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Testing Weak Form of Market Efficiency of Exchange Traded Funds at the NSE Market

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Abstract This study appreciates the importance of having a better understanding of the market efficiency when trading an Exchange Traded Fund of any given set of securities in an exchange market as it is extremely vital for any prospective investor who may be looking to make sound investment decisions as well as market trend predictions. When trading in a market with few traders who likes dominating the market through insider trading, it is more likely to experience securities exchange market without confidence of investors thus depicting weak form of efficient market efficiency. While testing of the weak form of efficient market hypothesis (EMH) of the Nairobi stock exchange (NSE) is done through daily as well as weekly index data from NSE 20 share index over the three months period. The research study applies the use of secondary data that was obtained from Nairobi Stock Exchange market website. This research has deviated from the normal and traditional linear approach to test market efficiency and use of using unit roots to test serial correlation. The daily returns in aspect to skewness and kurtosis was found to be non-normal. From the results, null hypothesis of normality was not rejected. In this study, there is the use of fractional integration thus utilization of ARFIMA to test long term memory and even the traditional unit root test is incorporated to compare both results thus giving a perfect conclusion on whether NSE stock market is definitely weak form efficient in the market. The NSE-20 share Index stocks are used to make an Exchange Traded Fund that is priced and forecasted. Ultimately, the forecasted values of ETF are done on the trend lines similar to the NSE-20 share Index trends, which helps investors to make informed financial decisions when buying any securities traded in NSE market.

Keywords: *MAPE, ARFIMA, NSE-20 share index, EMH, ETF, weak form EMH*

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1. Introduction

The objective of this paper is to propose to test how the Nairobi Stock Exchange (NSE) uses indices to determine the trends in the market thus helping investors make decisions when investing in the market from Nairobi All Share Index and NSE-20 share Index among many others that are being used as a market index to determine whether the economy of the country is doing well or not see [1]. It measures an overall indicator of the market performance see [2]. The index always incorporates all the tradings in the number of shares of the day from those companies that are perceived to perform well thus making them lucrative for the investors for investment purposes. It has attention that is therefore important on the determining the trends on the overall market capitalization and the price movements of the selected securities that are being traded on the market.

While in Kenya, the stock market is usually measured by three stock indices namely NSE-20 Index, the NSE All Share Index and MCSE Share Index. NSE-20 Index is the most commonly used since it incorporates 20 companies cutting across all sectors in the economy. This index has always been a great importance in the world markets NSE being one of these growing markets see [3]. The index has helped the world market in the analysis and portfolio management. Therefore, the index value is used when measuring the performance of a stock market and the institutions as well as the individuals can get to know how the market is performing and their investments in general see [4].

The weak form of an efficient market hypothesis exist when the market price of an investment security incorporates all the information, which is contained within the historical prices of that particular investment. Should the weak form of EMH holds, then trading rules that are based only in the historical data bout the price of the security should not be capable of generating higher investment returns for an investor [5]. The above trading rule form that use historical data of NSE when predicting the present or even future prices that is referred to as technical or chartist analysis.

As a way of testing the weak form of efficient market hypothesis assist investors in the selection of portfolio as well as enabling investors to have equal chances making profit from their investments. Hypothesis of Market Efficiency has always been an essential concept for many investors looking forward to hold internationally portfolios in a diversified way see [6]. In addition, with increased investments movement globally across international boundaries thanks to the high levels of integration experienced in many economies of the world. Having a understanding of efficiency as an investor of the emerging markets can offer an individual a competitive advantage thus gaining more returns on investment within a shorter time period [7].

The Nairobi Securities Exchange Market offer investors both locally and internationally an opportunity to earn proceeds from any preferred security in terms of a company where they would like holding a stake through acquisition of the company [8]. For example, an investor looking for ownership can purchase as many as possible shares that will offer them an opportunity to hold shareholding certificate thus participating in decision makings of the company that has affected many sectors of the Kenyan economy [9] during the pandemics experienced in the country that has affected many businesses leading to closure. In addition, many developing economies in the world in terms of securities markets are now getting momentum as reliable as well as profitable opportunity for the investors.

For any type of an investor looking for a ownership through the stock market there is only win or even lose position when doing trading in a given market. Thus, the efficient security market necessity is vital because in any form of an inefficient market, an investor may decide to generate abnormal profits by generating abnormal losses from poor decisions that is different from rest of market investors [10]. When doing test for the weak form of efficient market hypothesis, it offers information that will help an investors in the portfolio selection while making sure that all investors get a similar chance of making profit from sale of ownership especially during extreme events such as covid-19 see see [11].

