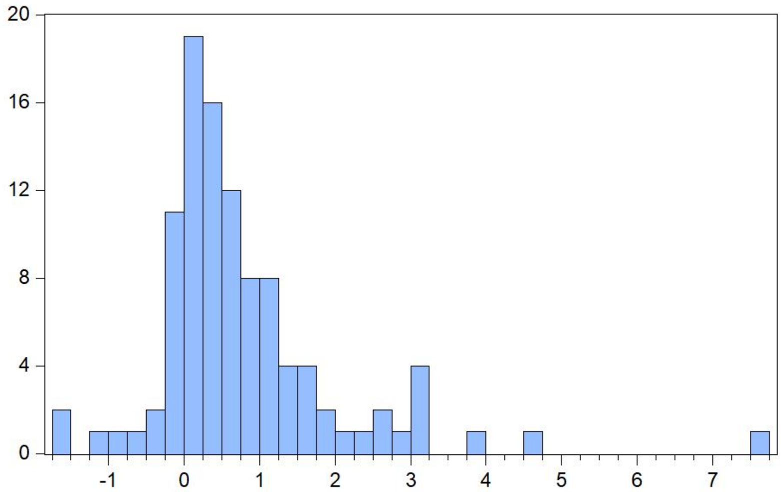
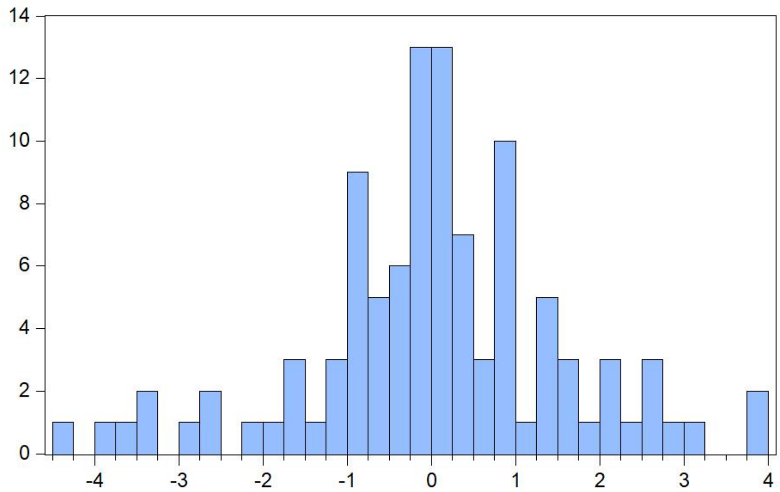
APPENDIX

Figure 7.1: Descriptive Statistics of the BSE ALSI Weekly Share Index Returns (2005-2007)



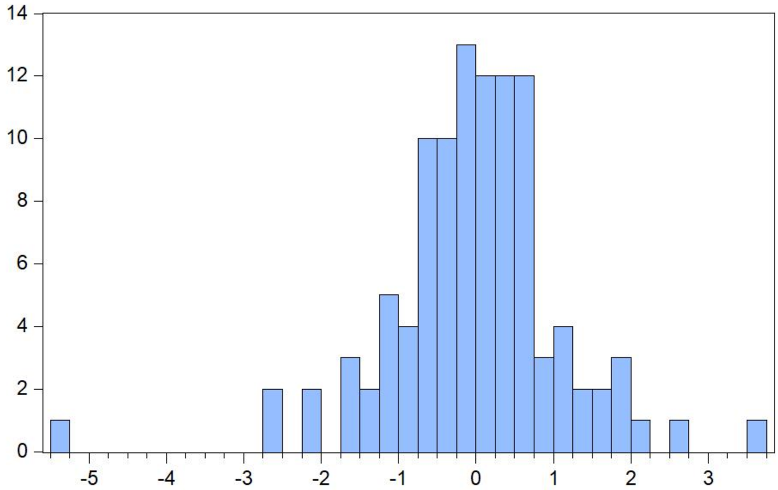
Series: BSE ALSI (2005 - 2007)	
Sample: 07/01/2005 - 29/12/2006	
Observations: 103	
Mean	0.789550
Median	0.467334
Maximum	7.721844
Minimum	-1.675592
Std. Dev.	1.259950
Skewness	2.207277
Kurtosis	11.52651
Jarque-Bera	395.6472
Probability	0.000000

Figure 7.2: Descriptive Statistics of the BSE ALSI Weekly Share Index Returns (2007-2009)



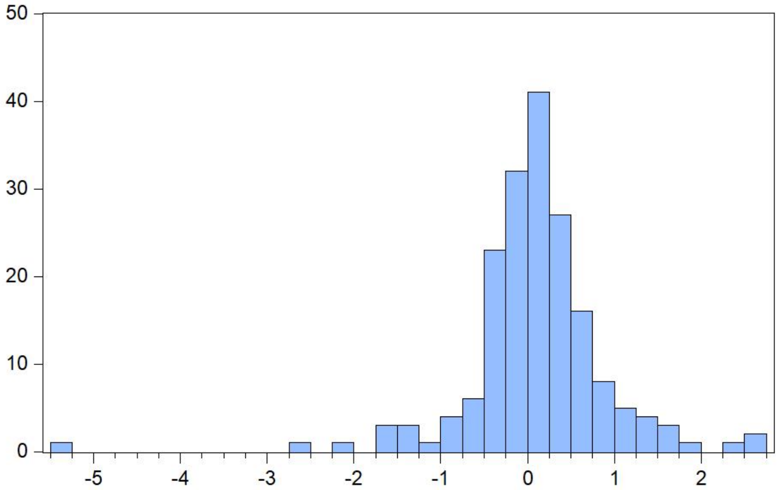
Series: BSE ALSI (2007 - 2009)	
Sample: 05/01/2007 - 26/12/2008	
Observations: 104	
Mean	0.036336
Median	0.005395
Maximum	3.813427
Minimum	-4.335400
Std. Dev.	1.532915
Skewness	-0.297507
Kurtosis	3.855798
Jarque-Bera	4.707869
Probability	0.094995

Figure 7.3: Descriptive Statistics of the BSE ALSI Weekly Share Index Returns (2009-2011)



