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Stochastic Analysis of the Impact of Growth-Rates on Stock Market Prices in Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A stochastic analysis of stock market expected returns and Growth-rates were investigated. The precise conditions for obtaining the drifts, volatilities and Growth-rates of four different stocks were also considered herein. From the stochastic analysis of the model; systems of non-linear stochastic differential equations were developed by means of covariance matrix solution on the stochastic part of the expected returns of investors while the deterministic part a function of the drift parameter as a mean column vector. A condition were imposed that multiplied drift parameter by one and solving simultaneously to obtain future stock prices. From the estimated growth-rates shows severe depletion of securities which are indexed by per thousands of naira leading to financial liquation. Also there are also good increases in growth rate values which dominantly indicate high stock returns over the trading period. This remark leads to a favorable profit margin on the aspect of investors. These are obtainable and conferred in this paper.

Keywords: Stock market price; drift; volatility; growth-rates; SDE and stochastic analysis.

1. INTRODUCTION

Mathematical models grow out of equations of which stock price models cannot be left behind due to its numerous applications in our daily trading activities. Such applications include quantitative finance, Accountancy, Banking and finance etc. In many fields of science and

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engineering the accurate analysis, design and assessment of system subjected to realistic environment effects must take into account of the potential of “white noise” random forces that would affect the system or error measurements in the system. Randomness is intrinsic to the mathematical formulation of many phenomena, such as, fluctuations in the stock market, noise in population systems, communication networks or irregular fluctuation in observed signals.

The unstable nature of stock prices has kept our nation on economic crisis; investors, policy makers, families and federal Government do not predict the future due to uncertainty involve in stock trading. Unstable stock prices puts fear in lives of the people which results to lots of criminal activities in order to meet up individual demands, and results to panic buying. Even financial analysts who invest in stock market are usually not conscious of the stock market behavior; also went through this problem of stock trading; without knowing which stocks to buy and sell in order to maximize profits. Both financial analysts and potential investors need regular information in forecasting the behavior of stock prices in Nigeria for the good of our country.

The unstable property and other considerable factors such as liquidity on stock return, since the sudden change in share prices occur randomly and frequently. Researchers are interested to study the behavior of the unstable market variable so as to enable investors and owners of cooperation make decisions on the level of their investment in stock market exchange, [1].

Nevertheless, the price evolution of a risky assets are usually modeled as the trajectory of a risky assets that are usually of a diffusion process defined on some underlying probability space ,with the geometric Brownian motion the paramount tool used as the established reference model, [2].

A lot of scholars have modeled Stock market prices with different approaches and results obtained differently. For instance, [3] considered the unstable nature of stock market forces using proposed differential equation model. In the work of [4] studied stability analysis of stochastic model of price change at the floor of a stock market. In their research précised conditions are obtained which determines the equilibrium price and growth rate of stock shares.

[1] Considered stochastic analysis of the behavior of stock prices. Results reveal that the proposed model is efficient for the prediction of stock prices. In the same vain, [5] studied the stochastic model of some selected stocks in the Nigerian Stock Exchange (NSE), in their research the drift and volatility coefficients for the stochastic differential equations were determined and the Euler-Maruyama method for system of SDE’S was used to stimulate the stock prices [6], built the geometric Brownian Motion and studied the accuracy of the model with detailed analysis of simulated data.

[7] Worked on stochastic modeling of stock prices; applied a method of Brownian motion model to explain the stock price time series. The result showed that as long as a model based upon the white noise is fitted to the market values, the two interpretations will provide different estimates of the parameters, but identical values concerning the predicted stock prices.

However [2] worked on stochastic model of the fluctuation of stock market price is considered. Here conditions for determining the equilibrium price, sufficient conditions for dynamic stability and convergence to equilibrium of the growth rate of the value function of shares. On the other hand, [8] considered a stochastic model of price changes at the floor of stock market. In their research the equilibrium price and the market growth rate of shares were determined. See [9] for considerable extensions and constrains subsequently in this particular area of study. There are lots of scholarly articles on stock prices which can also be seen in the works of [10-14] etc.