Most researchers have done a lot of work on testing of the weak form of the NSE. In the year 2007, [12] had studied the weak form of market efficiency in many of the African markets. They used variables such as daily closing prices of stocks as well as volume traded of the stocks for Kenyan market from Jan 1997 to May 2002. In their study, they used run tests together with serial correlation tests to test the dependence between the stock prices. They concluded that Kenyan market was more efficient in the weak form as significant number followed by the random walk see [4] in modeling of Nairobi 20 Share Index using log-normal distribution.

[13] did a paper that was investigating revitalization process enhancing stock market micro structure of NSE. They also tested the market efficiency. Data used in the in- vestigation was the monthly data form Nairobi Stock exchange by looking at NSE-20 share index from the year January 1870 to December 1999. They used unit root test and serial correlation test [14]. The researchers concluded that NSE is not efficient in the weak form see [15] In addition, [16] did a research paper to ascertain that index of stock market price s did follow random walk process.

The research was done in the following countries Egypt, Nigeria, Morocco, Kenya, Botswana and Mauritius. The historical data used were from NSE 20 share index form the 3rd week of January to the final week of August 1998. In the methodology, they used multiple variance ratio test of the Chow and Denning to test independence of stock prices [17]. The analyzed results showed that hypothesis of random walk is rejected the stock prices were auto-correlated. [7] had investigated if behavior of Kenyan market was consistent with the weak form of EMH due to Covid-19 see [18].

2. Mathematical Modeling of the NSE-20 Share Index

The NSE-20 index is going to be modeled with respect with time, *t* as follows:

$$\pi_t = \alpha^T Z_t + e_t \tag{1}$$

where $t = 1, 2, 3, ...$ and Z_t refers to a vector of deterministic terms that could join the line where $Z_t = 1$ while e_t error term is represented by that follows the form process below;

$$(1-L)^c y_t = u_t \tag{2}$$

where $t = 1, 2, 3, ...$

In which $c \in \mathbb{R}$ is at a point when the equation is zero, which means that covariance stationary process of a given spectral density function is greater than zero and bounded at the zero frequency giving room for weak autocorrelation of the *ARMA* model.

$$M(L)u_t = (L)U_t. \tag{3}$$

In this case is an *AR* polynomial while $\varphi(L)$ is an *MA* the error term becomes the white noise. $C = 0$ is when $I(0)$ representation; $c = 1$ refers to the unit root. This was established through the US series of macroeconomics which showed that only one that was not exposed to unit roots and not the common trend-stationary processes.

Setting c in equation (3) to be a fraction and possibly have the values greater than one while $(1-L)^c$ can be expressed through binomial expansion where for all $c \in \mathbb{R}$.

$$\begin{aligned}(1-L)^c &= \sum_{k=0}^{\infty} N_j L_j = \sum_{k=0}^{\infty} \binom{c}{j} (-1)^j L_j \\ &= 1 - cL + \frac{c(c-1)}{2} L^2.\end{aligned} \tag{4}$$

Therefore, it is easy to define the following equation 4 as follows;

$$(1-L)^c y_t = y_t - cy_{t-1} + \frac{c(c-1)}{2} e_{t-1} \tag{5}$$

In the equations (5), *c* serves an essential, it shows the degree of reliance of the series. When the *c* value is high the association level is also high. For instance, in equation

(2) where $c > 0$ expresses the, "long memory" that is how its decay of its autocorrelation takes place and that the density function is bounded at origin.

2.1. Hypothesis Testing

Standard unit root formula is applied thereafter an estimation of the fractional differencing estimate by applying whittle function in all frequency domain. According to [19] testing procedures drought about are applied in estimating if the actual value of c in $I(c)$ models. Lastly, Lagrange multiplier methods should be shown as the perfect one in the fractional integration. It is applied in testing for the null hypothesis $H_0 : c = c$ for numbers in equation 4 and 5 and various types of disturbances.

A confidence interval for true values can be constructed since it follows the normal distribution. There are additional parametric methods that can be employed like the maximum likelihood estimation (MLE) this is applied alongside the Detrended Fluctuations Analysis.

An example of $ARFIMA(p,c,q)$ model can be given in the form:

$$V(L)(1-L)^c(e_t - r - s_t) = L(W_t) \tag{6}$$

where $W_t \sim iid(0,\sigma^2)$.