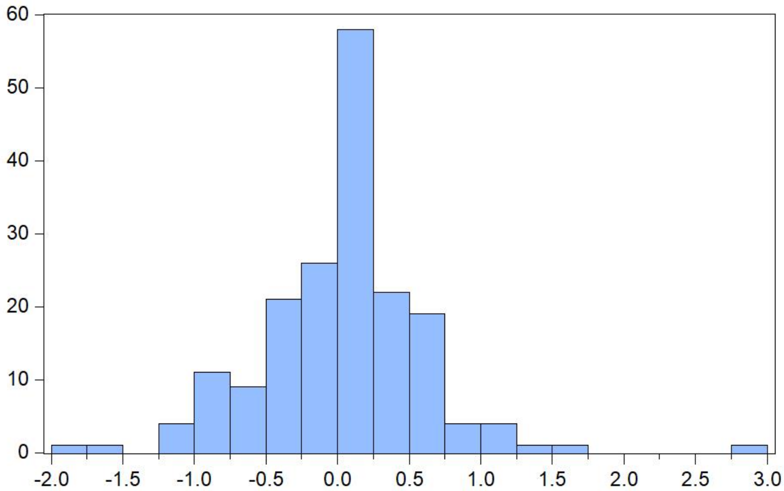
Series: BSE ALSI (2009 - 2011)	
Sample: 02/01/2009 - 31/12/2010	
Observations: 105	
Mean	-0.022458
Median	0.000268
Maximum	3.592792
Minimum	-5.400592
Std. Dev.	1.143105
Skewness	-0.729055
Kurtosis	7.442576
Jarque-Bera	95.64876
Probability	0.000000

Figure 7.4: Descriptive Statistics of the BSE ALSI Weekly Share Index Returns (2010-2013)



Series: BSE ALSI (2010 - 2013)	
Sample: 01/01/2010 - 28/06/2013	
Observations: 183	
Mean	0.094545
Median	0.083102
Maximum	2.565300
Minimum	-5.400592
Std. Dev.	0.820310
Skewness	-1.540920
Kurtosis	14.48751
Jarque-Bera	1078.638
Probability	0.000000

Figure 7.5: Descriptive Statistics of the BSE ALSI Weekly Share Index Returns (2013-2017)



Series: BSE ALSI (2013 - 2017)	
Sample: 05/07/2013 - 30/12/2016	
Observations: 183	
Mean	0.036870
Median	0.050425
Maximum	2.929346
Minimum	-1.911625
Std. Dev.	0.569997
Skewness	0.333637
Kurtosis	6.675054
Jarque-Bera	106.3785
Probability	0.000000

Table 7.1: Runs Test of the BSE Weekly Share Index Returns (2005 – 2007)

Runs Test

	BSE ALSI 2005 – 2007
Test Value[a]	0.789550%
Cases < Test Value	66
Cases >= Test Value	37
Total Cases	103
Number of Runs	38
Z	-2.243
Asymp. Sig. (2-tailed)	.025

a. Median (Cut-off Point)

Table 7.2: Runs Test of the BSE Weekly Share Index Returns (2007 – 2009)

Runs Test

	BSE ALSI 2007 – 2009
Test Value[a]	0.0054%
Cases < Test Value	52
Cases >= Test Value	52
Total Cases	104
Number of Runs	16
Z	-7.292
Asymp. Sig. (2-tailed)	.000

a. Median (Cut-off Point)

Table 7.3: Runs Test of the BSE Weekly Share Index Returns (2009 – 2011)

Runs Test

	BSE ALSI 2009 – 2011
Test Value[a]	0.0003%
Cases < Test Value	52
Cases >= Test Value	53
Total Cases	105
Number of Runs	28
Z	-5.001
Asymp. Sig. (2-tailed)	.000

a. Median (Cut-off Point)

Table 7.4: Runs Test of the BSE Weekly Share Index Returns (2010 – 2013)

Runs Test

	BSE ALSI 2010 – 2013
Test Value[a]	0.0831%
Cases < Test Value	91
Cases >= Test Value	92
Total Cases	183
Number of Runs	67
Z	-3.780
Asymp. Sig. (2-tailed)	.000

a. Median (Cut-off Point)

Table 7.5: Runs Test of the BSE Weekly Share Index Returns (2010 – 2013)

Runs Test

	BSE ALSI 2013 – 2017
Test Value[a]	0.0504%
Cases < Test Value	91
Cases >= Test Value	92
Total Cases	183
Number of Runs	61
Z	-4.670
Asymp. Sig. (2-tailed)	.000

a. Median (Cut-off Point)

Table 7.6: ADF Test of the BSE Weekly Share Index Returns (2005 – 2007)

Null Hypothesis: D(LR_CRISIS_05_07) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-12.66104	0.0000
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LR_CRISIS_05_07,2)
Method: Least Squares
Date: 04/21/18 Time: 23:26
Sample (adjusted): 2/04/2005 12/29/2006
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_CRISIS_05_07(-1))	-1.961633	0.154935	-12.66104	0.0000
D(LR_CRISIS_05_07(-1),2)	0.421181	0.093819	4.489312	0.0000
C	0.000651	0.002943	0.221177	0.8254

@TREND("1/07/2005")	-1.03E-05	4.84E-05	-0.211985	0.8326

Table 7.7: PP Test of the BSE Weekly Share Index Returns (2005 – 2007)

Null Hypothesis: D(LR_CRISIS_05_07) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2.54 (Andrews automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-17.61090	0.0000
Test critical values:	1% level	-4.051450	
	5% level	-3.454919	
	10% level	-3.153171	

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

Residual variance (no correction)	0.000224
HAC corrected variance (Bartlett kernel)	0.000109

Phillips-Perron Test Equation
Dependent Variable: D(LR_CRISIS_05_07,2)
Method: Least Squares
Date: 04/21/18 Time: 23:28
Sample (adjusted): 1/28/2005 12/29/2006
Included observations: 101 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_CRISIS_05_07(-1))	-1.384673	0.094219	-14.69624	0.0000
C	0.000448	0.003141	0.142608	0.8869
@TREND("1/07/2005")	-6.86E-06	5.19E-05	-0.132070	0.8952

Table 7.8: ADF Test of the BSE Weekly Share Index Returns (2007 – 2009)

Null Hypothesis: D(LR_CRISIS_07_09) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.225601	0.0000
Test critical values:	1% level	-4.052411	
	5% level	-3.455376	
	10% level	-3.153438	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LR_CRISIS_07_09,2)
Method: Least Squares
Date: 04/21/18 Time: 23:29
Sample (adjusted): 2/02/2007 12/26/2008
Included observations: 100 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_CRISIS_07_09(-1))	-2.115532	0.229311	-9.225601	0.0000
D(LR_CRISIS_07_09(-1),2)	0.633856	0.173008	3.663734	0.0004
D(LR_CRISIS_07_09(-2),2)	0.281434	0.101350	2.776847	0.0066
C	0.002163	0.006993	0.309275	0.7578
@TREND("1/07/2005")	-1.72E-05	4.37E-05	-0.392666	0.6954

Table 7.9: PP Test of the BSE Weekly Share Index Returns (2007 – 2009)

Null Hypothesis: D(LR_CRISIS_07_09) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 1.58 (Andrews automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.31918	0.0000
Test critical values:	1% level	-4.050509	
	5% level	-3.454471	
	10% level	-3.152909	

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

Residual variance (no correction)	0.000169
HAC corrected variance (Bartlett kernel)	0.000153