Previous studies for instance, [5] investigated a stochastic model of some selected stocks in Nigeria Stock Exchange (NSE) where the Euler-Maruyam method for system of (SDE) was used to simulate the stock prices and result showed that stock (1) gave the best return on investment compared to stock(2),stock(3) and stock(4). The advantage of this work over the work of [5] is that the present work models the impact of growth-rates on stock market price prediction with respect to volatility and the drift. For the very first time; the technique of two key stock variable of SDE was used to determine growth rates and its impacts to stock price changes. To the best of our knowledge this novel contribution complements the previous finding as it extends the area of applicability of problem of this nature.

The aim of this paper is first, to present the unstable nature of stock market prices which aimed at determining the drifts, volatilities and Growth-rates of asset returns. From the stochastic analysis of the model; firstly the two parameters of the model and imposed a condition which the stock drift parameter (dt) was multiplied by one; this way, an accurate analytical solution of future stock prices were obtained.

This paper is arranged as follows: Section 2 presents mathematical modeling of asset returns, the formulation of the problem is seen in Subsection 2.1, Subsection 2.2 is Estimation of parameters, data analysis and discussion of results of relevant parameters are seen in Section 3 and the paper is concluded in Section 4.

2. MATHEMATICAL MODELING OF ASSET RETURNS

Here, the mathematical models are reviewed with all relevant stochastic methods that would help in achieving the derivation.

Let $S(t)$ be the price of some risky asset at time t and μ an expected rate of returns on the stock and dt as a relative change during the trading days such that the stock price follows a random walk which is governed by a stochastic differential equation.

$$dS(t) = \mu S(t)dt + \sigma S(t)dW_t \quad (1)$$

Where, μ is drift and σ the volatility of the stock, W_t is a Brownian motion or Wiener's process on a probability space $(\Omega, \xi, \wp), \xi$ is a $\sigma-\text{algebra}$ generated by $W_t, t \geq 0$.

Definition 1.1 A standard Brownian Motion is simply a stochastic process $\{B_t\}_{t\in\tau}$ with the following properties:

i) With probability 1, $B_0 = 0.$
ii) For all $0 \leq t_1 \leq t_2 \leq \cdots \leq t_n,$ the increments $B_{t2-}B_{t1}, B_{t3-}B_{t2}, B_{t2}, \cdots, B_{tn} - B_{tn-1}$ are independent.
iii) For $t \geq s \geq 0,\ B_t - B_s \sim N(0, t-s)$.
iv) With probability 1, the function $\to B_i$ is continuous.

Stock Price Modelling

Theorem 1.1 (Ito's formula) Let $(\Omega, \beta, \mu, \mathrm{F}(\beta)$ be a filtered probability space $X = \{X, t \geq 0\}$ be an adaptive stochastic process on $(\Omega, \beta, \alpha, \mathrm{F}(\beta)$ processing a quadratic variation (X) with SDE defined as:

$$dX(t) = g(t, X(t))dt + f(t, X(t))dW(t) \quad (2)$$

$t \in \Re$ and for $u = u(t, X(t) \in C^{1\times2}(\Pi \times \mathbb{R}))$

$$du(t, X(t)) = \left\{\frac{\partial u}{\partial t} + g\frac{\partial u}{\partial x} + \frac{1}{2}f^2\frac{\partial^2 u}{\partial x^2}\right\}d\tau + f\frac{\partial u}{\partial x}dW(t) \quad (3)$$

Using theorem 1.1 and equation (3) comfortably solves the SDE with a solution given below:

$$S(t) = S_0 \exp\left\{\sigma dW(t) + \left(\alpha - \frac{1}{2}\sigma^2\right)t\right\}, \forall t \in [0,1]$$

Following the properties of standard Brownian motion process for $n \geq 1$ such that any sequence time has it thus: $0 \leq t_0 \leq t_1 \leq \cdots \leq t_n,$ .Hence, we have Euler's method for discretization of the SDE as follows:

$$\ln S_t - \ln S_{t-1} = \left(\mu - \frac{\sigma^2}{2}\right)\Delta t + \sigma\left(W_t - W_{t-1}\right) \tag{4}$$

Definition 1.2: A random variables say $W_t - W_{t-1}$ are functions, σ and therefore independent; which has a standard normal distribution with zero mean and variance one respectively.

