# Does Automation Improve Stock Market Efficiency? Evidence from Ghana

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*Justice Tei Mensah*[↑], *Maame Pomaa-Berko*[♦] *and Philip Kofi Adom*[♣]

## Abstract

*As a burgeoning capital market in an emerging economy, automation of the stock market is regarded as a major step towards integrating the financial market as a conduit for economic growth. The automation of the Ghana Stock Exchange (GSE) in 2008 is expected among other things to improve the efficiency of the market. This paper therefore investigates the impact of the automation on the efficiency of the GSE within the framework of the weak-form Efficient Market Hypothesis (EMH) using daily market returns from the Ghana Stock Exchange All-Share index from 2006 to 2011. The Unit Root Random Walk and the GARCH models were used to analyze the efficiency of the GSE in the pre and post automation sample periods. Results show that the GSE was weakly inefficient in both pre and post automation periods, suggesting that the automation of the GSE have not yielded the needed impact towards improving the efficiency of the exchange.*

[↑] Corresponding Author: Department of Economics, Swedish University of Agricultural Sciences, Email:myjumens@gmail.com

[♦] University of Ghana, mamapoms@yahoo.com

[♣] Department of Economics, University of Ghana. Email: adomonline@yahoo.co.uk

## 1.0 Introduction

After the financial turmoil in Ghana between 1983 and 1988, the financial sector witnessed a myriad of reforms aimed at liberalizing and opening up access to long-term capital for investments (Frimpong, 2008). In 1988, the Financial Sector Adjustment Programme (FINSAP) was launched to restructure the financial sector and foster the creation of new institutions to revitalize the financial sector. This resulted in among other things the establishment of the Ghana Stock Exchange (GSE). The Ghana Stock Exchange (GSE) was incorporated as a private company limited by guarantee under Ghana's Companies Code, 1963 (Act 179) in July 1989. Trading commenced in 1990 with 12 listed companies and one Government bond (Frimpong, 2008). In April 1994, it was converted into a public company limited by guarantee.

Today, the GSE is the principal capital market in Ghana and one of the highest performing exchanges in Sub-Saharan Africa. In 2008 the GSE witnessed one of the most outstanding performances of its listed equities with a gain in the GSE All-share Index of 58% and was rated ahead of all the African markets[1]. The 2009 financial year was however a difficult year for the stock market as performance of the listed equities plummeted by - 46.58% in the GSE All-Share index from the record levels in 2008. The dip in performance was attributed to be a corollary of the global financial crisis which began to be felt in the fourth quarter of 2008 and the surge in domestic interest rates which made short term financial instruments in the banking sector more attractive to investors than the stock market. Also the migration of the Exchange from paper certification to electronic book entry securities under a new automated Trading System was another contributing factor. This is because the migration process naturally requires time since investors need to be convinced to get on board[2]. Again, as a corollary of the tumbling stock prices on the Exchange, market capitalization of the GSE declined by 11% from GH¢17.90billion in 2008 to GH¢15.94billion in 2009.

The performance of the exchange in the 2010 financial year was, however, impressive. As a consequence, the GSE was adjudged the "Most Innovative African Stock Exchange for 2010" at the Africa investor (Ai) prestigious annual Index Series Awards held at the New York Stock

[1] http://www.gse.com.gh/index1.php?linkid=21&archiveid=233&page=1&adate=24%2F02%2F2010
[2] http://www.gse.com.gh/index1.php?linkid=21&archiveid=233&page=1&adate=24%2F02%2F2010

Exchange (NYSE). Thus, despite the macroeconomic challenges that confronted the economy, the performance of the GSE on the average has not been bad.

The performance of the stock market is highly influenced by the efficiency of the exchange. Market efficiency explains the degree to which share prices reflect all available and relevant information (Gupta and Basu, 2005). Efficiency on the exchange ensures accurate pricing of stocks by avoiding under and over valuation of stocks which encourages share buying. This is because when stocks are incorrectly priced, it deters potential investors from buying shares for fear of a perverse price when they decide to sell their shares and this ultimately reduces the availability of capital to firms for growth. Secondly, it ensures efficient allocation of resources in the sense that firm's performance is reflected in their stock prices which informs potential investors to take optimal investment decisions.

In Ghana, available studies on the efficiency of the GSE show that the exchange is inefficient. For instance, Osei (2002) in a study on the efficiency of capital markets in Africa including the Ghana Stock Exchange concluded that the capital markets in Africa are inefficient. Frimpong (2008) analyzing the efficiency of the capital market in Ghana (1999-2004) also obtained similar result. Several reasons have been cited to account for the inefficiency of the Ghanaian capital market. Prominent among them was the hitherto manual listing and paper certification on the exchange which hindered information flow. During this era there were delays in adjusting stock prices to reflect available information on the market with the resultant effects of over and under valuation of stock prices. This adversely the mobilization of savings, growth and development of firms listed on the exchange.

To perform its core functions effectively in mobilizing domestic and international capital for economic development, recent reforms in the GSE have centered on promoting institutional development. These include the migration to the electronic trading system to ensure efficient and wider diffusion of information, the enactment of the Central Securities Depository (CSD) Bill into law, the adoption and implementation of the Rule Book in 2007, which partially liberalizes commissions charged so as to encourage investors' shop for available best rates (Frimpong, 2008), inter alia.

The automation of the Ghana Stock Exchange was premised on the belief that it would improve the efficiency (both operational [3] and informational) of the market. Thus after years of implementation of the automation of the exchange, the question that beckons is whether the automation of the exchange has improved the efficiency of the Ghana Stock exchange? The purpose of this study is thus, to examine the efficiency of the Ghana Stock Exchange taking into consideration the role of automation of the exchange.

The current paper is novel with regard to the country under study in that previous attempts in Ghana has failed to examine the role of automation on stock market efficiency (see Frimpong, 2008 and Osei, 2002). It is also important to point out that discussion of the effect of automation or electronic listing on stock markets efficiency is very scanty in the literature, particularly in sub-Saharan Africa. Evidence emanating from this study is hoped to advance knowledge in the literature on the effect of electronic listing of firms on stock market efficiency from the perspective of an emerging economy.

The rest of paper is organized as follows: Section 2 reviews relevant literature on the capital market. Section 3 presents a discussion on theoretical and empirical models, whilst our Results and Analysis of the data are presented in Section 4. Section 5 concludes the paper with summary of findings and policy implications that follow from the findings.

## 2.0 Literature Review

The Efficient Market Hypothesis (EMH) is the most widely accepted model underlying the efficiency of capital markets. Formulated by Eugene Fama (1970), the EMH posits that a market is efficient when it is able to adjust instantaneously to take account of all available information, such that no single agent in the market obtains more information than the information that is already reflected in the market prices (Osei, 1998). In other words the market is efficient when prices adjust to reflect fully, all available information. Thus with a given set of information , market efficiency results if it is impossible for any agent to make economic profits by trading on the basis of this information set (Ross, 1987 cited in Frimpong, 2006) since all

[3] Operational efficiency measures the market's ability to operate at lower costs either through improved liquidity, more rapid execution or lower trading costs whereas informational efficiency reflects the market's ability to evaluate information and determine the fair (true) value of a stock (Fama, 1970 and Debysingh and Watson, 2009)

agents in the market are privy to the same information. The EMH, further explains that in an efficient market, stock prices are random than predictable, such that it becomes impossible for any market watcher to successfully execute a planned investment strategy that beats the market consistently. Thus in inefficient markets, the presence of momentum in stock prices and anomalies (seasonal and day-of-the week effects) enable market agents to accrue excess returns on their investments (Malkiel, 2007). Fama (1970) outlined three main dimensions of capital market efficiency: weak- form market efficiency, Semi-strong market efficiency and Strong market efficiency, each depending on the information set available

Weak-form market efficiency exists when current prices fully reflect all historical price information, such that prices automatically adjust to information changes without lags. Thus excess gains cannot be made by studying the pattern of past price changes (Malkiel, 2007). The weak form efficiency is based on the random walk hypothesis where future price changes are independent of price changes in the past (Malkiel, 2007), implying that price changes do not follow any systematic pattern over time (Osei, 1998).