Phillips-Perron Test Equation
Dependent Variable: D(LR_CRISIS_07_09,2)
Method: Least Squares
Date: 04/21/18 Time: 23:30
Sample (adjusted): 1/19/2007 12/26/2008
Included observations: 102 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_CRISIS_07_09(-1))	-1.339223	0.095157	-14.07386	0.0000
C	0.000907	0.007063	0.128356	0.8981
@TREND("1/07/2005")	-7.48E-06	4.44E-05	-0.168593	0.8665

Table 7.10: ADF Test of the BSE Weekly Share Index Returns (2009 – 2011)

Null Hypothesis: D(LR_CRISIS_09_11) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=12)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.79009	0.0000
Test critical values:	1% level	-4.050509	
	5% level	-3.454471	
	10% level	-3.152909	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LR_CRISIS_09_11,2)
Method: Least Squares
Date: 04/21/18 Time: 23:31
Sample (adjusted): 1/23/2009 12/31/2010
Included observations: 102 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_CRISIS_09_11(-1))	-1.745913	0.161807	-10.79009	0.0000
D(LR_CRISIS_09_11(-1),2)	0.302936	0.098920	3.062434	0.0028
C	0.000433	0.010395	0.041698	0.9668
@TREND("1/07/2005")	-1.79E-06	3.95E-05	-0.045424	0.9639

Table 7.11: PP Test of the BSE Weekly Share Index Returns (2009 – 2011)

Null Hypothesis: D(LR_CRISIS_09_11) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 1.83 (Andrews automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-14.54665	0.0000
Test critical values:	1% level	-4.049586	
	5% level	-3.454032	
	10% level	-3.152652	

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

Residual variance (no correction)	0.000144
HAC corrected variance (Bartlett kernel)	0.000126

Phillips-Perron Test Equation
Dependent Variable: D(LR_CRISIS_09_11,2)
Method: Least Squares
Date: 04/21/18 Time: 23:32

Sample (adjusted): 1/16/2009 12/31/2010
Included observations: 103 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_CRISIS_09_11(-1))	-1.336547	0.094102	-14.20310	0.0000
C	-0.001024	0.010587	-0.096706	0.9232
@TREND("1/07/2005")	4.03E-06	4.03E-05	0.099961	0.9206

Table 7.12: ADF Test of the BSE Weekly Share Index Returns (2010 – 2013)

Null Hypothesis: D(LR_AUTO_10_13) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.17171	0.0000
Test critical values:	1% level	-4.009849	
	5% level	-3.434984	
	10% level	-3.141481	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LR_AUTO_10_13,2)
Method: Least Squares
Date: 04/21/18 Time: 23:33
Sample (adjusted): 1/22/2010 6/28/2013
Included observations: 180 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_AUTO_10_13(-1))	-1.661192	0.117219	-14.17171	0.0000
D(LR_AUTO_10_13(-1),2)	0.274604	0.072572	3.783901	0.0002
C	0.000688	0.004354	0.157922	0.8747
@TREND("1/07/2005")	-1.74E-06	1.22E-05	-0.142507	0.8868

Table 7.13: PP Test of the BSE Weekly Share Index Returns (2010 – 2013)

Null Hypothesis: D(LR_AUTO_10_13) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 2.01 (Andrews automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-19.31328	0.0000
Test critical values:	1% level	-4.009558	
	5% level	-3.434844	

	10% level	-3.141399

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

Residual variance (no correction)	7.66E-05
HAC corrected variance (Bartlett kernel)	5.47E-05

Phillips-Perron Test Equation
Dependent Variable: D(LR_AUTO_10_13,2)
Method: Least Squares
Date: 04/21/18 Time: 23:33
Sample (adjusted): 1/15/2010 6/28/2013
Included observations: 181 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_AUTO_10_13(-1))	-1.300175	0.071590	-18.16145	0.0000
C	5.96E-05	0.004467	0.013346	0.9894
@TREND("1/07/2005")	-2.96E-08	1.26E-05	-0.002355	0.9981

Table 7.14: ADF Test of the BSE Weekly Share Index Returns (2013 – 2017)

Null Hypothesis: D(LR_AUTO_13_17) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=13)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-10.46073	0.0000
Test critical values:	1% level	-4.010440	
	5% level	-3.435269	
	10% level	-3.141649	

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

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LR_AUTO_13_17,2)
Method: Least Squares
Date: 04/21/18 Time: 23:35
Sample (adjusted): 8/09/2013 12/30/2016
Included observations: 178 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_AUTO_13_17(-1))	-2.276504	0.217624	-10.46073	0.0000
D(LR_AUTO_13_17(-1),2)	0.853865	0.177225	4.817972	0.0000
D(LR_AUTO_13_17(-2),2)	0.463026	0.127567	3.629657	0.0004
D(LR_AUTO_13_17(-3),2)	0.192512	0.074930	2.569236	0.0110
C	0.001365	0.004269	0.319675	0.7496
@TREND("1/07/2005")	-2.54E-06	7.92E-06	-0.320347	0.7491

Table 7.15: PP Test of the BSE Weekly Share Index Returns (2013 – 2017)

Null Hypothesis: D(LR_AUTO_13_17) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 1.73 (Andrews automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-17.71279	0.0000
Test critical values:	1% level	-4.009558	
	5% level	-3.434844	
	10% level	-3.141399	

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

Residual variance (no correction)	3.27E-05
HAC corrected variance (Bartlett kernel)	2.99E-05

Phillips-Perron Test Equation
Dependent Variable: D(LR_AUTO_13_17,2)
Method: Least Squares
Date: 04/21/18 Time: 23:35
Sample (adjusted): 7/19/2013 12/30/2016
Included observations: 181 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LR_AUTO_13_17(-1))	-1.265658	0.072355	-17.49226	0.0000
C	0.000423	0.004411	0.095802	0.9238
@TREND("1/07/2005")	-7.45E-07	8.21E-06	-0.090732	0.9278

Table 7.16: Correlogram Tests of the BSE Weekly Share Index (2005 – 2007)

Date: 04/21/18 Time: 23:51
Sample: 07/01/2005 - 29/12/2006
Included observations: 102

	AC	PAC	Q-Stat	Prob
1	-0.378	-0.378	14.989	0.000
2	-0.212	-0.414	19.770	0.000
3	0.271	0.001	27.630	0.000
4	-0.196	-0.195	31.792	0.000
5	-0.116	-0.267	33.264	0.000
6	0.215	-0.101	38.382	0.000
7	-0.064	-0.077	38.834	0.000
8	-0.102	-0.146	40.002	0.000
9	0.140	-0.085	42.230	0.000
10	-0.103	-0.180	43.466	0.000
11	0.092	0.051	44.444	0.000
12	-0.047	-0.120	44.698	0.000
13	-0.041	-0.097	44.896	0.000
14	0.068	-0.069	45.451	0.000
15	-0.081	-0.147	46.259	0.000
16	0.072	-0.015	46.896	0.000
17	0.061	0.007	47.353	0.000
18	-0.102	-0.043	48.671	0.000
19	-0.011	-0.072	48.685	0.000
20	-0.027	-0.238	48.778	0.000
21	0.043	-0.071	49.025	0.000
22	0.002	-0.154	49.026	0.001
23	0.157	0.144	52.348	0.000
24	-0.212	-0.174	58.446	0.000
25	0.035	-0.114	58.613	0.000
26	0.052	-0.153	58.995	0.000
27	0.013	0.044	59.017	0.000
28	0.027	0.064	59.123	0.001
29	-0.056	-0.026	59.582	0.001
30	-0.003	-0.054	59.584	0.001
31	0.010	0.075	59.597	0.002
32	0.006	0.009	59.602	0.002
33	-0.141	-0.199	62.649	0.001
34	0.213	-0.020	69.751	0.000
35	-0.042	0.111	70.024	0.000
36	-0.133	-0.001	72.870	0.000