From (4) if we let $y = \ln S_t - \ln S_{t-1},\ \varepsilon = W_t - W_{t-1}$ and $\Delta t = 1$ (4) becomes

$$y_t = \mu - \frac{1}{2}\sigma^2 + \sigma\varepsilon_t \tag{5}$$

Linking (4) and (5) gives:

$$\ln S_t = \ln S_{t-1} + \left(\mu - \frac{\sigma^2}{2}\right)\Delta t + \sigma\varepsilon(\sqrt{dt}) \tag{6}$$

Divide both sides by $\ln$ gives

$$S_t = S_{t-1} e^{\left(\mu - \frac{\sigma^2}{2}\right)\Delta t + \sigma\varepsilon(\sqrt{dt})} \tag{7}$$

2.1 Formulation of the Problem

Let S_1, S_2, S_3 and S_4 represents daily prices in naira of four selected stocks. Time t is counted for trading days in multiples of fundamental unit, say days. Also ,let an $N \times n$ data matrix associated with $S_0(1), S_0(2), S_0(3)$ *and* $S_0(4)$ be X_{it} ,We consider N stocks over n trading days; time horizon. For each of four X_i ,we define the vector D_{it} as follows:

$$D1_{it} = \frac{1}{N}\sum_{i=1}^{N}\left(D_{i1}, D_{i2}, D_{i3}, \cdots, D_{in}\right) \tag{8}$$

$$D2_{it} = \frac{1}{N}\sum_{i=1}^{N}\left(D_{i1}, D_{i2}, D_{i3}, \cdots, D_{in}\right) \tag{9}$$

$$D3_{it} = \frac{1}{N}\sum_{i=1}^{N}\left(D_{i1}, D_{i2}, D_{i3}, \cdots, D_{in}\right) \tag{10}$$

$$D4_{it} = \frac{1}{N}\sum_{i=1}^{N}\left(D_{i1}, D_{i2}, D_{i3}, \cdots, D_{in}\right) \tag{11}$$

Thus, from where further statistics are derived we also define Growth-rates as:

$$Gr_i = \frac{\sigma_i - \mu_i}{\sigma_i} \tag{12}$$

Following the method of [5], we define covariance matrix as:

$$B(\mathrm{t}, \mathrm{S}_1, \mathrm{S}_2, \mathrm{S}_3, \mathrm{S}_4) = \begin{pmatrix} dS_1 & dS_1S_2 & dS_1S_3 & dS_1S_4 \\ dS_2S_1 & dS_2 & dS_2S_3 & dS_2S_4 \\ dS_3S_1 & dS_3S_2 & dS_3 & dS_3S_4 \\ dS_4S_1 & dS_4S_2 & dS_4S_3 & dS_4 \end{pmatrix}^{\frac{1}{2}} \tag{13}$$

Where covariance matrix represents the volatility coefficient of the stochastic differential equation. It is sufficient to know that covariance matrix is a positive definite symmetric matrix with a positive definite square-root. While stock drift is represented as a column vector form which we considered the mean of each of the companies represented below:

$$\mu(t, S_1, S_2, S_3, S_4) = \begin{pmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{pmatrix} \tag{14}$$

Combining (9) and (10) gives

$$dS(t) = \begin{pmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{pmatrix} dt + \begin{pmatrix} dS_1 & dS_1S_2 & dS_1S_3 & dS_1S_4 \\ dS_2S_1 & dS_2 & dS_2S_3 & dS_2S_3 \\ dS_3S_1 & dS_3S_2 & dS_3 & dS_3S_4 \\ dS_4S_1 & dS_4S_2 & dS_4S_3 & dS_4 \end{pmatrix}^{\frac{1}{2}} dW(t) \tag{15}$$

This invariably gives us system of stochastic differential equations.

$$dS(t) = \begin{pmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{pmatrix} dt + \begin{pmatrix} dS_1 & dS_1S_2 & dS_1S_3 & dS_1S_4 \\ dS_2S_1 & dS_2 & dS_2S_3 & dS_2S_3 \\ dS_3S_1 & dS_3S_2 & dS_3 & dS_3S_4 \\ dS_4S_1 & dS_4S_2 & dS_4S_3 & dS_4 \end{pmatrix} dW(t) \tag{16}$$

2.2 Estimation of Parameters

Using data provided in [5] which covers sixty days daily stock price data from NSE. The estimation of two key parameters are as follows: volatility (σ) and the drift (μ) of the stock price for the four selected company such as S1-INTERBREW,S2-AP,S3-ASHAKACEM and S4-STANBIC. The daily stock prices is made of 60 observations where we partitioned each stock to be four (4) compartments which gave fifteen (15) Tables.