With semi-strong form efficiency, market prices reflect available public information including company reports, annual earnings, stock splits and company public profits forecasts. The stronger forms of efficiency, however, exist when prices reflect both public and private information about earnings, book values, investment opportunities, inter alia (Malkiel, 2007). Thus, the strong form efficiency requires market prices to fully incorporate even private information such as an impending merger between some firms and technological change (Osei, 1998). Under this form of efficiency, not even the experts (portfolio managers and analyst) would be able to beat any index traded on the stock market (Malkiel, 2007). Intuitively, it implies that all markets can be weakly efficient but not all markets can exhibit the stronger forms of market efficiency (Frimpong, 2008).

The efficient market hypothesis has been closely linked with the idea of “random walk,”-a term used to characterize a price series where all future price changes represent random deviations from past prices (Malkiel, 2003). The random walk concept posits that in the absence of informational constraints, stock prices adjust to reflect the information at a given time such that future price changes will reflect only future information and will be independent of the price changes today. However, since news (information) by definition is unpredictable, it therefore implies that the resulting price changes be unpredictable and random (Malkiel, 2003). The implication is that in any capital market where stocks follow or exhibit random walk, prices fully reflect all known information, such that any investor (novice) buying a diversified portfolio at the tableau of prices given by the market will maximize the rate of return as that achieved by the financial experts (Malkiel, 2003). Thus, with random walk, future stock price changes are independently and identically distributed (iid).

Extensive literature abounds on the efficiency of the stock markets across the various exchanges in the world (see Borges (2008), *inter alia,* for extensive review). Nonetheless, the majority of the studies on stock market efficiency have focused on the behaviour of stock markets especially in developed economies where the weak-form efficiency hypothesis has seldomly been rejected (e.g., Kendall, 1953 and Fama, 1970). Borges (2008) studied the efficiency of stock market indexes of France, Germany, UK, Greece, Portugal and Spain and found out that the stock markets of France, Germany, UK and Spain exhibits a random walk behavior, while the markets in Greece and Portugal exhibits inefficiency due to serial positive correlation. Despite the fact that some studies have witnessed predictability of future price changes in these markets (Poterba and Summers, 1988; Hudson, Dempsey and Keasy, 1996), no evidence of profitable trading strategies based on that predictability has been shown. Hence, developed financial markets as a whole have proved to be weak-form efficient.

In contrast, evidence from emerging countries is controversial. Most of the research conducted on emerging markets in Asian and Latin American stock markets, produced mixed results. Barua (1987), Chan et al (1996) observed that the major Asian markets were weak form inefficient. Sharma and Kennedy (1977) tested random walk hypothesis on the Bombay Stock Exchange (BSE) and proved it as a weak-form efficient market. Poshakwale (1996) showed that Indian stock market was weak form inefficient; using daily BSE index data for the period 1987 to 1994. Also Gupta and Basu (2005), Mishra (2009) and Mishra et al (2009) found a consistent result that the Indian capital market does not exhibit a random walk behavior and are therefore inefficient. A synonymous result was obtained by Barnes (1986) on the Kuala Lumpur stock exchange. In Korea, Ryoo and Smith, (2002) using a variance ratio test found the market to follow a random walk process if the price limits were relaxed during the period March 1988 to Dec 1988.

Literature on the efficiency of capital markets in Africa are limited compared to other emerging markets. As noted by Mollah and Vitalli (2011), majority of the available empirical researches on Africa have focused mainly on the Johannesburg Stock Exchange (JSE) in South Africa. Studies on the efficiency of the JSE reveal that the exchange is weakly inefficient (see: Magnusson and Wydick, 2002; Smith, Jefferis and Ryoo, 2002; Simons and Laryea, 2005) except Appiah-Kusi and Menyah (2003) and Smith (2008). In Nigeria, Olowe (2002) and Okpara (2010) albeit using different methodological approaches found out that the Nigerian stock market exhibits a weak form market efficiency which contradicts previous results. The result on Ghana by Frimpong (2008) found that the Ghana stock exchange is not weak form efficient. Similar results were obtained for Egypt and Botswana (Mecagni and Sourial, 1999; Mollah, 2007).

Cross country analyses of the capital markets in Africa also reveal mixed results about the efficiency of capital markets in Africa. For instance, Magnusson and Wydick (2002), using three successively stronger tests of random walk, reveal that equity markets in Ghana and Zimbabwe, are not weak-form efficient. They however conclude that emerging capital markets such as Botswana, Cote d'Ivoire, Kenya, Mauritius, Nigeria and South Africa, exhibit are weak-form efficient. Again, Appiah-Kusi and Menyah (2003) found five (namely Egypt, Kenya, Mauritius, Morocco and Zimbabwe) out of eleven African countries to be weak-form efficient. However, as cited in Mollah and Vitalli (2011), Smith, Jefferis and Ryoo (2002) using the multiple variance ratio test on eight African stock market price indices (Botswana, Egypt, Kenya, Mauritius, Morocco, Nigeria, South Africa and Zimbabwe) over the period 1990-1998, showed that only South Africa was weak-form efficient. Simons and Laryea (2005) performed both parametric and non-parametric tests on four stock markets for the period 1990-2003 and also showed that only South Africa capital market was weak-form efficient whereas Egypt, Ghana and Mauritius were not. Interestingly, Smith (2008) applying four joint variance ratio tests rejected the random walk hypothesis for all the eleven African stock markets investigated.

The above review suggests the existence of a large pool of papers that examine the efficiency of capital markets both in developed and emerging capital markets. Among the factors that contribute to stock market efficiency is the introduction of electronic listing of firms on the exchanges since this enhances information flow and efficiency. The finance literature asserts that the introduction of automation on the stock markets enhances informational flow and efficiency, as information are quickly transmitted to all relevant agents and the market. Thus it is expected that migrating stock markets from manual trading to electronic based automation will improve efficiency of the capital markets. However, there is still a dearth of research that analyses the role of automation in stock market efficiency. Even with the few that exist, empirical findings have been mixed.

Using nonparametric statistical analysis, Freund and Pagano (2000) measured the degree of market efficiency before and after automation at the New York and Toronto Stock Exchanges. Their findings indicate that the level of informational efficiency in these exchanges remains effectively unchanged during the automation period. Their findings further reveal that automation in these exchanges coincides with an improvement in market efficiency at the Toronto Stock Exchange relative to the New York Stock Exchange.

Debysingh and Watson (2007) using both parametric and non parametric approaches to the degree of informational efficiency before and after the automation of the Jamaica (JSE) and Trinidad and Tobago (TTSE) stock exchanges finds mixed results. Findings reveal that exchanges are highly inefficient in both the pre and post automation periods, albeit an improvement in efficiency. Further, Benouda and Mezzez (2003) finds that automation of the Tunisian Stock Exchange (TSE) results in the improvement in the liquidity of shares, decreased returns but did not have significant effect on volatility or efficiency.

The forgoing review shows that although a lot of investigations have been conducted on stock markets efficiency across different markets in the world, little has been done in terms of investigating the potential role of electronic listing in stock market efficiency both in developed and particularly, in emerging markets in Africa. Findings from this paper is thus hoped to expand prevailing evidence on the role of automation in stock market efficiency from the perspective of an emerging capital market in sub-Saharan Africa.

## 3.0 Theoretical and Empirical Approach

The stock market is said to be efficient if the current stock market price fully mirrors all the available information about that stock market such that current stock prices is the best predictor of future prices. In other words, a stock market is said to be efficient if the stock market price follows a random walk. This implies that no prospective investor can readily earn extra profit above the market profit since information is fully reflected in the current price.