Table 7.17: Correlogram Tests of the BSE Weekly Share Index (2007 – 2009)

Date: 04/21/18 Time: 23:45
Sample: 05/01/2007 - 26/12/2009
Included observations: 103

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.335	-0.335	11.903	0.001
		2	-0.085	-0.222	12.680	0.002
		3	-0.118	-0.270	14.195	0.003
		4	0.016	-0.203	14.223	0.007
		5	0.107	-0.041	15.496	0.008
		6	0.044	0.039	15.707	0.015
		7	-0.123	-0.085	17.407	0.015
		8	0.001	-0.049	17.407	0.026
		9	-0.051	-0.114	17.700	0.039
		10	0.156	0.052	20.524	0.025
		11	-0.084	-0.056	21.351	0.030
		12	-0.099	-0.163	22.514	0.032
		13	0.129	0.049	24.507	0.027
		14	-0.097	-0.103	25.658	0.029
		15	0.111	0.011	27.161	0.027
		16	0.032	0.091	27.289	0.038
		17	-0.194	-0.134	32.029	0.015
		18	0.168	0.089	35.628	0.008
		19	-0.121	-0.100	37.508	0.007
		20	0.030	-0.105	37.626	0.010
		21	0.121	0.105	39.571	0.008
		22	-0.177	-0.129	43.759	0.004
		23	0.152	0.086	46.898	0.002
		24	-0.160	-0.121	50.402	0.001
		25	0.045	-0.080	50.680	0.002
		26	0.032	-0.060	50.826	0.003
		27	-0.011	-0.040	50.843	0.004
		28	0.012	-0.055	50.864	0.005
		29	0.043	0.034	51.128	0.007
		30	-0.069	0.026	51.826	0.008
		31	0.104	-0.000	53.436	0.007
		32	-0.198	-0.115	59.408	0.002
		33	0.199	0.083	65.512	0.001
		34	-0.076	-0.079	66.423	0.001
		35	-0.064	-0.055	67.079	0.001
		36	0.133	0.018	69.940	0.001

Table 7.18: Correlogram Tests of the BSE Weekly Share Index (2009 – 2011)

Date: 04/21/18 Time: 23:58
Sample: 02/01/2009 - 31/12/2010
Included observations: 104

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.335	-0.335	12.004	0.001
		2	-0.137	-0.281	14.039	0.001
		3	0.017	-0.166	14.070	0.003
		4	0.030	-0.083	14.171	0.007
		5	-0.053	-0.110	14.479	0.013
		6	-0.051	-0.149	14.767	0.022
		7	-0.015	-0.166	14.791	0.039
		8	0.078	-0.061	15.495	0.050
		9	-0.122	-0.205	17.235	0.045
		10	0.067	-0.111	17.762	0.059
		11	0.061	-0.049	18.203	0.077
		12	-0.055	-0.104	18.561	0.100
		13	0.138	0.111	20.863	0.076
		14	-0.072	0.024	21.496	0.090
		15	-0.048	-0.014	21.780	0.114
		16	-0.042	-0.088	22.002	0.143
		17	-0.001	-0.092	22.002	0.185
		18	0.072	0.002	22.667	0.204
		19	0.006	0.051	22.671	0.252
		20	-0.111	-0.070	24.288	0.230
		21	0.157	0.083	27.578	0.153
		22	-0.153	-0.118	30.716	0.102
		23	0.109	0.026	32.336	0.093
		24	0.054	0.086	32.738	0.110
		25	-0.041	0.067	32.972	0.132
		26	-0.091	-0.058	34.132	0.132
		27	0.004	-0.051	34.134	0.162
		28	-0.072	-0.171	34.886	0.173
		29	0.128	-0.014	37.298	0.139
		30	-0.092	-0.092	38.570	0.136
		31	0.112	0.001	40.461	0.119
		32	0.004	-0.001	40.464	0.145
		33	-0.055	-0.012	40.936	0.161
		34	-0.042	-0.151	41.218	0.184
		35	0.076	-0.020	42.148	0.189
		36	0.084	0.084	43.297	0.188

Table 7.19: Correlogram Tests of the BSE Weekly Share Index (2010 – 2013)

Date: 04/22/18 Time: 00:00
Sample: 01/01/2010 - 28/06/2013
Included observations: 182

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.299	-0.299	16.498	0.000
		2	-0.156	-0.270	21.054	0.000
		3	0.053	-0.103	21.571	0.000
		4	-0.095	-0.183	23.261	0.000
		5	-0.015	-0.147	23.302	0.000
		6	-0.002	-0.147	23.304	0.001
		7	0.030	-0.083	23.476	0.001
		8	0.007	-0.072	23.486	0.003
		9	0.004	-0.050	23.490	0.005
		10	-0.101	-0.178	25.469	0.005
		11	0.063	-0.082	26.252	0.006
		12	0.059	-0.021	26.940	0.008
		13	-0.004	0.008	26.943	0.013
		14	-0.047	-0.066	27.378	0.017
		15	-0.073	-0.157	28.460	0.019
		16	0.043	-0.101	28.840	0.025
		17	-0.042	-0.158	29.203	0.033
		18	0.177	0.086	35.564	0.008
		19	-0.086	-0.066	37.079	0.008
		20	-0.071	-0.130	38.114	0.009
		21	0.107	-0.014	40.517	0.006
		22	-0.070	-0.048	41.557	0.007
		23	0.027	0.007	41.714	0.010
		24	0.010	-0.034	41.736	0.014
		25	-0.022	-0.068	41.840	0.019
		26	-0.080	-0.163	43.216	0.018
		27	0.120	0.025	46.325	0.012
		28	-0.141	-0.168	50.660	0.005
		29	0.136	-0.005	54.685	0.003
		30	0.017	-0.093	54.749	0.004
		31	-0.014	0.018	54.792	0.005
		32	0.030	0.038	54.992	0.007
		33	-0.085	-0.003	56.634	0.006
		34	0.044	0.013	57.071	0.008
		35	0.002	0.029	57.072	0.011
		36	-0.082	-0.101	58.619	0.010

Table 7.20: Correlogram Tests of the BSE Weekly Share Index (2013 – 2017)