The formula for the volatility and drift of the stock price is defined as follows:

2.2.1 the volatility, σ

Let S_i represent each of the initial stock prices at the end of $i-th$ trading period, $T = t, -t_{i-1}, i \geq 1.$ we define it as the logarithm of the daily return on each of four compartments of stock prices such that:

$$\mu_i = \ln\left[\frac{S_i}{S_{i-1}}\right] \tag{16}$$

The mean of each of stock prices are given as

$$\bar{u} = \frac{1}{N}\sum_{i=1}^{n} u_i \tag{17}$$

The standard deviation is given as

$$v = \frac{\sqrt{\sum |u_i - \bar{u}|^2}}{n-1} \tag{18}$$

The volatility of the daily stock return:

$$\sigma = \frac{v}{\sqrt{\tau}} \tag{19}$$

2.2.2 The drift parameter, μ

This simply means expected annual rate of return which is given as

$$\mu = \frac{\bar{u}}{\tau} + \frac{1}{2}\sigma^2 \tag{20}$$

3. DATA ANALYSIS AND DISCUSSION OF RESULTS OF RELEVANT PARAMETERS

To demonstrate the unstable nature of stock market prices. The daily prices in naira of four (4) selected stocks for sixty (60) trading days from Nigeria stock Exchange (NSE) extracted from [5].The stock prices were partitioned into four(4) compartments each to having a total of fifteen(15) compartments in sixty(60) trading days , see appendix 1.

The initial stock prices were taken from each of the respective compartments to give a total of fifteen (15) observations for different stocks (ie $S_0(1), \cdots, S_0(4)$). The volatility and drift coefficients were obtained from each of these four (4) different stocks (ie S_i's, $\text{i} = 1, 2, 3, 4$ using equations (15)-(19). The trading days were taken to be $\sqrt{60}$ .This computations were made using the stochastic part which is the function of stock volatility and stock drift as column vector while the Growth rates were obtained using (12) see Table 1 and 2 respectively.

In Table 1, the values of volatility and the drift of each respective daily stock price (stock (1) and stock (2)) were obtained for the purpose of prediction during the trading period. The value of the volatility and the drift of each daily stock will be used to predict the value of the subsequent stock price. This will be a guide for an investor who wants to invest in stock exchange trading business for the determination of profit making. The distribution of these stock variables is seen in columns 2, 3, 6 and 7. However, the drift as a daily expected rate of return of the stock for each day shows a varying distribution of the return rate. The drift values have very low returns on the stocks as can be seen above.

It is very clear that majority of the growth rates can be observed to produce lower values which leads to a severe depletion of the original stock prices. This observation shows that such a reduction in the growth rates can lead to some kind of financial bankruptcy on the part of interested investors which cannot be of good benefit in the trading business of sixty (60) trading days.

However, there are also good increases in growth rate values which dominantly indicate high stock returns over the trading period. This remark leads to a favorable profit margin on the aspect of investors. This is in agreement with result of [15]. The same interpretation holds for Table 2; except where there are negative growth rate values indicating crashes in the stock exchange business; see Table 2 of column 8.

In the Fig. 1, above shows stochastic nature of stock prices in respect to growth rates. This is highly reliable because; it describes the stock volatility as time dependent variable which is characterized by random features. There were lots of crashes in Growth-rate (4) this lead to a severe depletion of securities which are indexed by per thousands of naira leading to financial liquation. This result is in consonance with the result of [15]. The study also demonstrated that the Nigerian stock exchange (NSE) is not efficient even in the weak form and investment strategies based on past information of the NSE will not necessarily yield higher returns since the price formation is assumed to be stochastic process.