In this case $V(L)$ is an *AR* of order *p* polynomial while (L) is an *MA* of order *q*. When the log NSE-20 is not stationary when performing the initial differencing, regression comes first. The MLE is applied in determining parameters in equation (6) with an assumption that the error term is normally distributed. As a way of making a good choice, correct model several tests have to be done for a perfect choice.

2.2. Detrended Fluctuation Analysis (DFA) of NSE-20 Share Index

For it to be easy to investigate the existence of long memory, there is need to check if trend exists. In case of the existence of trend in the NSE data, the Hurst rescaled range analysis as well as other non-trending methods would easily give spurious results after the analysis. *DFA* has always been well established robust method that has been used widely in ascertaining the scaling behavior of NSE noisy data with all the available diverse trends that exists during modeling.

For purposes of a record, Let $[Y(i), I = 1,2,..,N]$ where N denotes the length of record. The *DFA* procedure has the following 4 steps as;

Step One

There is a need to determine the profile of $Y(i)$

$Y(i) =$ sum from ($k = 1$ to i) of $Yk - Y$, where Y is the mean of the record.

Step Two

The second step is to divide the profile $Y(i)$ into all $Ns = N/s$ boxes. in each of the boxes, we will fit all integrated time series by the use of polynomial function, $P_y(i)$ normally defined as the local trend. For the order of *DFA*, *n* order of polynomial function is then applied to the approximation of fitting. We will subtract the local trend in every box to obtain the detrended function of $Y_s(i)$.

Where; $Ys(i) = Y(i) - P_y(i)$.

Step Three

In each and every box of the size s, we thus determine the root mean square (RMS) fluctuation of $F(s)$ where $F(s) =$ square root ($1/Ns$ sum of ($Ys^2(i)$) from $i = 1$ to Ns).

Step Four

The fourth step is to repeat the procedure for different box sizes, with different scales, In case there is a power-law relation between $F(s)$ and s. Then

$$F(s) \sim\sim S \tag{7}$$

This is indicating the presence of the scaling property with the parameter (h), known as the scaling exponent or the fluctuation exponent is representing the correlation proportion of the NSE data. When looking at the correlation exponent Z_s, derived from the auto-correlation function, a similar approximation for the value of $F(s)$ is given by;

$$F(s) \sim\sim S^{1-\frac{z}{2}} \tag{8}$$

By making a comparison of the equation (7) and (8), we will be able to obtain;

$$Z = 2 - 2h \ for \ 0 < Z < 1.$$

The above is a brief certification of the relationship between Z and h. The analysis is done using *R* statistical programming language.

In the use of DFA method, a straight line in the log-log graph indicate the presence of statistical affinity. Often, the scaling exponent is the slope of the straight line fitting to the log-log graph. In fact, this exponent generalization is the Hurst exponent.

2.3. Stationarity of NSE-20 Share Index Data

The two periods are defined as pre-crisis as well as crisis was included in this research. Before 2007/08 *PEV* and after Stationarity tests/unit root tests Non-stationary data, as a statistical rule, are unprecedented and cannot be predicted or modeled. Note that the first lag value is statistically important, whilst partial auto-correlations for all other lags are not statistically important. From the suggestions of a possible *AR*(1) model for the NSE data, it is illustrated as below:

2.4. Unit Root Tests

In this unit root test, this study test for non-stationarity.

Table 1. Augmented Dickey-Fuller Test

Data Type:	NSE Data	
Dickey-Fuller = -1.5944 Alternative hypothesis: We fail to reject H_0 at 5%	Lag order = 3 Stationary hence there is unit root	p-value = 0.7501

We fail to reject H_0 at 5% since we do not have enough confidence at a level of 5% to make such statistical claims from the above Augmented Dickey-Fuller Test. This means that the NSE-20 Share Index that has been used is normally distributed.

Table 2. Phillips-Perron Unit Root Test

Phillips-Perron	Unit Root Test Data Type:	NSE Data
Dickey-Fuller Z(alpha) = -4.3894 Alternative hypothesis:	Truncation lag parameter = 10 Stationary	p-value = 0.8649

It is important to note that we fail to reject H_0 at 5% since we do not have enough confidence at a level of 5% to make such statistical claims from Table 2 for Phillips-Perron Unit Root Test. This means that the NSE-20 Share Index that has been used is normally distributed.