The Efficient Market Hypothesis (Fama,1970) expressed stock market efficiency as;

$$E(P_{j,t+1} \mid \phi_t) = P_{jt} + E(r_{j,t+1} \mid \phi_t)P_{jt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where E is the expectation value operator, $P_{jt}$ is the price of the j stock at time t, $P_{j,t+1}$ is the price of the j stock at time t+1, $r_{j,t+1}$ is the change in the stock market price index (return), and $\phi_t$ is the information set operator. Equation 1 says that the expected j stock price at time t+1 conditioned on the information available at time t is the sum of the j stock price at time t and the product of the expected return of the j stock at time t+1 conditioned on the information available at time t and the j stock market price at time t. The stock market equation expressed above in equation (1) implies that in determining the equilibrium expected returns, the information set operator is fully exploited.

The underlying assumption that market equilibrium determination can be stated in terms of expected returns conditioned on the information set available at the time has an important implication. That is, the possibility of engaging in a trading system where the expected profit is in excess of the equilibrium expected profit is ruled out. The mathematical exposition that iterates this process is given as;

$$X_{j,t+1} = P_{j,t+1} - E(P_{j,t+1} \mid \phi_t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where $X_{j,t+1}$ is the excess market value of the j stock at time t+1. Equation 2 says that the excess market value of a stock is the difference between the actual observed stock market price at time t+1 and the expected stock market price at time t+1 conditioned on the information available at time t. Given the fact that the expected stock market price at time t+1 conditioned on the information available is assumed to be zero, that is,

$$E(P_{j,t+1} \mid \phi_t) = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The excess market value of the j stock at time t+1 is identical to the actual observed stock market price at time t+1. That is equation (2) now becomes;

$$X_{j,t+1} = P_{j,t+1} \qquad (4)$$

Various techniques have been employed in the literature to analyse the weak form efficiency hypothesis. These include the Runs test (Bradley, 1968), LOMAC variance ratio test (Lo and Mackinlay, 1988), Durbin Watson test, Unit root test of randomness in series, the GARCH model, inter alia. In this study we employ both the unit root test of randomness of series and GARCH (1, 1) model to test for the efficiency of the Ghana Stock Exchange Market prior to the automation period and post the automation period.

### 3.1 Unit root test of Random Walk Hypothesis

The most widely used approaches in the literature to examine whether the variable of interest follows a random walk is the unit root test. A time series variable is observed to follow a random walk if the variable contains unit root (non-stationary). A *stationary* time series is one whose statistical properties such as mean, variance, autocorrelation, are time invariant. Thus stationarized series is relatively easy to predict[4], hence does not follow a random walk process.

The weak form efficiency of the Efficient Market Hypothesis (EMH) implies that stock prices (returns) are due to the residual error term which is stochastically determined. In other words the market is efficient if the returns (prices) follow a random walk. The random walk hypothesis however requires that the price index series contains a unit root or non-stationary in levels.

However, Gilmore and McManus (2003, p.44) argues that, “a unit root is a necessary but not sufficient condition for a random walk”. Vitali and Molah (2011) stress that “in fact, a unit root process may imply the presence of predictable elements, in this case predictable successive price changes or returns, which are not consistent with the RWH, where these returns should be unpredictable, i.e. independent. It follows that the non-stationarity hypothesis can be verified through unit root tests whereas the independence assumption through the use of other tests”. As a result, this paper adopts the BDS test of Non-Linear Serial Independence would be used to supplement the results of the Unit root test.

Notable among the unit root tests of randomness of series include Dickey Fuller test (DF), Augmented Dickey Fuller test (ADF), Phillip-Perron test (PP), and Kwiatkowski, Phillips,

[4] http://www.duke.edu/~rnau/411diff.htm

Schimdt and Shin (KPSS) test. Specifically, this study adopts the ADF and the PP tests of randomness of series.

### 3.2 Non-Linearity Test

A crucial assumption of the efficient market hypothesis is that agents on the market are rational. That is, brokers are risk averse, make unbiased forecasts, and respond instantaneously to new information (Gandhi et al, 2005). Thus, the assumption of rationality implies linearity in the data generating process. However, emerging stock markets are characterized by market imperfections which sometimes cause investors to behave irrationally: an indication of non-linear dependencies. Gandhi et al (2005) asserts "given that a significant number of traders in emerging markets may trade on the basis of imperfect information, share prices are likely to deviate from their equilibrium values. In addition, given the informational asymmetries and lack of reliable information, noise traders in emerging markets may also lean towards delaying their responses to new information in order to assess informed traders' reaction, and then respond accordingly. The theory and empirical evidence of non-linearity in share price changes suggest that the i.i.d assumption is a necessity for an appropriate examination of efficiency market hypothesis". Therefore, this paper will examine the non-linearity in the stock market returns using the BDS test.

### 3.3 The GARCH (1, 1) Model

The ARCH models and the generalized ARCH models (GARCH) were introduced by Engle (1982) and Bollerslev (1980) respectively. These models are widely used in various branches of econometrics especially in financial time series analysis. These models permit for a time variant conditional variance and nonlinearities in the data generating mechanism. As noted by Brook and Burke (2003), the GARCH (1, 1) model is sufficient to capture all of the volatility clustering present in the data.

The GARCH (1, 1) model is based on the fundamental premise that the forecasts of time varying variance depend on the lagged variance of the asset. Based on the standard GARCH (1, 1) model specification, we specify the GARCH (1, 1) estimated in this work as;

$$r_t = w_1 + \gamma r_{t-1} + \zeta_t \qquad (6)$$

$\delta_t^2 = w_2 + \alpha\zeta_{t-1} + \beta\delta_{t-1}^2$..............................(7)

Where equation (10) is the mean equation expressed as a function of previous return ($r_{t-1}$), which is the change in the stock price index, a mean, $w_1$, and an error term, $\zeta_t$. Since $\delta_t^2$ is the one-period ahead forecast variance conditioned on past information, equation (7) is called the conditional variance equation. This equation has three parts;

The mean; $w_2$.

News about volatility from the previous period, measured as the lag of the squared residual from the mean equation; $\zeta_{t-1}$ (the ARCH effect).

Last period's forecast variance; $\delta_{t-1}^2$ (the GARCH effect).

The estimation of the ARCH models is based on the method of maximum likelihood estimation method under the assumption that the errors are conditionally normally distributed. The conditional variance equation is often interpreted in financial context as where an agent or trader predicts this period's variance by forming a weighted average of a long term average (constant term), the forecasted variance from the last period (the GARCH effect), and information about volatility observed in the previous period (the ARCH effect). If the asset return was unexpectedly large in either the upward or downward direction, then the trader will increase the estimate of the variance for the next period.

The autoregressive root which governs the persistence of volatility shocks is the sum of alpha and beta, that is $\alpha + \beta < 1$, which is expected to be less than one an indication of stock market efficiency. However, if, $\alpha + \beta \approx 1$, or even $\alpha + \beta > 1$ it shows a very high volatility clustering which is an indication of an inefficient stock market. Both $\alpha$ and $\beta$ should be nonnegative. Specifically, we estimate the above GARCH (1, 1) model using the Bollerslev-Woldridge's Quasi-Maximum Likelihood Estimator (QMLE) assuming the Gaussian standard normal distribution. This work differs from the works by Frimpong (2007), and Efobi (2010) since it assesses the effect of automation (technology) on the efficiency level of stock market in Ghana. To determine whether electronic listing of stock market prices impacts on stock market efficiency, two separate regressions were estimated using the before-after-approach. Specifically, we run the same GARCH models for the pre and post automation sample periods.

### 3.4 Data type and sources

The tests outlined were estimated using the logarithmic returns of the closing prices of the Ghana Stock Exchange All-Share index from 2006 to 2011. To differentiate between the efficiency levels in the pre and post automation periods, estimations were done for the pre-automation and post automation periods. Since the automation process took some time before it was finally implemented as a result of some institutional challenges including a fire outbreak at the exchange, the periods of implementation were excluded. Therefore the pre-automation period is taken as the 684 trading days from 17th February 2006 to 13th November 2008, whiles the post automation period is taken as the 684 trading days[5] spanning from 30th March 2009 to 30th December, 2011. Thus, the period starting from 14th November 2008 to 27th March 2009 were excluded from the analysis since during this period the GSE was operating under both manual listing and automated listing. In addition to the comparative analysis of the efficiency analysis, we present analysis of the overall efficiency of the exchange over the entire period from 17th February 2006 to 30th December, 2011. The essence of this is to compare analysis of stock market efficiency that does not consider the impact of technology with stock market efficiency analysis that considers the impact of technological change.