Table 1. The Values of initial stock prices, volatility, Drift and Growth-rates for stock (1) and stock (2)

$S_0(1)$	**Volatility** (σ_1)	**Drift** (μ_1)	**Growth-rate** (Gr_1)	$S_0(2)$	**Volatility** (σ_2)	**Drift** (μ_2)	**Growth-rates** (Gr_2)
20.71	0.3986	0.07983	0.7997	22.52	0.0000	0.00036	0.0000
21.66	0.4895	0.12017	0.7545	22.52	0.0000	0.00036	0.0000
18.90	0.9177	0.42149	0.5407	22.52	0.0000	0.00036	0.0000
21.49	0.0000	0.00038	0.0000	21.49	0.0000	0.00036	0.0000
21.49	0.2591	0.03394	0.8690	22.52	0.0000	0.00036	0.0000
20.00	0.0000	0.00041	0.0000	20.00	0.2425	0.02979	0.8772
20.00	0.0000	0.00041	0.0000	21.00	0.2425	0.02940	0.8788
20.00	0.0000	0.00041	0.0000	20.38	0.155	0.01241	0.9199
20.00	0.3569	0.06409	0.8204	20.10	0.03465	0.000998	0.9712
20.01	0.0025	0.00041	0.836	20.02	0.0000	0.000406	0.0000
19.50	0.1184	0.00743	0.9372	21.35	0.2125	0.02296	0.8919
19.07	0.2734	0.03779	0.8618	20.50	0.0000	0.000396	0.0000
19.52	0.1301	0.00889	0.9317	20.50	0.2454	0.03050	0.8757
19.00	0.125	0.00824	0.9341	21.35	0.0000	0.000380	0.0000
19.50	0.0000	0.00042	0.0000	21.35	0.0000	0.000380	0.0000

Table 2. The Values of initial stock prices, volatility, Drift and Growth-rates for stock (3) and stock (4)

$S_0(3)$	**Volatility** (σ_3)	**Drift** (μ_3)	**Growth-rates** (Gr_3)	$S_0(4)$	**Volatility** (σ_4)	**Drift** (μ_4)	**Growth-rates** (Gr_4)
21.02	0.3501	0.061689	0.8238	21.01	0.1275	0.03289	0.7420
19.32	0.52	0.1356	0.7392	20.00	0.12	0.02921	0.7566
21.40	0.3882	0.07574	0.8049	18.50	0.6336	0.8032	-0.2677
19.95	0.0000	0.000407	0.0000	19.90	0.6062	0.7353	-0.2130
20.57	0.0000	0.000395	0.0000	20.00	0.4295	0.3693	0.1402
21.50	0.0000	0.00038	0.0000	19.90	0.0000	0.0004	0.0000
21.00	0.0000	0.00038	0.0000	19.00	0.0000	0.0004	0.0000
20.47	0.1325	0.00092	0.9931	19.90	0.2250	0.1017	0.548
21.50	0.2974	0.04461	0.85	19.90	0.0000	0.0004	0.0000
21.57	0.0175	0.00053	0.96971	19.90	0.0289	0.000207	0.9927
22.60	0.275	0.03822	0.8610	15.03	0.4660	0.4348	0.0670
22.00	0.125	0.00819	0.9345	17.00	0.2246	0.1014	0.5485
21.50	0.2264	0.02601	0.8851	19.90	1.4001	3.9207	-1.8003
22.15	0.0000	0.00037	0.0000	15.05	0.0000	0.0005	0.0000
21.10	0.3559	0.06370	0.8210	15.05	0.0000	0.0005	0.0000