3. Forecasting of NSE-20 Share Index Prices Using Normal Distribution

A lognormal) distribution commonly known as log-normal distribution is a continuous PDF of a random variable where natural logarithms of the individual random variables are normally distributed as [20]. This means that when you take the natural logarithms of the random variables, the random variables will normally distributed with mean $= \theta$ and variance= σ^2 . Therefore, if any given random variable X with log-normally distributed, then $Y = ln(X)$ follows a normal distribution. On the contrary side, if Y has a normal or Gaussian distribution, then Z distribution of the exponential function, $X = exp(Z)$, has a log-normal distribution. The feature of a log normal distribution that makes it necessary when modeling the NSE-20 Share Index only takes positive values while taking care of the possibility of extreme events during trading in the financial markets.

Let Z to be defined as a standard normal distribution with mean $= 0$ as well as variance $= 1$. This means that distribution of a random variable

$$Y = e^{\theta + \sigma Z} \tag{9}$$

where Y has a log-normal distribution with parameters, mean $= \theta$ and variance $= \sigma^2$.

$$\begin{aligned} f(y) &= \frac{d}{dy}(P[Y \le y] = \frac{d}{dy}P[lnY = lny] \\ &= \frac{d}{dy}[\Phi(\frac{lny - \theta}{\sigma}] \end{aligned} \tag{10}$$

$$f(y) = \zeta(\frac{lny - \theta}{\sigma}) * \frac{d}{dy}(\frac{lny - \theta}{\sigma})$$

$$f(y) = \zeta(\frac{lny - \theta}{\sigma}) * \frac{1}{dy}$$

$$f(y) = \zeta(\frac{lny - \theta}{\sigma}) * \frac{1}{dy}$$

$$f(y) = \frac{1}{y} * \frac{1}{\sigma\sqrt{2\pi}} exp\{(\frac{lny - \theta}{\sigma})\} \tag{11}$$

In terms of the cumulative density function, *CDF*, the log-normal distribution will be;

$$F(Y) = \int_{lny} f(y)dy$$

$$F(Y) = \Phi(\frac{lny - \theta}{\sigma}) \tag{12}$$

From equation (12), the mean as well as variance of the log-normal distribution will be given by;

$$mean(y) = [E(y)] = e^{(\theta + \frac{\sigma^2}{2})} \tag{13}$$

$$variance(y) = [E(y)]^2 (e^{\sigma^2} - 1) \tag{14}$$

3.1. Return Modeling

The series of NSE-20 share Index returns can be defined as;

$$R_t = \frac{lnS_{t+1}}{lnS_t} \tag{15}$$

$$R_t = logS_{t+1} - lnS_t$$

where R_t is the return on a NSE-20 share Index at time t and the NSE-20 share Index at time $t+1$ for S_{t+1} and t for S_t respectively during the time of trade. It is important to note that the Return on NSE-20 share Index is modeled as log-normal distribution with the mean as well as variance of returns given above equation 3.7 that is important in modeling of Exchange traded funds that mimics the behavior of a stock index.

3.2. Non-normality Assumption Test

$$f(y) = \frac{1}{\sigma\sqrt{2\pi}} exp\{-\frac{1}{2}(\frac{lny - \theta}{\sigma})^2\} \tag{16}$$

The distribution of NSE-20 share Index from the Nairobi Securities Exchange market, are assumed not to follow a normal distribution to take into consideration the presence of extreme events such the existing presence of Covid-19 that massively affects the behavioral of investors see [9]. Using the procedure of [21], which as assumption that all data available at NSE is not normal. We will obtain the *MLEs* of the log normal distribution as well as their corresponding standard errors. The results are shown below;

Table 3. Maximum Likelihoods Estimates of the log Normal Distribution

Parameters	Estimates	Standard Error
θ	3888.886	0.0189152
σ	809.5395	0.0134072

From the above Table 3, the estimation of the parameters are as follows; θ = 3888.886 and σ = 809.5395 with the standard error of 0.0189152 and 0.0134072 respectively. While these are parameters for the normal distribution, we can use the same parameters to obtain the parameters of the log-normal distribution as in equation (3.9) and (3.10) respectively.

$$e^{(\theta+\frac{\sigma^2}{2})} = 3888.886 \quad (17)$$

$$[E(y)]^2(e^{\sigma^2}-1) = 655354.3 \quad (18)$$

Solving equation (17) and (18) simultaneously;

$$(e^{\sigma^2}-1) = \frac{655354.3}{3888.886^2} = 0.0433342$$

$$e^{\sigma^2} = 1.0433342 \Rightarrow \sigma^2 = \ln 1.0433342$$

$$\sigma = \sqrt{0.04242} \Rightarrow \sigma = 0.206. \quad (19)$$

Replacing back the value of σ to equation (19) to obtain the value of θ,

$$\theta = ln(3888.886) - \frac{0.206}{2}$$

$$\theta = 8.256 \quad (20)$$

From equations (19) and (20), we can derive that the value of NSE-20 share Index follows a log-normal distribution that has the following parameters of $\theta = 8.256$ and $\sigma = 0.206)$ i.e. $Y \sim LG(\theta = 8.256, \sigma = 0.206)$.

