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Statistical Characteristics of Markets: The Case of the Johannesburg Stock Exchange (JSE)

Brian Opiyo Yalla*, Gideon Ntui Ateke and Prosper Makotore

World Quant University, New Orleans, Louisiana, U.S.A

*Corresponding Author
Brian Opiyo Yalla, World Quant University, New Orleans, Louisiana, U.S.A.

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Abstract

This study employs exploratory data analysis to assess the statistical characteristics of emerging markets using the Johannesburg Stock Exchange (JSE) as a proxy. The study deploys a number of tests using R- software to assess stationarity, stability, regime changes, market anomalies, autocorrelation of returns and predictability of the returns. Daily closing price data for the JSE All Share index covering the period 2005 to 2020 obtained from the JSE is used in this study. Several key findings emerge from the study; (i) returns of the JSE are mean reverting and display volatility clustering where periods of high returns are followed by periods of high returns and period of low returns are succeeded by periods of low returns, (ii) contrary to numerous studies on market returns in emerging markets the prices and returns of the JSE display low average returns and low volatilities, (iii) there is no proof of Monday effect in the JSE returns however January effect is observable from the assessment, (iv) the returns of the JSE follow a random walk process and hence the returns are unpredictable, (v) the market returns of the JSE are non- stable and non -stationary based on the KPSS stationarity test. These findings produce mixed results with regards to theoretical assertions about emerging markets and asset markets in general. From a policy perspective, the study and the findings herein buttress the significance of exploratory data analysis in market assessment and decision making.

Keywords: Stationarity, Stability, Regime Changes, Market Anomalies, Autocorrelation, Predictability.

1. Introduction to the Study

For many years researchers and practitioners have made several attempts to study characteristics of financial markets. Most of the existing studies have been conducted to understand the different statistical properties of financial markets with the objective of trying to predict and simulate market directions. These studies reveal some interesting characteristics of financial market assets. For instance, markets have been found to be susceptible to external shocks and are likely to show dynamic trends which reflect the extent to which exogenous factors have impacted markets over time. The distribution of financial time series has been found to follow a universal power-law distribution with an exponent $\zeta \approx 3$. While the temporal correlation of returns follows the process of random walks, the volatility of returns shows a long-term-memory property [1]. Certain characteristics have also been noted to be specific to mature markets while others are specific to less developed markets. There has been a myriad of studies carried out by many scholars to understand the statistical properties of financial markets but most of the studies have focused on develop markets because of the wide range of interest and large number of market participants that these markets attract. Emerging markets have also received their own fair share of interest from researchers. Recent research for example has shown that the distribution function of returns in emerging markets follows an exponential distribution, while the mature markets follow a power-law distribution with an exponent $\zeta \approx 3$ [1]. Most of the regime shifts are a product of exogenous variables which are beyond the control of market participants, otherwise known as systematic risk.

Financial markets are well known to exhibit certain statistical properties such as stationarity and varying volatility over time. It is also well known that markets are susceptible to external shocks and periodic regime shifts which affect the way market operates and bring about different market dynamics. Market participants such as traders, investors and regulators always attempt to understand specific market properties with the aim of serving their different needs and interests. Numerous studies have been carried out in different markets to ascertain specific features of these markets such as returns, volatility, and price movements. What previous studies have been able to publish in their findings as being common to most markets, time and financial instruments is what is now termed 'stylized facts'. Some of these stylized facts include; volatility clustering, autocorrelations, heavy tails (conditional and unconditional), volume/volatility correlation and aggregational gaussianity. Statistical analysis of financial time series data shows properties that are different from the random-walk model based on

Efficient Market Hypothesis (EMH). Prior studies have also shown that the returns of both stocks and foreign exchange rate have a variety of stylized facts. The dynamic nature of the global economic environment coupled with the behavioural biases often displayed by the various market participants, implies that markets are likely to exhibit different statistical properties over time and therefore necessitates occasional study to review these statistical properties. There is therefore need to carry out further research to reassess the statistical properties of these markets to gain a better understanding of their nature and behaviour in order to better serve the interest of the various stakeholders at different times.

This study analyses the statistical properties of emerging or developing markets using the Johannesburg Stock Exchange (JSE) market. The JSE is the oldest stock exchange in Africa and is currently ranked among the top 20 largest stock exchanges in the world by market capitalization. In addition, South Africa and the JSE is ranked top among exchanges in terms of regulation of securities exchanges, number of single stock futures and the number of currency derivatives. A number of financial instruments such as equities, bonds and financial derivatives are traded on the exchange and there are approximately 400 companies listed on the exchange across its main board and AItX.

The goal of this study is to analyse different statistical properties for the selected financial market using statistical techniques as well as the returns from the market to uncover patterns and any anomalies. In addition, the study assesses and records instances that have resulted in regime shifts in the markets through the use of summary statistics and graphical representation.
To this end the objectives of this research include.

1. Analyzing the characteristics of JSE All share index prices and returns so as to note patterns, anomalies and provide insights about the markets.
2. To conduct market efficiency test for the JSE over a period of time.
3. Record instances of structural and functional changes in these markets with the use of summary statistics and graphical representation.

More specifically, the research questions for this study include the following;

- What are some of the statistical properties of prices in Emerging markets such as the JSE?
- Do the statistical characteristics of financial markets such as JSE show any patterns over time?
- What are the statistical properties of returns inferred from the assessment of the JSE ALSI?
- Do the returns from this market reveal any anomalies or insights about market behaviors?
- Is there any evidence of regime shifts from the analysis of the data from the JSE?