## 4. Analysis of Results

### 4.1 Descriptive Statistics of the GSE Returns during Pre and Post Automation Periods

A summary of the descriptive statistics of the GSE returns over the two sub-periods are presented in Table1. The descriptive statistics reveal that the average return in the pre-automation period is higher than the post automation period. The average market returns is positive for the pre-automation period whilst negative for the post-automation era. This perhaps indicates that returns to the GSE All Share index generally slumped after the automation of the exchange. However, despite the relatively low average returns of the post-automation period the standard deviation reveals relatively high volatility in returns during this period than the pre-automation period. Evidence of such volatility is shown in figure 1. As shown in Figure 1, the Q-Q plot for the pre-automation period is concave, confirming that the distribution of the GSE returns is positively skewed with a long right tail. Also the Quantile-Quantile plot of the GSE

[5] Trading days excludes public and statutory holidays and weekends

returns for the post automation period is convex which indicates that the distribution of the GSE returns is negatively skewed with a long left tail. For the post automation period, the distribution is very close to a lognormal distribution. This confirms the descriptive statistics shown in Table 1. The relatively high volatility in the post-automation period signals high risk during the period of automation of the exchange.

Table 1: Descriptive statistics

| **Measures** | **Pre-Automation** | **Post-Automation** |
|---|---|---|
| Observations | 684 | 684 |
| Mean | 0.001181 | -0.000377 |
| Median | 0.000137 | 9.86E-06 |
| Maximum | 0.059186 | 0.048302 |
| Minimum | -0.019862 | -0.087540 |
| Standard Deviation | 0.004651 | 0.010774 |
| Skewness | 6.520576 | -1.041882 |
| Kurtosis | 65.28186 | 13.72070 |
| Jacque-Bera | 115399.4 | 3399.350 |
| Probability | 0.000000 | 0.000000 |

The return for the GSE during pre-automation period is positively skewed indicating a greater probability of large increases in market portfolio returns than falls. On the other hand, return for the post-automation period is negatively skewed indicating a higher probability of large decreases in market portfolio returns than increases. In other words, the returns in both periods can be described as asymmetric.

However, the distribution of returns in both periods is highly leptokurtic[6] (peaked). Thus, skewed and leptokurtic frequency distributions of GSE returns series in both periods indicate that the distributions are not normal. These results are consistent with the Jarque-Bera test of normality. It rejects the null hypothesis of normal distribution for both periods. Further tests for normality as shown in Table 2 reject the null hypothesis of normality at the 1% significance level, confirming the result of the descriptive statistics shown in Table 1. Thus, the GSE returns do not exhibit normal distribution for both periods.

[6] When the kurtosis or degree of excess in the  returns is very large greater than the normal value of 3

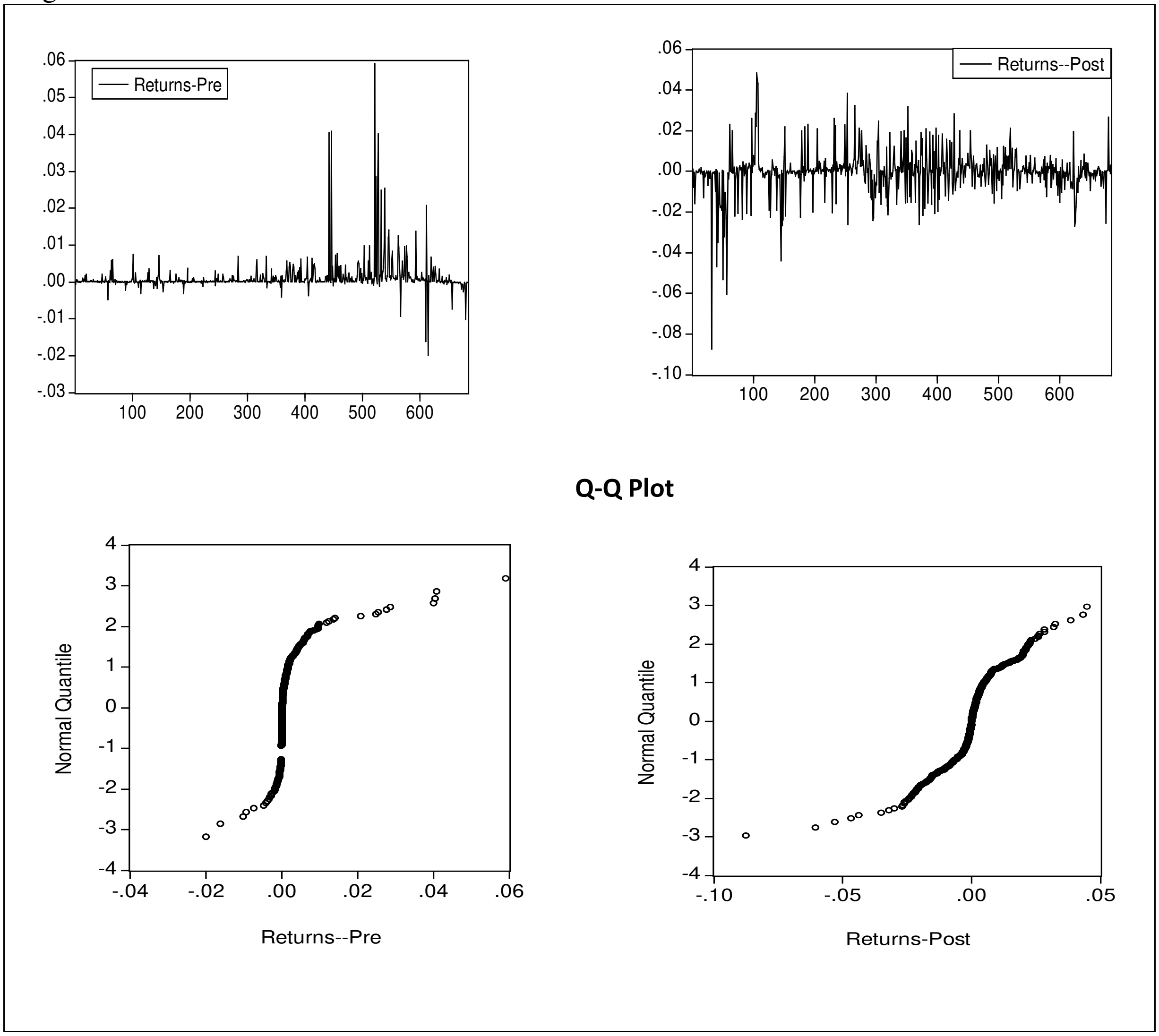
**Table 2: Empirical Distribution Test**

| Method | Pre-automation Period | Post-automation Period |
|---|---|---|
| Lillie Fors (D) | 0.312017*** | 0.186164*** |
| Cramer-Von Mises (W2) | 27.46562*** | 8.316571*** |
| Watson (V2) | 26.71817*** | 8.282180*** |
| Anderson-Darling (A2) | 149.3697*** | 40.01088*** |

***** *indicates significance at 1%.*

Rejecting the normality assumption has implications for the random walk model. If stock returns series follow a normal distribution, it implies that it exhibits a random-walk process and hence the market is said to exhibit weak-form of efficiency. Thus, given the results of the normality test we can say the market during both periods shows some level of weak- form inefficiency.

Figure 1: GSE Returns and Tail Distribution




## 4.2 Unit Root Test and the Weak Form Efficiency Hypothesis

The unit root approach was used to test for the weak form efficiency hypothesis using the Augmented Dickey Fuller test and the Phillip-Perron tests. The test was conducted for two cases; constant, and constant and linear trend. Results of the unit root tests (Table 3) in all the two cases considered reveal that all the series (market returns) in both the pre and post automation periods are stationary in levels. Thus we reject the null hypothesis that the series contain unit root at 1% significance level.