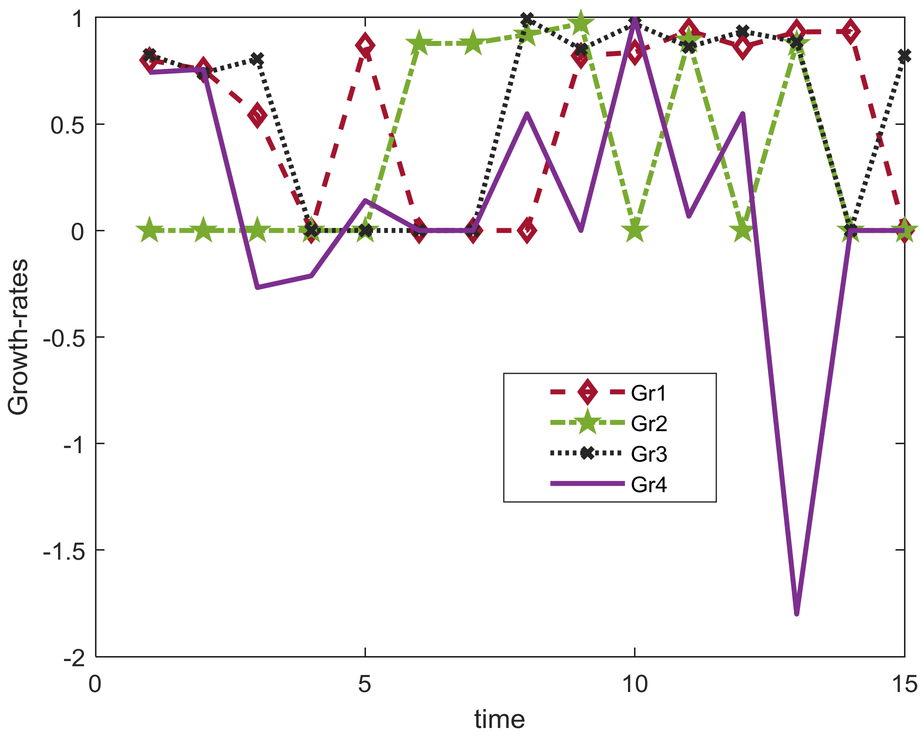

Fig. 1. Intrinsic Growth-rates 0f four Securities

Using equation (14) gives a system of stochastic differential equation

$$dS(t) = \begin{pmatrix} 0.7843 \\ 0.1294 \\ 0.4654 \\ 6.5328 \end{pmatrix} dt + \begin{pmatrix} 0.2486 & 0.1122 & 0.1503 & 0.0624 \\ 0.1122 & 0.1039 & 0.0616 & 0.0849 \\ 0.1503 & 0.0616 & 0.0894 & 0.1323 \\ 0.0624 & 0.0849 & 0.1323 & 0.37 \end{pmatrix} dW(\mathrm{t})$$

This gives systems of non-linear stochastic differential equation below:

$$dS_1 = dS_2 = dS_3 = dS_4 = 0 \;\; and \; dt = 1$$

$$\begin{aligned} 0.2486dW_1 + 0.1122dW_2 + 0.1503dW_3 + 0.0624dW_4 &= -0.7843 \\ 0.1122dW_1 + 0.1039dW_2 + 0.0616dW_3 + 0.0849dW_4 &= -0.1294 \\ 0.1503dW_1 + 0.0616dW_2 + 0.0894dW_3 + 0.1323dW_4 &= -0.4654 \\ 0.0624dW_1 + 0.0849dW_2 + 0.1323dW_3 + 0.37dW_4 &= -6.5328 \end{aligned}$$

Putting the above in matrix form gives

$$dS(\mathrm{t}) = \begin{pmatrix} 0.2486 & 0.1122 & 0.1503 & 0.0624 \\ 0.1122 & 0.1039 & 0.0616 & 0.0849 \\ 0.1503 & 0.0616 & 0.0894 & 0.1323 \\ 0.0624 & 0.0849 & 0.1323 & 0.37 \end{pmatrix} \begin{pmatrix} dW_1 \\ dW_2 \\ dW_3 \\ dW_4 \end{pmatrix} = \begin{pmatrix} -0.7843 \\ -0.1294 \\ -0.4654 \\ -6.5328 \end{pmatrix}$$

Solving simultaneously gives the following stock prices

$$dW_1 = 35.5069,\ dW_2 = -19.8008,\ dW_3 = -62.0535,\ dW_4 = -1.00175$$

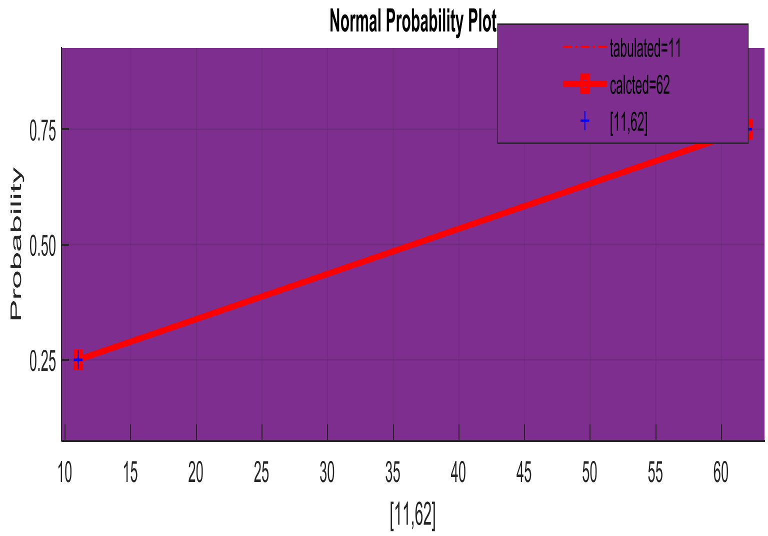

Fig. 2. Graphical representation of normal distribution of stock prices

Fig. 2 is just to attest for the adequacy of the propose model. The normal distribution is vital because it makes statistics a lot easier and more practicable in the life of every investor. They are correlated with equal variances displaying good agreement in the stock expected returns of investors.