2. Literature Review

Financial markets as an area of study has received tremendous attention during the last century from both scholars and practitioner. The important role that financial markets play within an economy cannot be overemphasized. The statistical features of these markets act as indicators for different stakeholders who in all try to understand market behaviours at various times and attempt to gauge market directions. This study reviews the various category of information and body of knowledge that has been contributed by different scholars and practitioner.

2.1 Review of Theoretical Literature

One of the bed rock assumptions of modern financial market theory is that financial markets are perfectly competitive and efficient. In this sub section, we examine some of the theories underlying this key assumption such as the Efficient Market Hypothesis (EMH). Furthermore, we also assess how financial assets traded in some of these modern markets are valued and analyse the gap in or limitation of some of these theories.

2.2 The Efficient Market Hypothesis (EMH)

The efficient market hypothesis seems to have dominated most of the modern-day discussions about the workings of modern financial markets. Other highly debated issues in financial market theory include volatility, predictability, speculation, and anomalies. These issues are also related to market efficiency and are all interdependent [2,3].

An efficient financial market is a market that captures all available information and reflects the same in the prices of the instruments traded in that market. In theory, there are at least three forms of market; weak form efficiency, semi-strong form efficiency and strong form efficiency. The most desired form of efficiency is the strong form efficiency where all market participants are fully aware of all the available information, and this is further reflected in market prices. Early scholars in this area of study such as Fama and Samuelson in 1965 carried out a study and concluded that price changes seem to agree with this theory. Sharpe (1966), Friend et al. (1970), and Williamson (1972) conducted similar studies in the United States and came to similar conclusions [4-6]. There have however been serious criticisms of the EMH as many scholars have come to contest that markets are actually efficient in practice. Most of the criticisms of the EMH have come from psychologists and experimental economists who argue that there are a number of behavioural biases that often characterise human decision making under circumstances of uncertainty.

EMH has been the centre of many empirical studies over a long period of time especially with the goal of predicting prices from historical data, while also attempting to produce forecasts based on variables such as price to earnings (P/E) ratios, dividend yield, term structure variables, and announcements of various events, i.e. [7-9]. earnings, stock splits, capital expenditure, divestitures, and takeovers [10,11]. In an imperfect world, it is unlikely that markets will always reflect all the available information. Information asymmetry, adverse selection and morale hazards are likely to be prominent features of most markets. Some of these imperfections' accounts for most of the recent financial crises experienced across the globe. The JSE has

had its fair share of opinion and counter claims about the state of efficiency of the market. There are a number of studies that have supported the claim that the JSE is efficient through various tests while other studies claim that there is evidence to affirm that the market is inefficient. By testing for the Martingale hypothesis by means of rolling window VR tests, were able to establish that the JSE share index is weak-form efficient and that all the indices tested move from periods of efficiency to periods of relative predictability [12]. Another interesting fact revealed by the study is that, indices consisting of older and more established corporations in the JSE are more efficient than indices that consist of younger companies. Furthermore, it was confirmed that, the top 40 indices also rank higher up the efficiency scale while the smaller cap index rank close to the bottom. Empirical studies have therefore shown that the JSE has varying efficiency among the different indices trading the market.

3. Capital Asset Pricing Model (CAPM)

CAPM emphasizes the fact that the reward for a financial asset is based primarily on the risk assumed for that asset over a given time period. According to Cuthbertson (1996), CAPM is interpreted as a model of *equilibrium asset return* [3]. The linear relationship between risk and return projected by this model has brought this simplistic model under serious scrutiny. The model falls short of explaining the return of a financial assets over time due to its numerous inherent implicit assumptions which are possibly unrealistic in what would be considered efficient markets. One of such assumptions of the model is that historical data can be used to estimates future returns and risk. This is not always the case as empirical studies have shown. It's almost certain that risk and returns characteristics of the same assets are likely to change over time due to various reasons such as regime shift. The assumption of identical time horizon is also unrealistic as it tends towards the construct of a single period model. In practice, markets tend to exhibit both discrete and continuous time properties. Also, the basis for selecting a horizon is the characteristics of the asset but market participants estimate of asset value differ significantly even when the estimated earnings remain constant. The relevance of this model is better understood by making use of other market parameters alongside other macroeconomic multivariate analysis. Many scholars and practitioners such as Chen et al (1986), and Balvers et al (1990) use CAPM to explain the relationship between interest rates, macroeconomic activity, and stock returns [13,14]. Theoretically, the determination of stock prices should be subject to the same economic forces and relationships that determine the prices or value of other financial assets [15-17]. The ability of the model to quantify risk has earned the model tremendous credit as most market participants have previously noted that it offers a lot in terms of determining how asset returns are viewed in financial markets.

3.1 Arbitrage Pricing Theory (APT)

In recent years multi-factor modelling has become prominent [18-20]. The main premise for Arbitrage Pricing Theory is that an asset expected return is determined by a number of factors which seems realistic. The failure of the model to explain explicitly what these factors are has elicited criticism about the model. Individual markets tend to be influenced and control by different market factors and therefore to practically employ this model requires a careful study of the specific market as well as specific asset and delineate the respective nuances. The APT model is used to point out whether securities are overpriced or under-priced due to inefficiencies thus emphasizing the need to study individual market properties. The complexity of this model has limited its practical application.