**Table 3: Unit root test for GSE Market Returns**

| SAMPLE | INTERCEPT | | TREND & INTERCEPT | |
|---|---|---|---|---|
| | ADF | PP | ADF | PP |
| Pre-Automation | -5.922*** | -27.648*** | -6.131*** | -27.147*** |
| Post-Automation | -14.080*** | -25.231*** | -14.168*** | -25.201*** |

*** indicates 1% level of significance

This implies that for all the two cases the GSE market returns do not follow random walk hence exhibit weak form inefficiency. Thus, the automation of the exchange has not significantly improved the efficiency of the capital market. This inefficiency implies that the market provides the opportunity for profitable arbitrage by market watchers since returns can be accurately predicted using past information. Even though the unit root approach to testing the weak-form efficiency reveals knowledge on whether there is evidence of random walk or not, it fails to show the degree of volatility clustering

### 4.3 GARCH (1, 1) Model and Weak Form Efficiency Hypothesis

Contrary to the unit root test of weak-form efficiency, the GARCH (1, 1) model allows to determine the level of volatility clustering in market returns which has implications on the efficiency levels. Table 4 shows the result for the GARCH (1, 1) model for the pre and post-automation periods.

Table 4: GARCH (1, 1) Model for Stock Market Returns

| GARCH (1,1) | Pre-Automation | Post-Automation |
|---|---|---|
| ***Mean Equation*** | | |
| $w_1$ | 0.000233** | -6.52E-05 |
| AR(1) | 0.044148 | 0.101398** |
| ***Variance Equation*** | | |
| $w_2$ | 1.61E-08* | 1.30E-05 |
| ARCH(1) | 0.036469** | 0.073117* |
| GARCH(1) | 0.980558*** | 0.812700*** |

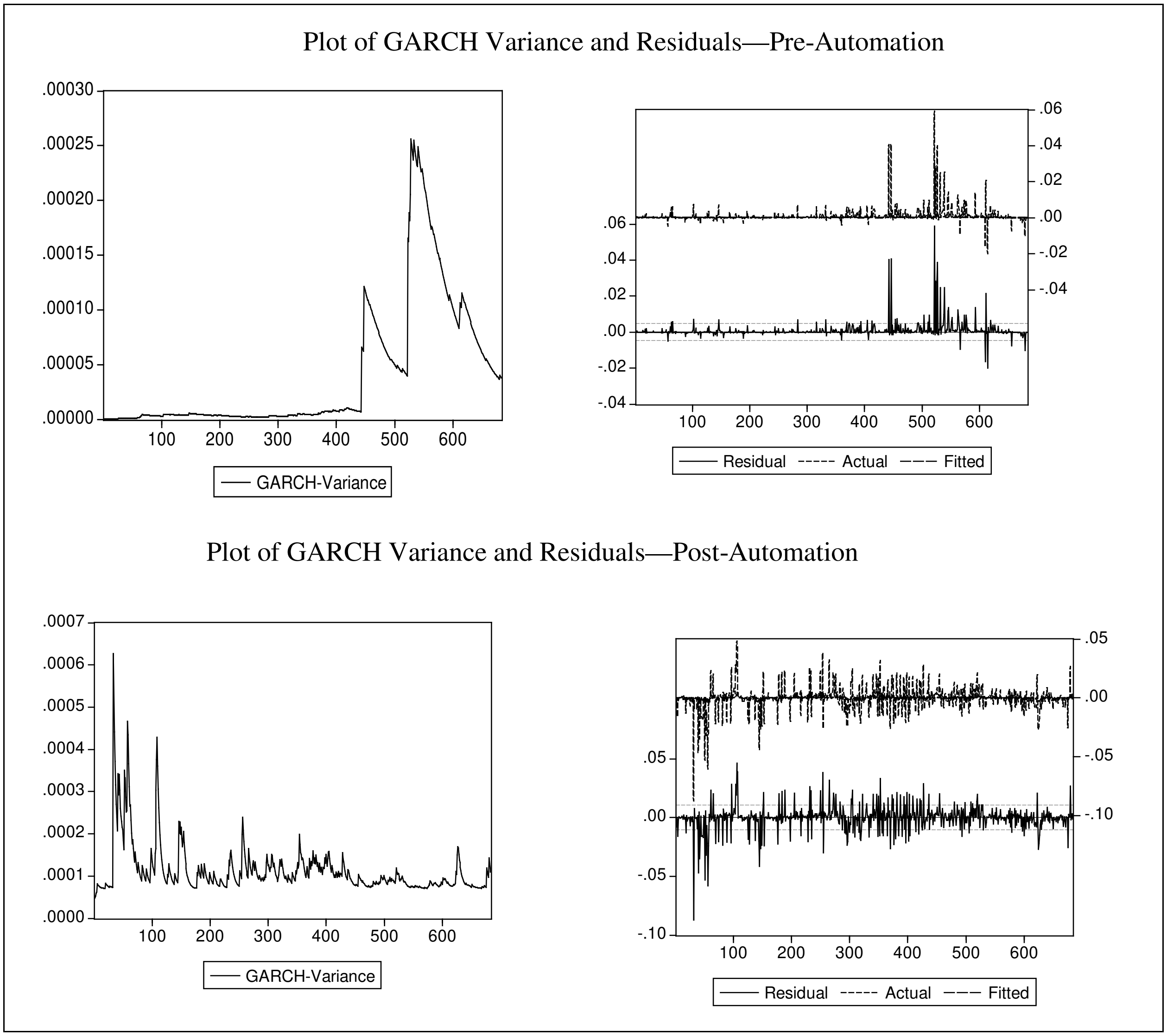
**,**,*** significance at 10%, 5% and 1% respectively*

Results for the GARCH (1,1) model for the Pre-Automation Period indicate that the AR(1) parameter in the mean equation is not statistically significant at even 10%. This confirms the random walk hypothesis which posits that changes in current prices are attributed to random (noise) effects rather than previous prices. In other words, stock market returns in the pre-automation period follow a random walk and as a result market watchers cannot easily forecast correctly future trends in market prices. Therefore GSE during the pre-automation period exhibited some weak form efficiency. However, the sum of the ARCH and GARCH effects in the variance equation shows contrary results. Weak form efficiency requires that the sum of the ARCH and GARCH terms to be less than unitary and significant. The results show that the sum of the ARCH and GARCH effects are approximately one which indicates the presence of very high persistence of volatility clustering on the GSE market during the period. This is an indication of inefficiency on the exchange.

Results for the GARCH (1,1) model for the Post-Automation Period (Table 4) indicate that the AR(1) parameter in the mean equation is statistically significant at 5%. This implies that current prices are determined largely by previous prices and thereby violates the random walk hypothesis which posits that changes in current prices are attributed to random (noise) effects. In other words, stock market returns in the post-automation period does not follow a random walk and as a result market watchers can easily forecast correctly future trends in market prices. Therefore GSE during the post-automation period do not exhibit weak form efficiency. This result is confirmed by the ARCH and GARCH effects in the variance equation which are significant at 10% and 1% respectively. The sum of the ARCH and GARCH effects is very high (0.88) and closer to 1. This suggests a high persistence of volatility clustering on the GSE market during the period. These results confirm that the GSE market during the post-automation period is (weakly) inefficient.

Figure 2 depicts the estimated GARCH variances and residuals for both periods. The variance plot for the pre-automation period reveals very high persistent volatility for the latter part of the period, remaining relatively stable however, for most part of the period. There is duration of time where the volatility is relatively high and relatively very modest. The plot of the conditional variance for the post-automation period portrays higher degree of volatility clustering for the first 100 observation but the degree of volatility persistence moderates thereafter.

Figure 2: Plot of GARCH Variance and Residuals




## 4.4 BDS Test for Linear Independence

From the GARCH model we generated the standardized residuals and used them to test for non-linear serial independence. Specifically, we used the BDS test of serial independence in which the significant levels are based on asymptotic theory and then bootstrap the significance levels using 1000 bootstrap replications under null hypothesis of serial independence. The results of the BDS test (shown in Table 5) indicate that BDS statistics for both periods are statistically significant at the 1% level.