On testing of the correlation between the different prices of the NSE-20 share Index during day tradings, the results are in the Table below:

Table 4. Relationship between Daily Lows and Highs of the NSE-20 Share Index

Residuals				
Min	1Q	Median	3Q	Max
-49.852	-0.197	0.030	0.277	36.77
Coefficients Intercept	Estimate -0.3292837	Std.Error 0.5445662	t-value -0.58340	$P(>\|t\|)$ 0.59978
Open	1.0000781	0.00001419	7045.95	$< 2.23e-17$
High				
Low				
Change %				
Residual	Error:	2.6 on 620	degrees	of Freedom
Multiple Error:	1	Adjusted R-squared:	1	
F-statistic:	$2.524e-7$	on 2 and 620 df	p-value:	$2.22e-16$

4. Data Analysis and Interpretation of Results

It is important that NSE-20 share Index used in modeling of Exchange Traded Funds are tested for normality since this is important in modeling purposes. This will also be important in modeling and forecasting of NSE-20 Share Index thus making vital for those Kenyan as well as international investors who may be interested in making decisions on whether to make the investment at the Nairobi Securities Exchange or not.

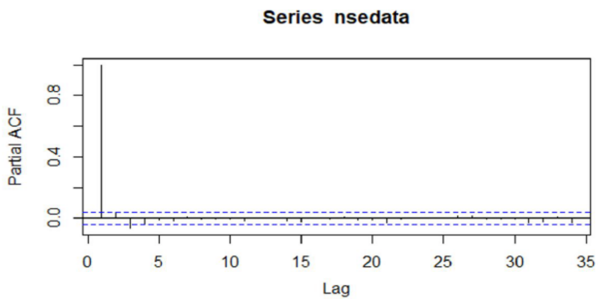

Figure 1. Series of the NSE-20 Share Index Data

The Stationarity data is shown in the Figure 2 below as follows;

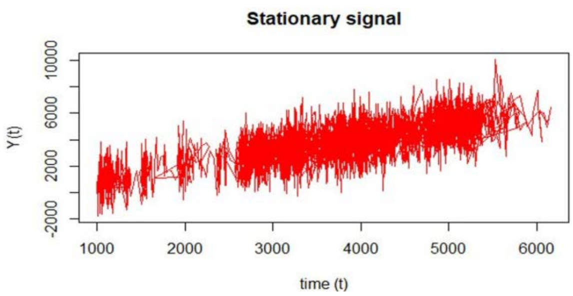

Figure 2. Stationarity of NSE-20 Share Index Data

Notably, the stationary signal shown in top left are results in few important lags, which exceed the ACF's confidence interval both in blue dashed line and bottom left. When a comparison is done with the time series having a trend (top right) results in all lags that exceeds the ACF's confidence interval (bottom right). In terms of quality, it is easy to see and make conclusions from the signal of the ACFs within left is stationary (from the lags, which die out) whereas the signal on the right is not stationary (as later lags do exceed the respective confidence intervals).On the Fitting the NSE-20 Share Index Data, it is calculated using the estimated parameters as follows;

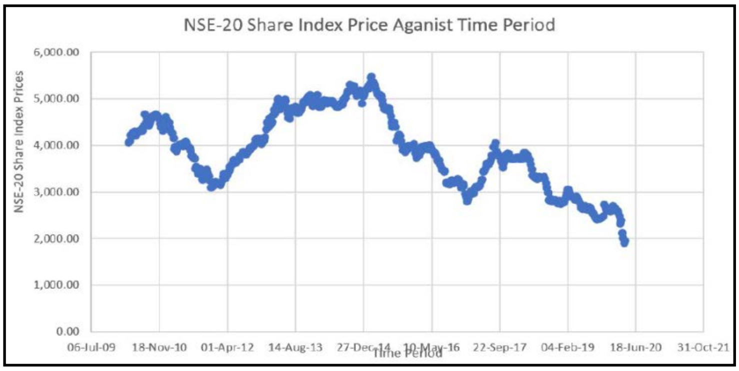

Figure 3. NSE-20 Share Index Trading Against Time

It is important to summarizes the relevant information on the empirical log-normal distributions of securities index returns under different consideration. The vital statistics that needs to reported includes mean, variance, standard deviation, minimum as well as maximum level of return during the trading period, kurtosis and coefficients of skewness.