Some of the shortfalls of the three theories discussed above create the necessity to occasionally undertake studies of individual markets in order to feed market participants and other stakeholders with up-to-date information about market properties. In this study we attempt to use an effective approach that is expected to provide new perspective and approach to studying specific markets.

4. Statistical Features of Asset Returns

Statistical Analysis of the Characteristics of Stock Returns in China's Securities Market by uses Vector Autoregression to examine the dynamic relationship between stock returns and trading volume [21]. They find that both the stock price and volume of trade in the market are stable. Stability of these series implies stationarity of the series, that is, both time series have a long term mean and variance to which they revert to over a long period of time. In addition to this they find that there exists unidirectional causality relationship between stock price and volume where stock returns inform the volume of stock traded but the volume of stock traded does not determine the returns of the stock. According to their statistical analysis, they find that small capitalization stocks outperform large capitalization stocks in the Chinese market. The findings in the research validate stylized facts in finance relating to mean reversion nature of financial time series and the outperformance of small capitalization stocks relative to large capitalization stocks. The scope of the study is however limited in the sense that it does not employ exploratory data analysis techniques, nor does it run a comparison between different markets to assess similarities and differences between these markets.

analyse daily logarithmic returns of stock market indices from three groups of countries based on IMF categorizations [22]. They assess data from "developing Asian countries", "newly industrialized Asian economies", and "major advanced economies". Indices for developing Asian countries are picked from markets in the following countries: Malaysia, Indonesia, Philippine, Sri Lanka, Pakistan, India, and China. The newly industrialized Asian economies are; Korea, Hong Kong, Taiwan, and Singapore and for major advanced economies are; United States of America (S&P), UK (FTSE), and Japan (Nikkei). Their analysis finds that the logarithmic returns in all the markets follow a non – Gaussian probability density which is stable and is symmetric with location parameter zero. Essentially the distribution has a constant mean. The standard deviation of the logarithmic returns also evolves with time in all three groups of markets and obeys a power law. The distinction in the standard deviations in the three group of countries is recorded in the difference in the stable density characteristic parameter α and

exponent b of the power law. The developing Asian countries record smallest and largest α and b respectively in comparison with the newly industrialized Asian economies and major advanced economies, except for China and India. The values of α and b for the two developing Asian countries, China, and India, are closer to those of the newly industrialized Asian economies. The values of α and b for the newly industrialized Asian economies are in between those of developing Asian countries and major advanced economies. In addition, the exponent b of the power law for the standard deviation of the logarithmic returns shows evidence of correlation remaining high as time difference increases for the developing Asian countries and the newly industrialized Asian economies -weak long-range correlation, whereas the logarithmic returns for the major advanced economies display a weak long-range anti-correlation. Although the study by builds a strong case with regards to comparison of the dichotomy of developing and advanced economies the scope of the study is specific to Asian countries, this study further expands this scope through assessment of the Johannesburg Stock Exchange, an African stock exchange [22].

An investigation of the statistical features of stock market indices in France, Germany, United Kingdom, Hong Kong, South Korea, United States of America and Japan by using the tail index finds that the absolute value distribution of the returns of the stock market indices follows a universal power-law distribution, with an exponent $\zeta \approx 3$ except the stock market index in Korea which does not follow and has an exponential distribution with $\beta \approx 0.7$ [1]. The study also finds that the time series of the market indices, the returns and sign series follow random walk processes ($H \approx 0.5$), but the normalized return series (logarithmic return divided by the standard deviation) does not. Furthermore, the study validates some theoretical propositions relating to emerging and mature markets such as high volatility in the Korea market which is an emerging market compared to the American market. In all cases the normalized logarithmic returns of the stock market indices are found to have non-linear features, however, the degree of distribution and correlation in the returns are different depending on whether it is an emerging or mature market. Similar to the scope of the study is limited to Asia, America and Europe, this study aims to add to the body of literature through a comparison with African markets [22].

An assessment of a select number of stocks at New York Stock Exchange characterized into a statistical ensemble of daily stock returns reveal that the mean, variance, skewness, and kurtosis (central moments) of the returns fluctuate with time and are in themselves stochastic processes [23]. The study also assesses the probability density function and temporal correlation properties of the central moments and find that they are characterized by a non-Gaussian probability distribution function and by a long-term time memory. These results are in line with findings by both [1,22]. The limitation of this study by lies in its focus on only one market [23].

5. Volatility and Stability of Markets

Empirical studies on the analysis of emerging markets have focused on the predictability of the asset returns, stability and volatility of the markets which are all vital to portfolio risk management. Divercha et al (1992) documented that emerging markets are more volatile than developed markets and that expected returns and risk premiums are high. This assertion is shared by a myriad of studies like Wilcox (1992), Aggarwal et al (1999) and Bekaert and Harvey (2000) [24,25]. A notable deviation from the norm was Hassan et al (2006) who examined different aspects of emerging stock markets of two European countries and the US and provided significant evidence that emerging markets are stable and some form of predictability exists [26].

Cheteni (2017) examined the relationship between risk and returns in South Africa and China markets. The study employed the GARCH model to estimate the volatility of the stock returns of the JSE and the Shanghai Stock Exchange. The study covered the period 1994 to 2014. Empirical results showed evidence of high volatility in both markets. The study documented that volatility is insistent in both markets and bears similar movement in asset returns.