Table 5: BDS Test of non-linear serial independence

| Dimension | Pre-Automation | Post-Automation |
|---|---|---|
| | BDS Statistic | BDS Statistic |
| 2 | 0.027543*** | 0.015426*** |
| 3 | 0.046444*** | 0.030004*** |
| 4 | 0.060275*** | 0.045470*** |
| 5 | 0.068008*** | 0.053533*** |
| 6 | 0.065970*** | 0.055137*** |

Thus we fail to accept the null hypothesis of serial independence for the GARCH model. This suggests that the residuals from the GARCH models for both pre and post automation periods are not identically independently distributed—an indication of some hidden non-linear structure that drives the GSE returns series. In other words the GSE returns in both periods do not follow random walk and hence inefficient. Thus, the evidence suggests that the introduction of automation to the operations of the Ghana Stock Exchange has not significantly improved the efficiency of the exchange.

## 4.5 Analysis for Entire Period

This section presents analysis of the Weak Form Efficiency for the GSE by using data from 17$^{th}$ February 2006 to 30$^{th}$ December, 2011 including the 90 trading days during which the exchange was being automated.

### 4.5.1 Descriptive Statistics

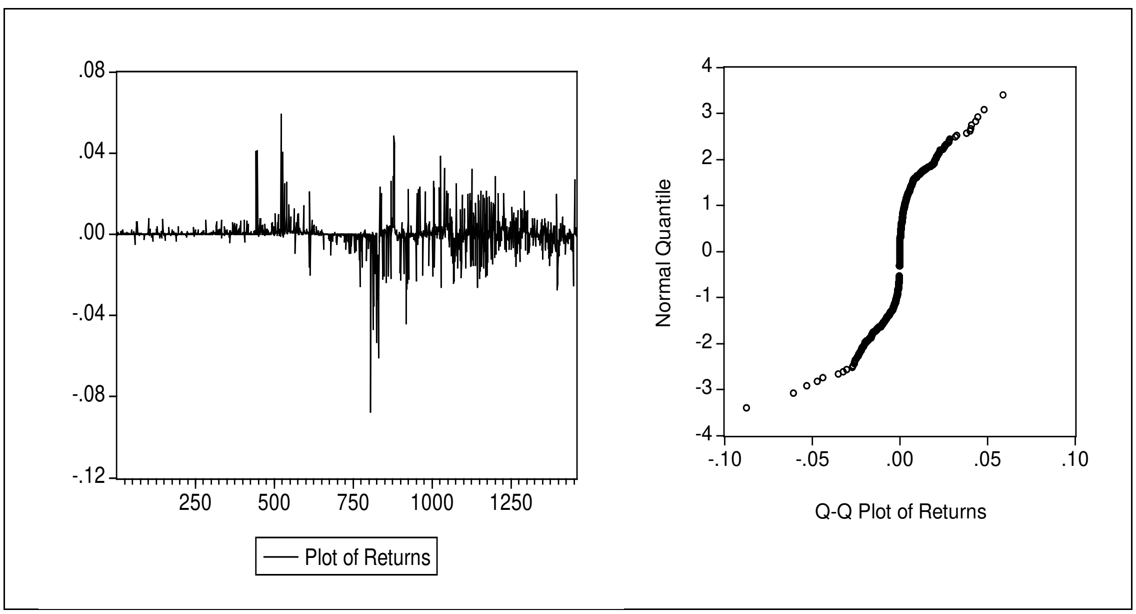
A summary of the descriptive statistics of the GSE returns over the entire period (with and without automation) are presented in Table 6. The diagnostic test reveal GSE returns ranges between -0.088 and 0.059 with a low positive average approximately equal to zero.

Table 6 Descriptive Statistics for the Entire Period

| Measures | GSE Returns |
|---|---|
| Observations | 1458 |
| Mean | 0.000283 |
| Median | 7.41E-05 |
| Maximum | 0.059186 |
| Minimum | -0.087540 |
| Standard Deviation | 0.008132 |
| Skewness | -0.743005 |
| Kurtosis | 23.81689 |
| Jacque-Bera | 26459.74 |
| Probability | 0.000000 |

The high standard deviation with respect to the mean is an indication of the high volatility in the market returns and the risky nature of the market (Frimpong, 2008). A plot of the returns in Figure 3 gives pictorial evidence of the volatility in the market returns and skewness.

Figure 3: GSE Returns and Tail Distribution




The GSE returns show evidence of significant negative skewness implying a higher probability of large decreases in market portfolio returns than increases. Also, the distribution of returns is highly leptokurtic. The nature of skewness and spread (kurtosis) signals asymmetry in the distribution of market returns. This is consistent with the results of the Jarque-Bera test of normality which shows that the distribution deviates from normality. Further test for normality (shown in Table 7) confirms the results of the Jacque Berra test indicating that the series are not normally distributed.

Table 7: Empirical Joint Distribution Test

| Method | Value | Probability |
|---|---:|---:|
| Lilliefors (D) | 0.252762 | 0.0000 |
| Cramer-von Mises (W2) | 35.79137 | 0.0000 |
| Watson (U2) | 35.78714 | 0.0000 |
| Anderson-Darling (A2) | 171.4071 | 0.0000 |

### 4.5.2 Unit Root Test and the Weak Form Efficiency Hypothesis

The results of the unit root test shows that the GSE returns over the entire period[7] are stationary in levels at 1% significance level. This implies that returns on the exchange do not exhibit any characteristics of random walk and therefore the stock prices can be accurately predicted thereby giving opportunity for profitable arbitrage by market watchers by forecasting accurately trends in market—a characteristic of market inefficiency

Table 8: Unit Root Test of GSE Returns

| TEST STATISTIC | INTERCEPT | TREND & INTERCEPT | NONE |
|---|---|---|---|
| ADF Statistic | -10.29053*** | -10.31882*** | -10.27005*** |
| PP Statistic | -39.42858*** | -39.37020*** | -39.46531*** |

### 4.5.3 GARCH (1,1) Model

Results for the GARCH (1,1) model reveal that the AR(1) parameter in the mean equation is not statistically significant at even 10%. In other words previous stock prices do not significantly determine current prices. This connotes the postulate of the random walk hypothesis that changes in series are attributed solely to random (noise) events.

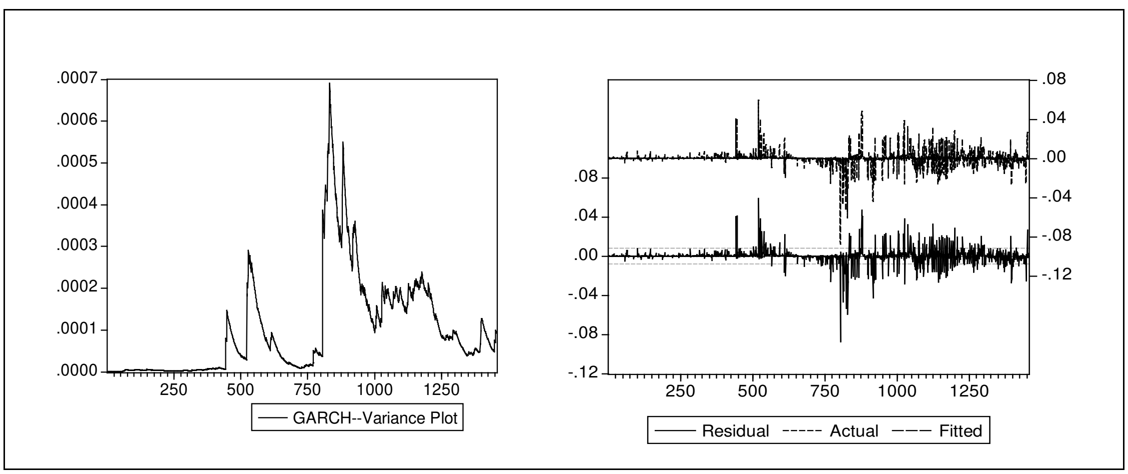
[7] with and without automation

Table 9: GARCH (1,1) Model

| GARCH (1,1) | |
|---|---|
| ***Mean Equation*** | |
| $w_1$ | 0.000214 |
| AR(1) | 0.061789 |
| ***Variance Equation*** | |
| $w_2$ | 3.15E-08*** |
| ARCH(1) | 0.045797** |
| GARCH(1) | 0.971067*** |

This implies that the stock market returns in the entire period follow a random walk and hence efficient. However, the sum of the ARCH and GARCH effects in the variance equation shows contrary conclusions. The combined ARCH and GARCH effects is very high (1.01)—an indication of persistent high volatility clustering in the GSE market returns and hence inefficient. A plot (figure 4) of the variance and residuals generated from the GARCH (1,1) estimated confirm the presence of high volatility in the returns.