Date: 04/22/18 Time: 00:02
Sample: 05/07/2013 - 30/12/2016
Included observations: 182

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.264	-0.264	12.873	0.000
		2	-0.176	-0.264	18.646	0.000
		3	-0.033	-0.186	18.844	0.000
		4	-0.035	-0.184	19.068	0.001
		5	0.115	-0.007	21.584	0.001
		6	-0.068	-0.094	22.451	0.001
		7	-0.105	-0.170	24.553	0.001
		8	0.021	-0.132	24.638	0.002
		9	0.125	0.018	27.642	0.001
		10	-0.106	-0.143	29.819	0.001
		11	0.061	-0.002	30.550	0.001
		12	-0.009	-0.020	30.567	0.002
		13	-0.029	-0.049	30.738	0.004
		14	-0.075	-0.186	31.855	0.004
		15	0.132	0.058	35.374	0.002
		16	-0.051	-0.070	35.901	0.003
		17	0.034	0.011	36.131	0.004
		18	-0.137	-0.193	39.968	0.002
		19	0.056	-0.017	40.615	0.003
		20	0.119	-0.023	43.558	0.002
		21	-0.089	-0.073	45.200	0.002
		22	0.047	0.016	45.667	0.002
		23	-0.029	0.026	45.848	0.003
		24	0.016	-0.043	45.899	0.005
		25	-0.030	-0.050	46.090	0.006
		26	-0.052	-0.116	46.666	0.008
		27	0.022	-0.038	46.771	0.010
		28	0.108	0.014	49.301	0.008
		29	-0.124	-0.100	52.673	0.005
		30	0.058	0.004	53.422	0.005
		31	0.006	-0.040	53.431	0.007
		32	0.073	0.058	54.607	0.008
		33	-0.050	-0.001	55.176	0.009
		34	-0.156	-0.152	60.712	0.003
		35	0.069	-0.079	61.807	0.003
		36	0.096	0.010	63.942	0.003

Table 7.21: Variance Ratio Test of the BSE Weekly Share Index (2005 – 2007)

Null Hypothesis: LR_CRISIS_05_07 is a random walk
Date: 04/22/18 Time: 00:29
Sample: 1/07/2005 12/30/2016
Included observations: 102 (after adjustments)
Standard error estimates assume no heteroscedasticity
Lags specified as grid: min=2, max=101, step=5

Joint Tests	Value	Df	Probability
Max |z| (at period 2)*	3.777183	102	0.0032
Wald (Chi-Square)	33.53066	20	0.0295

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.626003	0.099015	-3.777183	0.0002
7	0.199694	0.269869	-2.965538	0.0030
12	0.106792	0.371214	-2.406183	0.0161
17	0.073565	0.450554	-2.056214	0.0398
22	0.050651	0.517949	-1.832902	0.0668
27	0.050554	0.577560	-1.643892	0.1002
32	0.059166	0.631583	-1.489645	0.1363
37	0.044842	0.681343	-1.401874	0.1610
42	0.052777	0.727714	-1.301643	0.1930
47	0.040202	0.771304	-1.244383	0.2134
52	0.064305	0.812562	-1.151538	0.2495
57	0.041719	0.851824	-1.124975	0.2606
62	0.052345	0.889357	-1.065551	0.2866
67	0.062036	0.925368	-1.013611	0.3108
72	0.050290	0.960031	-0.989250	0.3225
77	0.083480	0.993485	-0.922530	0.3563
82	0.101094	1.025850	-0.876256	0.3809
87	0.142513	1.057224	-0.811074	0.4173
92	0.185518	1.087694	-0.748815	0.4540
97	0.191732	1.117333	-0.723390	0.4694

*Probability approximation using studentized maximum modulus with parameter value 20 and infinite degrees of freedom

Test Details (Mean = 0.000131780122208)

Period	Variance	Var. Ratio	Obs.
1	0.00026	--	102
2	0.00016	0.62600	101
7	5.2E-05	0.19969	96
12	2.8E-05	0.10679	91
17	1.9E-05	0.07356	86
22	1.3E-05	0.05065	81
27	1.3E-05	0.05055	76
32	1.6E-05	0.05917	71
37	1.2E-05	0.04484	66
42	1.4E-05	0.05278	61
47	1.1E-05	0.04020	56
52	1.7E-05	0.06430	51
57	1.1E-05	0.04172	46
62	1.4E-05	0.05235	41
67	1.6E-05	0.06204	36
72	1.3E-05	0.05029	31
77	2.2E-05	0.08348	26

82	2.7E-05	0.10109	21
87	3.7E-05	0.14251	16
92	4.9E-05	0.18552	11
97	5.0E-05	0.19173	6

Table 7.22: Variance Ratio Test (Original Data) of the BSE Weekly Share Index (2007 – 2009)

Null Hypothesis: LR_CRISIS_07_09 is a random walk
Date: 04/22/18 Time: 00:31
Sample: 1/07/2005 12/30/2016
Included observations: 103 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=2, max=102, step=5

Joint Tests	Value	Df	Probability
Max |z| (at period 2)*	3.326339	103	0.0083
Wald (Chi-Square)	801.9321	21	0.0000

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.672246	0.098533	-3.326339	0.0009
7	0.267385	0.268555	-2.727984	0.0064
12	0.182248	0.369407	-2.213688	0.0269
17	0.144476	0.448361	-1.908112	0.0564
22	0.119515	0.515428	-1.708258	0.0876
27	0.092224	0.574749	-1.579430	0.1142
32	0.096790	0.628510	-1.437067	0.1507
37	0.092025	0.678028	-1.339140	0.1805
42	0.081800	0.724173	-1.267930	0.2048
47	0.082154	0.767551	-1.195812	0.2318
52	0.060415	0.808608	-1.161979	0.2452
57	0.062552	0.847679	-1.105900	0.2688
62	0.054272	0.885029	-1.068584	0.2853
67	0.072505	0.920865	-1.007199	0.3138
72	0.116480	0.955359	-0.924804	0.3551
77	0.135257	0.988651	-0.874670	0.3818
82	0.162207	1.020858	-0.820676	0.4118
87	0.313355	1.052079	-0.652655	0.5140
92	0.319499	1.082401	-0.628696	0.5295
97	0.601270	1.111896	-0.358603	0.7199
102	0.592399	1.140629	-0.357348	0.7208

*Probability approximation using studentized maximum modulus with parameter value 21 and infinite degrees of freedom

Test Details (Mean = -0.000179692664482)

Period	Variance	Var. Ratio	Obs.
1	0.00019	--	103
2	0.00013	0.67225	102
7	5.1E-05	0.26738	97
12	3.5E-05	0.18225	92
17	2.8E-05	0.14448	87
22	2.3E-05	0.11952	82
27	1.8E-05	0.09222	77