5.1 Predictability of Returns

Several studies have recognized the presence of predictable variation in returns of developed countries but dismiss the random walk hypothesis for the stock returns. Chitenderu et al (1994) tested the Johannesburg stock exchange for the presence of the random walk hypothesis using the All Share Index (ALSI) monthly data covering the period 2000-2011. The study employed the ARIMA model, and the Variance Ratio test conducted under heteroscedasticity. Results concluded that returns follow a random walk process and opportunities of earning abnormal returns are a game of chance.

A similar study conducted by Sunde and Zviripamoyo (2008) for the Zimbabwe Stock Exchange (ZSE) using similar methods to those of Chitenderu et al (1994) showed that the ZSE does not follow a random walk and past prices can be used to predict future prices. Chikoko and Maparuri (2013) supported results of Chitenderu et al (1994) by dismissing the presence of a random walk on the Zimbabwe Stock Exchange [27]. The study tested the efficiency of the Zimbabwe Stock Exchange after the adoption of multiple currency exchange rate regimes. The non-parametric and parametric research methods through the partial autocorrelation function were used. The results of both tests showed that the successive stock price changes were dependent which indicates that the ZSE was not efficient in the weak form when the country used multiple currencies.

5.2 Regime Shifts in Financial Markets

Financial markets have the tendency to change abruptly and both short-term and longterm investors bear the risk of outsized market movements Nystrup (2018) [28]. Wasim and Sanjay (2013) examined regime shifts and stock market volatility of seven emerging markets "the Bricks" standing for Brazil, Russia, India, Indonesia, China, South Korea and South Africa for a period covering February 1996 to January 2012 [29]. The study employed Markov-regime switching mean-variance model and the results indicated the presence of two regimes in each of the

markets. The study acknowledged the presence of regimes in financial markets and concluded that these regimes can be used for asset allocation strategies.

5.3 Modelling Dynamic Financial Markets

Ang and Timmerman (2011), Wasim and Sanjay (2013) and Nystrup (2018) have made attempts to model emerging financial markets using regime switching models [28-30]. They articulated that regimes in financial markets can be identified by an econometric procedure. They documented that the means, volatilities, autocorrelations, and cross-covariance of asset returns tend to differ from one market to another and regime switching models are better suited to capture the styled behaviour.

Traditionally standard GARCH models have been used to forecast volatility in stock markets. The modern approach employs the use of Markov regime switching GARCH models. Macurcci (2005) set out to compare the out of sample performance in volatility forecasting using standard GARCH models and MRS-GARCH models [31]. The study considered GARCH (1,1), EGARCH (1,1) and GRJ (1,1) and the MRS – GARCH models where the first two conditional moments were allowed to switch between two regimes. Results indicated that MRS-GARCH models significantly out-perform standard GARCH models in short-term volatility forecasting. To test the assertion, their study applied pairwise test for predictive ability of the Diebold-Mariano type and they also applied the Reality check for superior predictive ability of White (2000) and the Predictive Ability of Hansen (2001). The tests results concluded that the MRS- Model outperforms competing models.

6. Methodology

The section discusses how the data was collected, measured, and analysed to achieve our research goals and objectives. The section is concluded with a summary.

6.1 Research Design

The research had its prime focus on establishing the statistical properties of the Johannesburg Stock Exchange hence an exploratory research design was adopted. Quantitative methods were used to analyse secondary data. The use of quantitative methods is objective because it eliminates bias which arises from the use of judgments when a qualitative approach is employed. Daily closing price data for the JSE All Share index from the JSE covering the period 2005 to 2020 is used in this study. The rationale for choosing the data time period corresponds to the pre and post Global financial crisis.

6.2 Unit Root Test

The study makes use of the Augmented Dickey Fuller Test (ADF) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) to check if the time series is stationary or not. A time series which is stationary is one whose properties do not depend on the time at which the series is observed. Time series with trends or seasonality are not considered stationary.

6.3 Augmented Dickey Fuller Test (ADF)

The ADF test tests the null hypothesis that a unit root exists in the time series. The alternative hypothesis is that of stationarity or trend- stationarity. The results of the tests show the ADF statistic and the p-value. The ADF statistic is a negative number and the more negative it is, the more we solidify our rejection of the hypothesis that a unit root exist at the given level of confidence.

6.4 Kwiatkowski-Phillips-Schmidt-Shin (KPSS)

The KPSS test tests the null hypothesis that the observed time series is stationary around a deterministic trend. The alternative is that there is a unit root. The most important thing to note about the test is that the absence of a unit root is not evidence of stationarity but that of trend stationarity. The test results reject the null hypothesis if the LM statistic is greater than the critical value that is the time series is not stationary.

7. Autocorrelation

Autocorrelation measures the similarity between observations as a function of the time lag between them. The test assists in identifying things such as periodic signals or missing fundamental frequency. The study will make use of the Autocorrelation function, Partial Autocorrelation function and The Box-Pierce test to test for autocorrelation which is also called serial correlation.

7.1 ACF and PACF

The ACF gives values of similarity between values of any series with its lagged values. The test factors in components such as trend, residual and seasonality while finding correlations. The PACF finds correlations of the residuals after removing effects which have already been explained by earlier lags. By so doing, information obscured in the residuals is explained in the next lag. The ACF and PACF will also help us in guessing the values for p and q in specifying the correct ARMA model.