Figure 4: Plot of GARCH Variance and Residuals




To ascertain the true efficiency status of the exchange over this period, the analysis was further subjected to test of non-linearity using the BDS Test of non-linear serial independence and presented in Table (10).

Table 10: BDS Test of non-linear serial independence

| Dimension | BDS Statistic |
|---|---|
| 2 | 0.031254*** |
| 3 | 0.065038*** |
| 4 | 0.092098*** |
| 5 | 0.109877*** |
| 6 | 0.120008*** |

The result from the BDS test is highly significant at 1%. Therefore we conclude that there is evidence of significant non-linearity in the DSI returns data and therefore GSE returns do not follow a random walk and hence inefficient.

### 4.5.4 Test for Serial Correlation, Heteroscedasticity, and Normality In Residuals

Finally, the estimated GARCH models were subjected to serial correlation, heteroscedasticity and normality in residuals tests. The correlogram of squared standardized residuals was used to test for the presence of serial correlation in residuals in the variance equation. The results (shown in the appendix) indicate that the GARCH models estimated for all the periods (pre and post, and entire-period) there is no serial correlation in residuals of the variance equation. This suggests that the variance equation is correctly specified.

The tests for heteroscedasticity and normality in residuals are shown in table 11. From the table it is evident that the standardized residuals do not exhibit additional ARCH effect for all models. This is shown by the insignificance of the ARCH LM Test. Also the Jacque Bera test shows that the null hypothesis of normally distributed residuals cannot be accepted. This means that the histogram plots of the residuals are not bell-shaped.

Table 11 Test for Heteroscedasticity and Normality of Residuals

| TEST | Pre-automation | Post-automation | Full period |
|---|---|---|---|
| ARCH LM TEST: Heteroscedasticity | 0.03296<br>(0.8560) | 0.00267<br>(0.9588) | 0.04240<br>(0.8369) |
| Jacque Bera Test of normality | 252362.6<br>(0.0000) | 8778.769<br>(0.0000) | 504295<br>(0.0000) |

*Figures in the parentheses are the probability values*

## 5. Conclusions and policy implications

This paper examines efficiency of the Ghana stock exchange within the framework of the Weak form efficiency for the periods before and after the automation of the exchange. The Weak form efficiency hypothesis for the GSE was tested using the GSE returns. The results of the study over the entire period confirms the findings of Frimpong (2008) that GSE market does not exhibit weak form efficiency. The study further assessed the effect of technology on stock market efficiency in Ghana. The result showed that, the stock market even after the automation did not exhibit weak-form efficiency. This suggest that the automation of the exhange has not improved the efficiency levels of the exchange.

From the foregoing, we recommend that: The trading rules of the exchange should be amended to allow on-line trading services to allow investors with the expertise to make their own trading decisions independent of the services of a certified stock broker. This has the advantage of faster transactions, low commission charges and have the tendency of increasing market volumes and capitalization. Also, information on the stock market, such as data should be made easily accessible to the public, especially, potential investors so as to improve the efficiency of the market. Further research could also be conducted into the post-automation efficiency level of the GSE by adopting different estimation techniques as well as extending the sample size so as to ascertain the exact impact of the automation on exchange.

# APPENDIX

**Table :** serial correlation test for post-automation garch model
Test name: correlogram of squared standardised residuals

Sample: 2 684
Included observations: 683

| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| .\|. \| | .\|. \| | 1 | -0.002 | -0.002 | 0.0027 | 0.959 |
| .\|. \| | .\|. \| | 2 | -0.000 | -0.000 | 0.0028 | 0.999 |
| .\|. \| | .\|. \| | 3 | -0.013 | -0.013 | 0.1122 | 0.990 |
| .\|. \| | .\|. \| | 4 | -0.008 | -0.008 | 0.1560 | 0.997 |
| .\|. \| | .\|. \| | 5 | -0.013 | -0.013 | 0.2748 | 0.998 |
| .\|. \| | .\|. \| | 6 | 0.004 | 0.004 | 0.2884 | 1.000 |
| .\|. \| | .\|. \| | 7 | -0.005 | -0.005 | 0.3035 | 1.000 |
| .\|. \| | .\|. \| | 8 | 0.065 | 0.064 | 3.2120 | 0.920 |
| .\|. \| | .\|. \| | 9 | -0.008 | -0.007 | 3.2521 | 0.953 |
| .\|. \| | .\|. \| | 10 | 0.009 | 0.009 | 3.3041 | 0.973 |
| .\|. \| | .\|. \| | 11 | 0.004 | 0.006 | 3.3182 | 0.986 |
| .\|. \| | .\|. \| | 12 | -0.004 | -0.003 | 3.3289 | 0.993 |
| .\|. \| | .\|. \| | 13 | 0.000 | 0.002 | 3.3289 | 0.996 |
| .\|. \| | .\|. \| | 14 | -0.014 | -0.015 | 3.4727 | 0.998 |
| .\|. \| | .\|. \| | 15 | -0.009 | -0.008 | 3.5278 | 0.999 |
| .\|. \| | .\|. \| | 16 | -0.010 | -0.014 | 3.5936 | 0.999 |
| .\|. \| | .\|. \| | 17 | -0.007 | -0.007 | 3.6317 | 1.000 |
| .\|. \| | .\|. \| | 18 | -0.012 | -0.013 | 3.7282 | 1.000 |
| .\|* \| | .\|* \| | 19 | 0.132 | 0.131 | 15.976 | 0.659 |
| .\|. \| | .\|. \| | 20 | -0.019 | -0.019 | 16.218 | 0.703 |
| .\|. \| | .\|. \| | 21 | 0.013 | 0.013 | 16.336 | 0.751 |
| .\|. \| | .\|. \| | 22 | -0.003 | 0.001 | 16.344 | 0.798 |
| .\|. \| | .\|. \| | 23 | -0.015 | -0.013 | 16.493 | 0.833 |
| .\|. \| | .\|. \| | 24 | 0.010 | 0.015 | 16.564 | 0.867 |
| .\|* \| | .\|* \| | 25 | 0.092 | 0.094 | 22.641 | 0.599 |
| .\|. \| | .\|. \| | 26 | -0.009 | -0.007 | 22.699 | 0.650 |
| .\|. \| | .\|. \| | 27 | 0.012 | -0.005 | 22.795 | 0.696 |
| .\|. \| | .\|. \| | 28 | -0.025 | -0.019 | 23.241 | 0.721 |
| .\|. \| | .\|. \| | 29 | -0.013 | -0.017 | 23.358 | 0.760 |
| .\|. \| | .\|. \| | 30 | 0.001 | 0.003 | 23.359 | 0.800 |
| .\|. \| | .\|. \| | 31 | 0.001 | 0.002 | 23.360 | 0.836 |
| .\|. \| | .\|. \| | 32 | 0.005 | 0.003 | 23.380 | 0.866 |
| .\|. \| | .\|. \| | 33 | -0.017 | -0.027 | 23.584 | 0.886 |
| .\|. \| | .\|. \| | 34 | 0.015 | 0.019 | 23.745 | 0.905 |
| .\|. \| | .\|. \| | 35 | -0.015 | -0.015 | 23.904 | 0.922 |
| .\|. \| | .\|. \| | 36 | -0.016 | -0.011 | 24.091 | 0.935 |