32	1.8E-05	0.09679	72
37	1.8E-05	0.09203	67
42	1.6E-05	0.08180	62
47	1.6E-05	0.08215	57
52	1.2E-05	0.06042	52
57	1.2E-05	0.06255	47
62	1.0E-05	0.05427	42
67	1.4E-05	0.07251	37
72	2.2E-05	0.11648	32
77	2.6E-05	0.13526	27
82	3.1E-05	0.16221	22
87	6.0E-05	0.31335	17
92	6.1E-05	0.31950	12
97	0.00011	0.60127	7
102	0.00011	0.59240	2

Table 7.23: Variance Ratio Test (Original Data) of the BSE Weekly Share Index (2009 – 2011)

Null Hypothesis: LR_CRISIS_09_11 is a random walk
Date: 04/22/18 Time: 00:32
Sample: 1/07/2005 12/30/2016
Included observations: 104 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=2, max=103, step=5

Joint Tests	Value	df	Probability
Max |z| (at period 2)*	3.340674	104	0.0174
Wald (Chi-Square)	1118.244	21	0.0000

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.672420	0.098058	-3.340674	0.0008
7	0.203617	0.267261	-2.979793	0.0029
12	0.112622	0.367627	-2.413800	0.0158
17	0.108201	0.446201	-1.998650	0.0456
22	0.099634	0.512944	-1.755291	0.0792
27	0.102281	0.571979	-1.569496	0.1165
32	0.077534	0.625481	-1.474812	0.1403
37	0.087748	0.674760	-1.351965	0.1764
42	0.083851	0.720683	-1.271224	0.2036
47	0.068913	0.763852	-1.218937	0.2229
52	0.080016	0.804711	-1.143248	0.2529
57	0.106578	0.843594	-1.059066	0.2896
62	0.090533	0.880764	-1.032590	0.3018
67	0.100671	0.916427	-0.981342	0.3264
72	0.101783	0.950755	-0.944741	0.3448
77	0.102171	0.983886	-0.912533	0.3615
82	0.093096	1.015938	-0.892677	0.3720
87	0.157174	1.047009	-0.804985	0.4208
92	0.344767	1.077184	-0.608283	0.5430
97	0.659302	1.106537	-0.307895	0.7582
102	1.517180	1.135132	0.455612	0.6487

*Probability approximation using studentized maximum modulus with parameter value 21 and infinite degrees of freedom

Test Details (Mean = 0.000117237913549)

Period	Variance	Var. Ratio	Obs.
1	0.00016	--	104
2	0.00011	0.67242	103
7	3.3E-05	0.20362	98
12	1.8E-05	0.11262	93
17	1.8E-05	0.10820	88
22	1.6E-05	0.09963	83
27	1.7E-05	0.10228	78
32	1.3E-05	0.07753	73
37	1.4E-05	0.08775	68
42	1.4E-05	0.08385	63
47	1.1E-05	0.06891	58
52	1.3E-05	0.08002	53
57	1.7E-05	0.10658	48
62	1.5E-05	0.09053	43
67	1.6E-05	0.10067	38
72	1.7E-05	0.10178	33
77	1.7E-05	0.10217	28
82	1.5E-05	0.09310	23
87	2.6E-05	0.15717	18
92	5.6E-05	0.34477	13
97	0.00011	0.65930	8
102	0.00025	1.51718	3

Table 7.24: Variance Ratio Test (Original Data) of the BSE Weekly Share Index (2010 – 2013)

Null Hypothesis: LR_AUTO_10_13 is a random walk
Date: 05/18/18 Time: 22:27
Sample: 1/07/2005 12/30/2016
Included observations: 182 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=10, max=180, step=10

Joint Tests	Value	df	Probability
Max |z| (at period 10)*	3.265309	182	0.0195
Wald (Chi-Square)	240.6631	18	0.0000

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
10	0.182776	0.250275	-3.265309	0.0011
20	0.091025	0.368394	-2.467399	0.0136
30	0.054458	0.457070	-2.068702	0.0386
40	0.046854	0.531171	-1.794423	0.0727
50	0.036105	0.596141	-1.616889	0.1059
60	0.037738	0.654700	-1.469775	0.1416
70	0.035366	0.708438	-1.361635	0.1733
80	0.032226	0.758378	-1.276110	0.2019
90	0.033844	0.805228	-1.199854	0.2302
100	0.040337	0.849499	-1.129681	0.2586
110	0.038032	0.891575	-1.078955	0.2806

120	0.047133	0.931752	-1.022662	0.3065
130	0.055793	0.970268	-0.973141	0.3305
140	0.044450	1.007312	-0.948613	0.3428
150	0.075438	1.043042	-0.886410	0.3754
160	0.083745	1.077588	-0.850284	0.3952
170	0.193794	1.111060	-0.725619	0.4681
180	0.609050	1.143553	-0.341873	0.7324

*Probability approximation using studentized maximum modulus with parameter value 18 and infinite degrees of freedom

Test Details (Mean = 2.09454059968e-05)

Period	Variance	Var. Ratio	Obs.
1	8.4E-05	--	182
10	1.5E-05	0.18278	173
20	7.7E-06	0.09102	163
30	4.6E-06	0.05446	153
40	4.0E-06	0.04685	143
50	3.0E-06	0.03611	133
60	3.2E-06	0.03774	123
70	3.0E-06	0.03537	113
80	2.7E-06	0.03223	103
90	2.9E-06	0.03384	93
100	3.4E-06	0.04034	83
110	3.2E-06	0.03803	73
120	4.0E-06	0.04713	63
130	4.7E-06	0.05579	53
140	3.8E-06	0.04445	43
150	6.4E-06	0.07544	33
160	7.1E-06	0.08374	23
170	1.6E-05	0.19379	13
180	5.1E-05	0.60905	3

Table 7.25: Variance Ratio Test (Original Data) of the BSE Weekly Share Index (2013 – 2017)

Null Hypothesis: LR_AUTO_13_17 is a random walk
Date: 05/18/18 Time: 22:27
Sample: 1/07/2005 12/30/2016
Included observations: 182 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=10, max=180, step=10

Joint Tests	Value	df	Probability
Max |z| (at period 10)*	3.220929	182	0.0228
Wald (Chi-Square)	41.82333	18	0.0012

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
10	0.193883	0.250275	-3.220929	0.0013
20	0.096003	0.368394	-2.453884	0.0141
30	0.068092	0.457070	-2.038873	0.0415
40	0.054903	0.531171	-1.779270	0.0752
50	0.048403	0.596141	-1.596261	0.1104

60	0.049864	0.654700	-1.451253	0.1467
70	0.043371	0.708438	-1.350337	0.1769
80	0.037260	0.758378	-1.269472	0.2043
90	0.046927	0.805228	-1.183607	0.2366
100	0.032630	0.849499	-1.138754	0.2548
110	0.046161	0.891575	-1.069836	0.2847
120	0.034481	0.931752	-1.036240	0.3001
130	0.047655	0.970268	-0.981527	0.3263
140	0.059905	1.007312	-0.933271	0.3507
150	0.090805	1.043042	-0.871676	0.3834
160	0.108926	1.077588	-0.826916	0.4083
170	0.177299	1.111060	-0.740465	0.4590
180	0.161076	1.143553	-0.733612	0.4632