7.2 The Ljung-Box –Pierce Test

The Box test tests if any group of autocorrelations of a time series is different from zero. The null hypothesis is that data is independently distributed. The alternative hypothesis is that the data is not independently distributed, that is, it exhibits serial correlation. It is worth noting that the test is applied to the residuals of a time series after fitting an ARMA (p,q) model to the data. The model lacks fit if the autocorrelations in the residuals are large at the given lag and confidence level. The model was also used to test for the predictability of the returns.

8. Stability test

The methodology for the testing of the stability of the asset returns is inspired by the work done by Hassan et al (2006) [26]. They used a combination of ARMA model and F-test to test for the structural stability of emerging markets. They specified the Box-Jenkins ARMA (p, q) model to test for the stability of six emerging markets. The equation is shown below.

$$y_t = \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \cdots + \alpha_p y_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + \beta_2 \varepsilon_{t-2} + \ldots + \beta_q \varepsilon_{t-q}$$

Where,

y_t is the return for the stock index at time t =1 to t =T

α_i is the coefficient on the lagged returns i = 1 to i= p

ε_t is the autoregressive error term

After estimating the model, we check for structural stability. The sample of observation T is comprised of m observations which are the original observations from the financial time series and n observations which are the forecasted observations. The equation is then estimated and an F – test is used to test the null hypothesis of no structural change. If the F-test fails to reject the null hypothesis of structural change, then the returns are stable.

8.1 Testing Market Efficiency- Wald-Wolfowitz Runs Test

The test for the weak form of market efficiency was conducted using the Wald-Wolfowitz runs test. The test is a statistical procedure that examines whether a data sequence is occurring in a random fashion. The test is mostly used in technical analysis to determine the price action of a security. The study uses the runs test to test the efficiency of the JSE stock market. If the observed All share index data shows that it is occurring randomly from the distribution, then the price of its securities are unpredictable, and the market is efficient in the weak form. The results of the test are interpreted as follows. If the p-value is less than or equal to the significance level the decision is to reject the null hypothesis and make a conclusion that the data is not random.

8.2 Random Walk Test – Variance Ratio Test

The variance test ratio is used to test for the random walk in the JSE market returns. Deviations from the random walk means the returns can be predicted. The study makes use of the Automatic Variance Ratio proposed by Kim, J. H. (2009) [32]. The test assesses whether the variance of two populations from which the samples have been drawn is equal or not. If the p-value is lower than the significance level, then the null hypothesis of equal variance is rejected.

8.2.1 Summary

This section provides a description of the various techniques that are used in this study to conduct exploratory analysis. The tests in the study are undertaken using the R- Software. The next section presents the results of the study.

9. Results and Discussion of Findings

This section covers the general discussions of the results of the exploratory data analysis such as the price behavior of the JSE index, unit root tests and some descriptive statistics. The section looks at the results of the predictability and stability of asset returns and the efficiency of the JSE market. The section also looks at the consistency of the study results with economic theory and is concluded by a summary.

9.1 Price Plot for the All Share Index

Preliminary insights concerning any financial markets start by understanding the price behaviour of the assets. Thus, the study begins by plotting the daily closing price of the All¬ share index from Jan 2005 to May 2020. Figure 1 below show the plot.

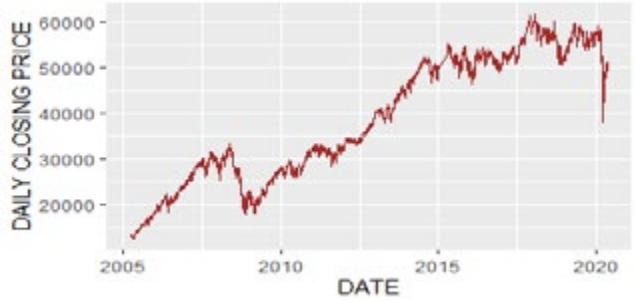

Figure 1: Daily Closing Prices of the Jse All Share Index

An inspection of the historic price plot reveals that the closing prices of ALSI index exhibit, a moderately volatile and a clear long-term upward trend. The upward trend shows signs of reversal notably around the years 2007-2009 and in the year 2020. These two shocks coincide with the Global recession of 2007 and the Covid-19 global pandemic which was detected at the conclusion of the year 2019.

9.2 Daily Returns Plot

Figure 2 provides a visual of the daily returns of the All share index from the year 2005 to the year 2020.

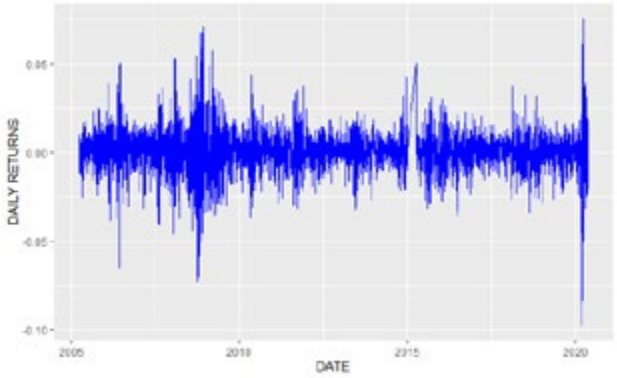

Figure 2: Daily Returns for The Jse All Share Index.