**Table :** serial correlation test for pre-automation garch model

testt name: correlogram of squared
Sample: 2 685
Included observations: 684

| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| .\|. \| | .\|. \| | 1 | -0.007 | -0.007 | 0.0332 | 0.855 |
| .\|. \| | .\|. \| | 2 | 0.002 | 0.002 | 0.0357 | 0.982 |
| .\|. \| | .\|. \| | 3 | -0.009 | -0.009 | 0.0939 | 0.993 |
| .\|* \| | .\|* \| | 4 | 0.090 | 0.090 | 5.7384 | 0.220 |
| .\|. \| | .\|. \| | 5 | -0.003 | -0.002 | 5.7455 | 0.332 |
| .\|. \| | .\|. \| | 6 | 0.009 | 0.009 | 5.8058 | 0.445 |
| .\|. \| | .\|. \| | 7 | -0.009 | -0.007 | 5.8565 | 0.557 |
| .\|. \| | .\|. \| | 8 | -0.004 | -0.012 | 5.8662 | 0.662 |
| .\|. \| | .\|. \| | 9 | -0.006 | -0.005 | 5.8878 | 0.751 |
| .\|. \| | .\|. \| | 10 | -0.008 | -0.010 | 5.9353 | 0.821 |
| .\|. \| | .\|. \| | 11 | -0.001 | 0.001 | 5.9356 | 0.878 |
| .\|. \| | .\|. \| | 12 | -0.009 | -0.008 | 5.9890 | 0.917 |
| .\|. \| | .\|. \| | 13 | -0.008 | -0.007 | 6.0341 | 0.945 |
| .\|. \| | .\|. \| | 14 | -0.007 | -0.005 | 6.0637 | 0.965 |
| .\|. \| | .\|. \| | 15 | -0.009 | -0.009 | 6.1209 | 0.978 |
| .\|. \| | .\|. \| | 16 | -0.007 | -0.006 | 6.1578 | 0.986 |
| .\|. \| | .\|. \| | 17 | -0.005 | -0.004 | 6.1783 | 0.992 |
| .\|. \| | .\|. \| | 18 | -0.003 | -0.002 | 6.1847 | 0.995 |
| .\|. \| | .\|. \| | 19 | -0.008 | -0.007 | 6.2325 | 0.997 |
| .\|. \| | .\|. \| | 20 | -0.008 | -0.007 | 6.2786 | 0.998 |
| .\|. \| | .\|. \| | 21 | -0.009 | -0.009 | 6.3409 | 0.999 |
| .\|. \| | .\|. \| | 22 | -0.009 | -0.010 | 6.4043 | 1.000 |
| .\|. \| | .\|. \| | 23 | -0.009 | -0.008 | 6.4630 | 1.000 |
| .\|. \| | .\|. \| | 24 | -0.008 | -0.007 | 6.5043 | 1.000 |
| .\|. \| | .\|. \| | 25 | -0.003 | -0.002 | 6.5129 | 1.000 |
| .\|. \| | .\|. \| | 26 | -0.001 | 0.000 | 6.5133 | 1.000 |
| .\|. \| | .\|. \| | 27 | 0.001 | 0.002 | 6.5135 | 1.000 |
| .\|. \| | .\|. \| | 28 | -0.007 | -0.006 | 6.5452 | 1.000 |
| .\|. \| | .\|. \| | 29 | -0.008 | -0.009 | 6.5962 | 1.000 |
| .\|. \| | .\|. \| | 30 | 0.009 | 0.008 | 6.6544 | 1.000 |
| .\|. \| | .\|. \| | 31 | -0.008 | -0.009 | 6.6979 | 1.000 |
| .\|. \| | .\|. \| | 32 | -0.007 | -0.007 | 6.7314 | 1.000 |
| .\|. \| | .\|. \| | 33 | -0.005 | -0.005 | 6.7516 | 1.000 |
| .\|. \| | .\|. \| | 34 | -0.007 | -0.009 | 6.7828 | 1.000 |
| .\|. \| | .\|. \| | 35 | -0.009 | -0.008 | 6.8423 | 1.000 |
| .\|. \| | .\|. \| | 36 | 0.002 | 0.002 | 6.8444 | 1.000 |

**Table :** serial correlation test for full-period garch model

Test name: correlogram of squared standardized residuals

Sample: 2/20/2006 12/30/2011

Included observations: 1457

| Autocorrelation | Partial Correlation | | AC | PAC | Q-Stat | Prob |
|---|---|---|---|---|---|---|
| \| \| | \| \| | 1 | -0.005 | -0.005 | 0.0426 | 0.837 |
| \| \| | \| \| | 2 | 0.001 | 0.001 | 0.0432 | 0.979 |
| \| \| | \| \| | 3 | -0.007 | -0.007 | 0.1150 | 0.990 |
| \| \| | \| \| | 4 | 0.040 | 0.040 | 2.4449 | 0.655 |
| \| \| | \| \| | 5 | -0.004 | -0.003 | 2.4632 | 0.782 |
| \| \| | \| \| | 6 | 0.003 | 0.003 | 2.4744 | 0.871 |
| \| \| | \| \| | 7 | -0.006 | -0.006 | 2.5336 | 0.925 |
| \| \| | \| \| | 8 | 0.004 | 0.002 | 2.5556 | 0.959 |
| \| \| | \| \| | 9 | -0.005 | -0.005 | 2.5914 | 0.978 |
| \| \| | \| \| | 10 | -0.003 | -0.003 | 2.6026 | 0.989 |
| \| \| | \| \| | 11 | -0.002 | -0.002 | 2.6101 | 0.995 |
| \| \| | \| \| | 12 | -0.007 | -0.007 | 2.6749 | 0.997 |
| \| \| | \| \| | 13 | -0.000 | -0.000 | 2.6752 | 0.999 |
| \| \| | \| \| | 14 | -0.006 | -0.006 | 2.7318 | 0.999 |
| \| \| | \| \| | 15 | -0.007 | -0.007 | 2.7955 | 1.000 |
| \| \| | \| \| | 16 | -0.006 | -0.006 | 2.8548 | 1.000 |
| \| \| | \| \| | 17 | -0.004 | -0.004 | 2.8820 | 1.000 |
| \| \| | \| \| | 18 | -0.004 | -0.003 | 2.9006 | 1.000 |
| \| \| | \| \| | 19 | 0.003 | 0.003 | 2.9152 | 1.000 |
| \| \| | \| \| | 20 | -0.007 | -0.007 | 2.9981 | 1.000 |
| \| \| | \| \| | 21 | -0.004 | -0.004 | 3.0188 | 1.000 |
| \| \| | \| \| | 22 | -0.007 | -0.007 | 3.0940 | 1.000 |
| \| \| | \| \| | 23 | -0.007 | -0.008 | 3.1757 | 1.000 |
| \| \| | \| \| | 24 | -0.005 | -0.005 | 3.2144 | 1.000 |
| \| \| | \| \| | 25 | 0.006 | 0.006 | 3.2611 | 1.000 |
| \| \| | \| \| | 26 | -0.002 | -0.002 | 3.2673 | 1.000 |
| \| \| | \| \| | 27 | 0.007 | 0.007 | 3.3357 | 1.000 |
| \| \| | \| \| | 28 | -0.007 | -0.006 | 3.4006 | 1.000 |
| \| \| | \| \| | 29 | -0.004 | -0.005 | 3.4273 | 1.000 |
| \| \| | \| \| | 30 | 0.003 | 0.003 | 3.4419 | 1.000 |
| \| \| | \| \| | 31 | -0.008 | -0.008 | 3.5270 | 1.000 |
| \| \| | \| \| | 32 | -0.006 | -0.006 | 3.5806 | 1.000 |
| \| \| | \| \| | 33 | -0.006 | -0.006 | 3.6384 | 1.000 |
| \| \| | \| \| | 34 | 0.044 | 0.044 | 6.5204 | 1.000 |
| \| \| | \| \| | 35 | -0.008 | -0.008 | 6.6267 | 1.000 |
| \| \| | \| \| | 36 | 0.014 | 0.014 | 6.9225 | 1.000 |

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