Table 5. Sample Moments Distributions of the NSE 20 Share Index

Mean	Variance	Std	Max Return	Min Return	Skewness	Kurtosis
5988.565	655354.3	809.5395	5491.37	1917.67	-0.0381	2.03802

From statistics analysis from [22] the third central moment is referred as an asymmetry measure or skewness within the specified distribution. From results illustrated in Table 5, it is important to note the data distribution is not symmetrical as it is negatively skewed with the skewness coefficient of -0.0381. In addition, the kurtosis, which is a measure of general peakedness or just flatness near the center of the distribution degree. The ratio is obtained by getting the ratio of the 4th central moment before dividing it by the variance square. For a normal distribution, the ratio should be equal to 3.00. Any ratio that is greater than 3 does indicate that more values within the neighborhood of its mean (which is more peaked compared to the normal or Gaussian distribution). From the analysis of our NSE-20 share index data, it is a heavy tailed, which is an excess kurtosis. This is shown by the coefficient of kurtosis of 2.038016. We can conclude that our data is mesokurtic.

The past researchers have been testing existence of unit root alone. However, less research is done on testing the long memory. As a way of fully investigating the existence in the weak form of the efficient market hypothesis, this research will test both unit root test and test for long memory. The NSE trends from 2002 to the year 2019 has been illustrated in the Figure 4 below;

Figure 4. NSE-20 Share Index With Time

4.1. Fitting a Log-Normal Distribution

With the data available at the NSE website, we can be able to fit the data with the log- normal distribution after estimation of the parameters to obtain new fitted data. The data is then used to model the new prices of NSE-20 share index that follows a long normal distribution with the estimated levels of volatility of the market compared to findings of [23] paper.

Figure 5. Estimated NSE-20 share Index volatility with Time

From Table 5, we can see that the daily volatility of the NSE-20 share Index is stochastic during the duration of trading in the market. The values changes daily as the value of the securities index changes during the trading periods with the mean volatility obtained in equation (19).

5. Conclusions

From the test carried out, the results strongly indicate that the NSE is not efficient in the weak form because high volatility levels, delay in electron trading when trading orders are made and poor flow of the information within the securities exchange market that can lead to insider tradings. The study used a log-normal distribution in finding returns in terms of logarithms price index as opposed to the simple price index changes. The argument is that the natural logarithms of price is the return, that has a continuous compounding, which you earn when hold the specific security for a particular day.

The results from the study as shown from Figure 4 that variability of security price index changes that makes it an increasing price index function. However, by taking the natural logarithms can neutralize the effects on price index levels. From the descriptive analysis, the historical data of NSE-20 share price index data shows that it heavy tailed and non-symmetrical as assumed by most papers. With skewness coefficient of and low kurtosis, the data is mesokurtic which disputes the previous assumptions.

On the recommendations, a test on the semi-strong form of the efficient market hypothesis can be done to ascertain whether the information that is available in the market shows the correct pricing of the prices of stock traded in the exchange market. This would surely help the investors make an informed decision from the NSE 20-share index whenever they want to make an investment from the market for possibility of getting higher returns. However, with strong form EMH, it is important that the traders take care of the insider trading that is a massive problem when dealing with the issues of trading. With no cases of insider trading, it would be possible to have an efficient market where the information available in the market reflects the demand and supply of traders thus the prices. With the assumption that volatility of the NSE-20 Share Index is constant over the period of trading is flawed since it changes over time when making investments especially for the cases of pandemics such as Covid-19 that has been experienced in Kenyan market.

From our results, we can affirm that log-normal distribution fits the NSE-20 share Index data when modeling the market trends especially when taking into considerations the cases of extreme events during the period of study. Since the trends of NSE-20 share Index are heavy tailed, it offers a clear evidence that the changes in price over a unit of time interval is not a constant variable. We can conclude that the future predictions of the NSE 20 Share Index returns should be based on a log normal distribution as opposed to a normal distribution. In addition, we recommend an investigation of the inverse gamma normal mixture distribution if it can best fit the returns of NSE 20 Share Index return as well as other normal mixtures.

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