The daily returns plot shows that it has a constant mean approximately equal to zero over the period of the study. Large deviations (> 0.1) from the mean are very infrequent. Volatility clustering is present with greatest volatilities around 2007-2009 and 2020. We can also see that the time series does not have a drift in either direction which might suggest some stationarity in the data.

9.3 Descriptive Statistics of Daily Returns

The results of the summary statistics of the daily returns are shown in Table 1.

INDEX	DAILY RETURNS
Min. :2005-03-31	Min. : -0.0972126
1st Qu.:2008-11-25	1st Qu.: -0.0056526
Median :2012-08-20	Median: 0.0007219
Mean :2012-09-23	Mean : 0.0004353
3rd Qu.:2016-08-16	3rd Qu.: 0.0070367
Max. :2020-05-18	Max. : 0.0753162

Table 1: Summary Statistics for the Daily Returns

The basic statistics for the daily returns of the ALSI index shows that daily returns ranges from a minimum of -0.0972126% to a maximum of 0.0753162%, with the mean and median of 0.0004353% and 0.0007219%, respectively. There were no instances where large returns greater than 1% were recorded.

9.4 Unit Root Tests

The study makes use of the Augmented Dickey Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests to test for the presence of unit roots in the price and return time series. The results are shown in Table 2 and 3

Variable	ADF statistic	P-Value
Price time series	-3.8141	0.01826
Returns time series	-15.316	0.01

Table 2: ADF test results

Variable	KPSS statistic	P-value
Price time series	35.26	0.01
Returns time series	0.25402	0.1

Table 3: KPSS test results

**** Tests Conducted at the 5% Significance Level****

The tests of stationarity on the price series show some mixed results. For the ADF test the p-value is significant and that means we can reject the null hypothesis of a unit root. This result is least expected since the stock index prices are usually non-stationary. Results of the KPSS tests show p-values which are significant, and the null hypothesis of stationary process is rejected. Thus, the results do not coincide with those obtained by the ADF test, but it is the generally accepted result.

The tests of stationarity on the return series also shows some mixed results. For the ADF test the p-value is significant and that means we can reject the null hypothesis of a unit root. Results of the KPSS tests show p-values which are insignificant, and the null hypothesis of stationary process is not rejected. The generally accepted result is that the time series of the first difference of the

price series (return series) is commonly stationary as shown by the ADF test.

9.5 Model Fitting

The study uses the Box-Jenkins (1976) ARMA (p, q) model to test for stability of the JSE. The ACF and PACF functions are used to estimate the model under AIC and BIC conditions. Figures 3 and 4 show the plot of the ACF and the PACF.

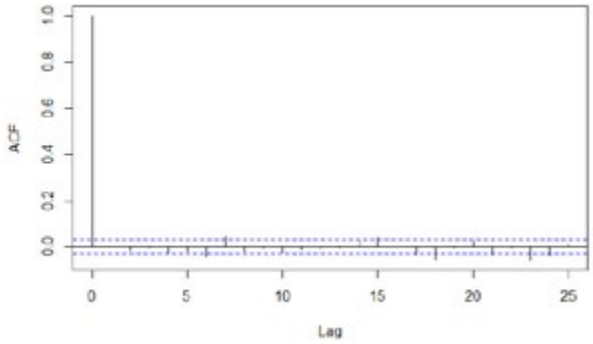

Figure 3: ACF Plot

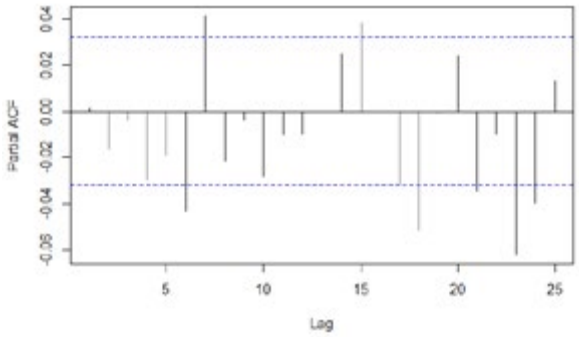

Figure 4: PACF Plot

From the plots above we note that the ACF and PACF for the ALSI index returns have significant values at lags 6 ,7 ,17 and 23 and for this reason we specify the maximum value of p = 8 and q = 8 in the auto. Arima (). The ARMA (2, 2) is selected by auto. Arima () using AIC and the ARMA (0, 0) is selected by auto. Arima () using BIC. The study checked for the residuals of the two models using the Box test to see whether there is serial correlation. Based on the results of the test we adopt the ARMA (2, 2) as the parsimonious and encompassing model. The results of the Box test are shown in Table 4 below.

	ARMA(0,0)		ARMA(2,2)	
Number of lags	**Q-value**	**p-value**	**Q-value**	**p-value**
10	22.391	0.01323	10.93	0.363
15	31.92	0.006602	22.421	0.09724
20	48.243	0.0003932	36.418	0.01373
25	70.474	3.271e-06	55.902	0.0003744

Table 4: Box-Pierce Test Results

From the results above, the JSE show signs of predictability only for higher lags above 20 at the 1% and 5% significance level. In addition, the autocorrelations of the residuals as shown by the ACF and the PACF are low. Low autocorrelations in financial markets show the absence of various imperfections in the functioning of the markets. Based on this, we find the JSE to be unpredictable.