*Probability approximation using studentized maximum modulus with parameter value 18 and infinite degrees of freedom

Test Details (Mean = 3.22465639704e-06)

Period	Variance	Var. Ratio	Obs.
1	3.5E-05	--	182
10	6.9E-06	0.19388	173
20	3.4E-06	0.09600	163
30	2.4E-06	0.06809	153
40	1.9E-06	0.05490	143
50	1.7E-06	0.04840	133
60	1.8E-06	0.04986	123
70	1.5E-06	0.04337	113
80	1.3E-06	0.03726	103
90	1.7E-06	0.04693	93
100	1.2E-06	0.03263	83
110	1.6E-06	0.04616	73
120	1.2E-06	0.03448	63
130	1.7E-06	0.04766	53
140	2.1E-06	0.05990	43
150	3.2E-06	0.09081	33
160	3.9E-06	0.10893	23
170	6.3E-06	0.17730	13
180	5.7E-06	0.16108	3

Table 7.26: Variance Ratio Test (Bootstrap Signs Test) of the BSE Weekly Share Index (2005 – 2007)

Null Hypothesis: LR_CRISIS_05_07 is a martingale
Date: 05/22/18 Time: 16:21
Sample: 1/07/2005 12/30/2016
Included observations: 102 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=2, max=104, step=5
Test probabilities computed using permutation bootstrap: reps=1000, rng=kn, seed=125438277

Joint Tests	Value	df	Probability
Max |z| (at period 2)	2.376354	102	0.0190
Wald (Chi-Square)	13.33951	21	0.9060

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.764706	0.099015	-2.376354	0.0150
7	0.549020	0.269869	-1.671110	0.0510
12	0.343137	0.371214	-1.769501	0.0190
17	0.266436	0.450554	-1.628138	0.0180
22	0.221034	0.517949	-1.503944	0.0160
27	0.196078	0.577560	-1.391928	0.0200
32	0.176471	0.631583	-1.303913	0.0260
37	0.161632	0.681343	-1.230463	0.0290
42	0.154995	0.727714	-1.161177	0.0380
47	0.136838	0.771304	-1.119094	0.0440
52	0.134238	0.812562	-1.065472	0.0750
57	0.098727	0.851824	-1.058050	0.0540
62	0.090449	0.889357	-1.022707	0.0750
67	0.083699	0.925368	-0.990201	0.0820
72	0.059913	0.960031	-0.979226	0.0620
77	0.042017	0.993485	-0.964265	0.0380
82	0.029651	1.025850	-0.945898	0.0260
87	0.040568	1.057224	-0.907501	0.0570
92	0.036232	1.087694	-0.886066	0.0470
97	0.029715	1.117333	-0.868394	0.0430
102	0.009612	1.146207	-0.864057	0.0000

Test Details (Mean = 0)

Period	Variance	Var. Ratio	Obs.
1	1.00000	--	102
2	0.76471	0.76471	101
7	0.54902	0.54902	96
12	0.34314	0.34314	91
17	0.26644	0.26644	86
22	0.22103	0.22103	81
27	0.19608	0.19608	76
32	0.17647	0.17647	71
37	0.16163	0.16163	66
42	0.15500	0.15500	61
47	0.13684	0.13684	56
52	0.13424	0.13424	51
57	0.09873	0.09873	46
62	0.09045	0.09045	41
67	0.08370	0.08370	36
72	0.05991	0.05991	31
77	0.04202	0.04202	26
82	0.02965	0.02965	21
87	0.04057	0.04057	16
92	0.03623	0.03623	11
97	0.02971	0.02971	6
102	0.00961	0.00961	1

Table 7.27: Variance Ratio Test (Bootstrap Signs Test) of the BSE Weekly Share Index (2007 – 2009)

Null Hypothesis: LR_CRISIS_07_09 is a martingale
Date: 05/22/18 Time: 16:21

Sample: 1/07/2005 12/30/2016
Included observations: 103 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=2, max=104, step=5
Test probabilities computed using permutation bootstrap: reps=1000,
rng=kn, seed=1656063456

Joint Tests	Value	df	Probability
Max |z| (at period 2)	3.251587	103	0.0191
Wald (Chi-Square)	12.43620	21	0.5890

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.679612	0.098533	-3.251587	0.0020
7	0.400832	0.268555	-2.231076	0.0070
12	0.245955	0.369407	-2.041230	0.0080
17	0.168475	0.448361	-1.854586	0.0090
22	0.155340	0.515428	-1.638754	0.0170
27	0.145631	0.574749	-1.486507	0.0300
32	0.106796	0.628510	-1.421146	0.0310
37	0.086854	0.678028	-1.346768	0.0260
42	0.082293	0.724173	-1.267249	0.0490
47	0.059698	0.767551	-1.225067	0.0380
52	0.036594	0.808608	-1.191438	0.0090
57	0.031170	0.847679	-1.142920	0.0130
62	0.025681	0.885029	-1.100889	0.0190
67	0.015795	0.920865	-1.068783	0.0050
72	0.014024	0.955359	-1.032048	0.0160
77	0.014500	0.988651	-0.996813	0.0680
82	0.009472	1.020858	-0.970290	0.0670
87	0.004575	1.052079	-0.946150	0.0370
92	0.004221	1.082401	-0.919972	0.1620
97	0.002302	1.111896	-0.897294	0.2670
102	0.000381	1.140629	-0.876376	0.2670

Test Details (Mean = 0)

Period	Variance	Var. Ratio	Obs.
1	1.00000	--	103
2	0.67961	0.67961	102
7	0.40083	0.40083	97
12	0.24595	0.24595	92
17	0.16848	0.16848	87
22	0.15534	0.15534	82
27	0.14563	0.14563	77
32	0.10680	0.10680	72
37	0.08685	0.08685	67
42	0.08229	0.08229	62
47	0.05970	0.05970	57
52	0.03659	0.03659	52
57	0.03117	0.03117	47
62	0.02568	0.02568	42
67	0.01579	0.01579	37
72	0.01402	0.01402	32
77	0.01450	0.01450	27
82	0.00947	0.00947	22
87	0.00458	0.00458	17
92	0.00422	0.00422	12
97	0.00230	0.00230	7
102	0.00038	0.00038	2

Table 7.28: Variance Ratio Test (Bootstrap Signs Test) of the BSE Weekly Share Index (2009 – 2011)

Null Hypothesis: LR_CRISIS_09_11 is a martingale
Date: 05/22/18 Time: 16:22
Sample: 1/07/2005 12/30/2016
Included observations: 104 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=2, max=104, step=5
Test probabilities computed using permutation bootstrap: reps=1000,
rng=kn, seed=2080094944