9.6 Stability of Returns

Table 5 details the results of the stability tests. The results show that the returns of the JSE All share index are not stable. Empirical evidence has suggested that emerging markets are generally rapidly changing, and return instability was expected in this instance.

				Stability Test	
Obs	**ARMA lag**	**Coefficient**	**P-Value**	**F-Statistic**	**P-value**
3730	AR(2)	0.80807044	< 2.2e-16	8.1831e-13	< 2.2e-16
	MA(2)	-0.84271206	< 2.2e-16		

Table 5: Stability Tests Results

9.6.1 Efficiency of the JSE

9.6.1.1 Weak form efficiency

Table 6 shows the results of the runs test for the weak form market efficiency. From the results of the analysis, we cannot reject weak form efficiency of the JSE at 1%, and 5% significance level. This result does not concur with most research that state emerging markets returns are predictable and therefore markets are not weak form efficient.

****test conducted at the 1% and 5% significance level****

Standardized runs test statistic	p-value
0.19651	0.8442

Table 6: Runs Test Results

9.6.1.2 Random Walk in Returns

We made use of the variance ratio test to test for random walk in the returns. Table 7 shows the results of the test. The p-value is not significant at the 1% and 5% significant level hence we reject the existence of autocorrelation in the JSE market. The JSE therefore follows a random walk process and the market is therefore unpredictable.

****test conducted at the 5% significance level****

test statistic	p-value
0.1520464	0.6965873

Table 7: Variance test ratio results

9.7 Summary

In this section we have presented the results of the research. The study has established that the JSE market is affected by global shocks in the same way as developed markets. The Global financial recession and the Covid-19 Pandemic sparked a bearish environment on the JSE. The study also established that the returns on the JSE follow a random walk and hence the market is unpredictable. Returns on the market are not stable.

10 Conclusion and Policy Implications

The JSE has undergone a series of institutional restructuring from its creation. The institutional restructuring has had serious implications on investors and other market participants and the functioning of the market. There is very strong evidence to suggest that the institutional restructuring that the market has experienced has been closely followed by regime switching. The Johannesburg Stock Exchange (JSE) was founded in 1887 and it joined the World Federation of Exchanges in 1963 and was upgraded to an electronic trading system in 1990. In 2003, the JSE launched an alternative exchange, AltX for small and mid-sized listings and yield X for interest rate and currency instruments. The JSE then acquired the South African Futures Exchange (SAFEX) in 2001 and the Bond Exchange of South Africa (BESA) in 2009. In 2006, the JSE ltd became listed on its own exchange and following the financial crisis of 2008, in 2009, JSE listed Single Stock Futures on Microsoft and Google which allowed retail investors to carry out trade in the two United States of America Corporations.

10.1 Major Findings

This section augments the discussion from the preceding section on results of the study in terms of the statistical properties of the JSE. It is important to emphasize that although the findings presented in this study are those of the JSE, similar features are expected to exist in other emerging markets.

10.1.1 The All Share Index Prices

The ALSI consist of some 150 corporations listed in the JSE and it constitute 99 percent of the market cap and liquidity of the market. This index can further be split into Top 40, Mid-cap and Small Cap indices. The results of the finding from this study reveals very interesting trends which seems to follow the trajectory of major global events. The empirical data from 2005 to 2020 reveals an upward trend in most parts during this period in the prices of the index. The prices fell sharply around 2006 and further plummeted in between 2008 and 2009 which coincides with the period of the global financial crisis. The ALSI had apparent positive trends between 2010 and 2015 which would be considered the recovery era from the global financial crises. There were significant fluctuations from 2015 to 2017 and further drop in the prices before 2020 inferably due to the global pandemic which had a significant impact on global economic activities.

10.1.2 Daily Returns and Volatility

Majority of previous studies seem to support the view that emerging markets are usually characterized by high returns and high volatilities. The findings from this study seems to defy this

common view. There is the existence of volatility clustering with very few large deviations. The greatest volatility interestingly occurs during the 2007 and 2009 which are periods of the global financial meltdown and in 2020 which depicts the effects of the global pandemic. The market returns are otherwise relatively stable.

10.1.3 Anomalies

There is evidence from the empirical data that there is presence of anomalies from different sources and caused by different factors. While anomalies are worth noting, care must be taken to properly understand how they can be handled by market participants. There is proof from the data of the day of the week effect and January effect from our time series. Monday seems be a normal day contrary to other studies carried out elsewhere. On the other hand, Thursday always seems to result in losses or have negative returns while Friday has the highest returns. The January effect is also very imminent in most of the time period under this study with the exception of the periods prior to crises. It is important to reiterate that while anomalies can be rewarding to investors who are quick to notice their existence, they are ephemeral in nature and no trading strategy can profit consistently bases on anomalies.

10.1.4 Investment Decision in the JSE using the ALSI

In theory, EMH and random walk are mostly used by market participants to try to understand stock price movements. Nonetheless, there are two main approaches that are commonly used in practice to study stock price movements: technical analysis and fundamental analysis.

Technical analysis is concerned with the study of past stock behaviours and the use of patterns found or observed in stock prices to predict future prices as past patterns are believed to repeat in the future. Fundamental analysis on the other hand utilizes macro and micro economic factors such as dividends of the firm, earnings of the firm and expected future interest rates in the economy. It is generally believed that most developing markets generate high returns, therefore selecting a firm with a potential for high return would not be the end point since most market participants would already have that information. An investor therefore has to get ahead by performing further analysis beyond stock selection. If the assumptions of the EMH are to hold, the analysis by investors becomes even more complex as they would need significant research capabilities to be able to outperform their benchmarks. A closer look at the JSE ALSI tends to support certain patterns where the index shows an upward or positive trend or movement in a majority of the period. It would therefore be more beneficial for an investor to hold stocks for longer periods in this market if the goal is to achieve higher returns.

10.2 Market Behaviours, Regime Change and Statistical Characteristics

Financial markets are known to change abruptly for a variety of reasons. Regime switching models have become very prominent in the study of financial markets. Changes in financial market behaviours can last for a period of time and this is usually followed by a change in financial market characteristics which are reflected in variables such as volatilities, means, autocorrelation among others. Market regulations, policies and other secular changes can bring about regime changes in financial time series. In equities for example, regimes can correspond to periods of high and low volatilities and bull and bear markets. For example, policy changes in the JSE such as; the Financial Markets Act, No 19 of 2012 replaced the Securities Services Act, No 34 of 2004, the launch of its public online virtual trading game in June 2012 and the Phase one of the move to T+3 implemented in July 2013 qualify as regime changes in the market. Regime changes are closely related to the cycle of economic activities such as period of expansion and recession. A very significant feature of regime change is that they tend of be reflected in the statistical characteristics of asset returns.

10.3 Policy Implications

10.3.1 Managing Risk

Risk management remains an important concern for most investors. In fact, the attractiveness of an investment can be viewed by the ease with which the risk can be quantified and simulated for decision making as shown by the different risk computation techniques in finance. There is no doubt that a study of the statistical properties of financial time series data can help inform market participants, particularly investors and traders of the risk associated with their investments. Our study has confirmed that asset prices are non-stationary and as such we must focus on asset returns for better decision making. Another clear fact is that it is difficult to say with any certainty whether future returns will be negative or positive but a careful look at the distribution of return can inform us about aspects such as the nature of the distribution, the evolution of the distribution over time, the quantiles and the scale and location of the distribution.

We have also confirmed that financial data always show volatility which are not independent and most other studies tend to use random walk which are most often approximations to the real scenarios. To be more precise, loss/profit-quantiles are likely to change over time and therefore Value at Risk (VaR) can be gauged. Empirically, VaR can be computed from the data as shown in this study. By taking the empirical quantile of the data as in the case of JSE-ALSI, the 1-day empirical VaR at 95% would inform us about the risk of investing in this market. This technique works well when using sufficient amount of data like the case of this study. The problem with this approach is that it will be more complex when calculating the volatility and the VaR of a portfolio of assets. Other models such as Random walk and GARCH can then be used to overcome the practical difficulties of VaR approach in this instance. While VaR remains an intuitive way of measuring risk, there are other measures that can be used to measure risk such as translational invariance, homogeneity, monotonicity, and sub-additivity. One apparent problem with VaR is that it can tend to discourage diversification when a portfolio involving several assets is constructed. To overcome the shortcomings of VaR, the other techniques mentioned above can be explored.

10.3.2 Predicting Market Returns

A myriad of previous studies had supported the view that aggregate market returns are predictable. An important aspect to consider is the strength of this predictability which is likely to vary significantly over time under different macroeconomic conditions. The predictable power of many instruments used in literature to predict excess aggregate equity returns, like dividend yields, term spreads, and default spreads, declined or even disappeared over the 1990s as documented by Welch and Goyal (2008) and Ang and Bekaert (2007), among others, and formally tested by Pesaran and Timmermann (2002) [33,34]. Our study reveals that the JSE ALSI is not readily predictable within certain lags below 20 as shown in Figure 4 and even above lag 20 the market returns cannot be easily predicted. Higher returns can be achieved in this market if investors invest over a long investment horizon since the market tends to have an overall positive trend in the long run.

11. Conclusions

We have studied the certain statistical properties for the JSE ALSI over a period of 15 years. The JSE just like any other emerging market possess certain specific and general statistical features when we examined the statistical characteristics of the prices and the returns of the JSE All share index over the period of time under consideration. It was noticed in the course of this study that the JSE ALSI prices show an upward or positive trend in the long run. As expected, there is evidence of random price movements in this market which tend to agree with what is obtainable in most other markets. The ALSI also exhibits volatility clustering over the 15 years period under study and that returns are very difficult to predict in this market especially over a long period of time. Anomalies were noted in the course of this research as revealed in the empirical data used for the study. Monday has shown normal returns as opposed to studies carried out elsewhere that seems to suggest otherwise, January effect on the other hand is observable in this market. Regime shifts are very prominent features in this market as revealed by the high and low volatility noticed over specific periods of time such as the prior crises and post crises periods. Weak-form efficiency was noted in this market following a test conducted at specified level of significance in the study. This result tends to support other studies conducted for this market by other researchers. The JSE remains a very important financial market that continues to attract investors in the African continent and the statistical characteristics of this market reveals that there are huge opportunities that could be explored by market participants to manage their risk and return objectives [35-46].

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Conflict of Interest: The authors declare that they have no conflict of interest.

Availability of data and Material: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Code Availability: The code used for analysis in this study are available from the corresponding author upon reasonable request.

Compliance with Ethical Standards

Ethics Approval: Not applicable

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