Joint Tests	Value	df	Probability
Max |z| (at period 2)	2.157277	104	0.0400
Wald (Chi-Square)	12.11833	21	0.6660

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.788462	0.098058	-2.157277	0.0240
7	0.541209	0.267261	-1.716640	0.0660
12	0.407051	0.367627	-1.612909	0.0740
17	0.289593	0.446201	-1.592125	0.0560
22	0.258741	0.512944	-1.445106	0.0950
27	0.232906	0.571979	-1.341122	0.1270
32	0.181490	0.625481	-1.308609	0.1120
37	0.177755	0.674760	-1.218574	0.1670
42	0.173077	0.720683	-1.147416	0.2300
47	0.154255	0.763852	-1.107210	0.2520
52	0.153107	0.804711	-1.052420	0.3230
57	0.155196	0.843594	-1.001435	0.3970
62	0.123449	0.880764	-0.995217	0.3910
67	0.082377	0.916427	-1.001305	0.3190
72	0.071581	0.950755	-0.976507	0.3780
77	0.068432	0.983886	-0.946825	0.4810
82	0.046435	1.015938	-0.938605	0.4570
87	0.032935	1.047009	-0.923645	0.4650
92	0.035953	1.077184	-0.894969	0.6760
97	0.025377	1.106537	-0.880787	0.7950
102	0.008296	1.135132	-0.873647	0.8360

Test Details (Mean = 0)

Period	Variance	Var. Ratio	Obs.
1	1.00000	--	104
2	0.78846	0.78846	103
7	0.54121	0.54121	98
12	0.40705	0.40705	93
17	0.28959	0.28959	88
22	0.25874	0.25874	83
27	0.23291	0.23291	78
32	0.18149	0.18149	73
37	0.17775	0.17775	68
42	0.17308	0.17308	63
47	0.15426	0.15426	58
52	0.15311	0.15311	53
57	0.15520	0.15520	48
62	0.12345	0.12345	43

67	0.08238	0.08238	38
72	0.07158	0.07158	33
77	0.06843	0.06843	28
82	0.04644	0.04644	23
87	0.03294	0.03294	18
92	0.03595	0.03595	13
97	0.02538	0.02538	8
102	0.00830	0.00830	3

Table 7.29: Variance Ratio Test (Bootstrap Signs Test) of the BSE Weekly Share Index (2010 – 2013)

Null Hypothesis: LR_AUTO_10_13 is a martingale
Date: 05/22/18 Time: 16:23
Sample: 1/07/2005 12/30/2016
Included observations: 182 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=2, max=180, step=10
Test probabilities computed using permutation bootstrap: reps=1000, rng=kn, seed=467052424

Joint Tests	Value	df	Probability
Max |z| (at period 2)	3.409747	182	0.0110
Wald (Chi-Square)	13.07869	18	0.4830

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.747253	0.074125	-3.409747	0.0100
12	0.417582	0.277900	-2.095782	0.0160
22	0.372627	0.387749	-1.617984	0.0790
32	0.343407	0.472819	-1.388678	0.1570
42	0.306122	0.544785	-1.273673	0.2030
52	0.265427	0.608304	-1.207576	0.2470
62	0.218717	0.665795	-1.173460	0.2530
72	0.172466	0.718703	-1.151426	0.2420
82	0.149558	0.767977	-1.107380	0.2660
92	0.150024	0.814275	-1.043844	0.3550
102	0.133376	0.858079	-1.009958	0.4180
112	0.116366	0.899754	-0.982085	0.4730
122	0.093677	0.939582	-0.964603	0.5030
132	0.065768	0.977789	-0.955454	0.4910
142	0.039003	1.014559	-0.947206	0.4440
152	0.015038	1.050042	-0.938022	0.2720
162	0.005698	1.084365	-0.916944	0.1870
172	0.004600	1.117634	-0.890631	0.3860

Test Details (Mean = 0)

Period	Variance	Var. Ratio	Obs.
1	1.00000	--	182
2	0.74725	0.74725	181
12	0.41758	0.41758	171
22	0.37263	0.37263	161
32	0.34341	0.34341	151
42	0.30612	0.30612	141
52	0.26543	0.26543	131

62	0.21872	0.21872	121
72	0.17247	0.17247	111
82	0.14956	0.14956	101
92	0.15002	0.15002	91
102	0.13338	0.13338	81
112	0.11637	0.11637	71
122	0.09368	0.09368	61
132	0.06577	0.06577	51
142	0.03900	0.03900	41
152	0.01504	0.01504	31
162	0.00570	0.00570	21
172	0.00460	0.00460	11

Table 7.30: Variance Ratio Test (Bootstrap Signs Test) of the BSE Weekly Share Index (2013 – 2017)

Null Hypothesis: LR_AUTO_13_17 is a martingale
Date: 05/22/18 Time: 16:24
Sample: 1/07/2005 12/30/2016
Included observations: 182 (after adjustments)
Standard error estimates assume no heteroskedasticity
Lags specified as grid: min=2, max=180, step=10
Test probabilities computed using permutation bootstrap: reps=1000,
rng=kn, seed=298585881

Joint Tests	Value	df	Probability
Max |z| (at period 2)	2.520248	182	0.0300
Wald (Chi-Square)	15.25267	18	0.8820

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.813187	0.074125	-2.520248	0.0090
12	0.336996	0.277900	-2.385765	0.0140
22	0.366633	0.387749	-1.633443	0.0510
32	0.432692	0.472819	-1.199841	0.1070
42	0.507064	0.544785	-0.904826	0.2130
52	0.546069	0.608304	-0.746223	0.3140
62	0.570011	0.665795	-0.645829	0.3770
72	0.569292	0.718703	-0.599285	0.4430
82	0.556151	0.767977	-0.577946	0.4590
92	0.552317	0.814275	-0.549793	0.4880
102	0.558500	0.858079	-0.514521	0.5230
112	0.563972	0.899754	-0.484609	0.5700
122	0.538462	0.939582	-0.491217	0.5860
132	0.494339	0.977789	-0.517147	0.6230
142	0.431048	1.014559	-0.560788	0.6690
152	0.334008	1.050042	-0.634253	0.6820
162	0.220594	1.084365	-0.718767	0.6540
172	0.094557	1.117634	-0.810143	0.3780

Test Details (Mean = 0)

Period	Variance	Var. Ratio	Obs.
1	1.00000	--	182
2	0.81319	0.81319	181

12	0.33700	0.33700	171
22	0.36663	0.36663	161
32	0.43269	0.43269	151
42	0.50706	0.50706	141
52	0.54607	0.54607	131
62	0.57001	0.57001	121
72	0.56929	0.56929	111
82	0.55615	0.55615	101
92	0.55232	0.55232	91
102	0.55850	0.55850	81
112	0.56397	0.56397	71
122	0.53846	0.53846	61
132	0.49434	0.49434	51
142	0.43105	0.43105	41
152	0.33401	0.33401	31
162	0.22059	0.22059	21
172	0.09456	0.09456	11