4. CONCLUSIONS

This paper considered the problem of stock market prices via stochastic differential equation. The precise conditions for obtaining the drifts, volatilities and growth-rates of four different stocks were considered. From the stochastic analysis of the model; systems of non-linear stochastic differential equations were developed by means of covariance matrix on the stochastic part of the expected returns of investors while the deterministic part a function of the drift parameter as a column vector. A condition were imposed that multiplied the drift parameter (dt) by one and solving simultaneously we obtained future stock prices and stock prices follows a normal distribution. From the estimated growth-rates; there was severe depletion of securities which are indexed by per thousands of naira leading to financial liquation as a result of low values of growth rates. Also there are also good increases in growth rate values which dominantly indicate high stock returns over the trading period. This remark leads to a favorable profit margin on the aspect of investors.

For the very first time; the technique of two key stock variable of SDE was used to determine growth rates and its impacts to stock price changes.

Owing to the fact that, there's non-stationary in stock price realization, it is recommended to use controllability analysis to reflect the changes of stock prices in respect to time.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix 1. Partitions of stock market price data

Table 1.

S_1	**20.71**	**21.60**	**20.63**	**19.65**
S_2	22.52	22.52	22.52	22.52
S_3	21.02	20.02	20.00	19.32
S_4	21.01	21.52	21.52	21.52

Table 2.

S_1	21.66	22.80	22.87	20.83
S_2	22.52	22.52	22.52	22.52
S_3	19.32	21.40	21.40	21.40
S_4	20.00	20.00	20.00	19.52

Table 3.

S_1	18.70	18.00	21.49	21.49
S_2	22.52	22.52	22.52	22.52
S_3	21.40	20.39	20.47	19.50
S_4	18.50	17.27	19.90	19.90

Table 4.

S_1	21.49	21.49	21.49	21.49
S_2	22.52	22.52	22.52	22.52
S_3	19.95	19.95	19.95	19.95
S_4	19.90	19.90	22.00	22.00

Table 5.

S_1	21.49	21.70	20.71	20.71
S_2	22.52	22.52	22.52	22.52
S_3	20.57	20.57	20.57	20.57
S_4	20.00	19.20	19.20	21.01

Table 6.

S_1	20.00	20.00	20.00	20.00
S_2	20.02	20.99	20.99	20.99
S_3	21.50	21.50	21.50	21.00
S_4	19.90	19.90	19.90	19.90

Table 7.

S_1	20.00	20.00	20.00	20.00
S_2	20.02	20.99	20.99	20.99
S_3	21.50	21.50	21.50	21.00
S_4	19.90	19.90	19.90	19.90

Table 8.

S_1	20.00	20.00	20.00	20.00
S_2	21.00	20.38	20.38	20.38
S_3	21.00	20.47	20.47	20.47
S_4	19.00	19.90	19.90	19.90

Table 9.

S_1	20.00	20.42	19.01	19.01
S_2	20.38	20.38	20.50	20.50
S_3	20.47	20.47	21.50	21.50
S_4	19.90	19.90	19.90	19.90

Table 10.

S_1	20.01	20.01	20.01	20.00
S_2	20.02	20.02	20.02	20.02
S_3	21.57	21.57	21.57	21.50
S_4	19.90	19.90	20.00	20.00

Table 11.

S_1	19.50	19.01	19.01	19.07
S_2	21.35	21.35	21.35	20.50
S_3	22.60	22.60	22.60	21.50
S_4	15.03	16.50	17.00	17.00

Table 12.

S_1	19.07	19.8	19.44	18.52
S_2	20.50	20.5	20.5	20.5
S_3	22.00	21.5	21.5	21.5
S_4	17.00	17	17.57	17.91

Table 13.

S_1	19.52	19.01	18.99	19
S_2	20.5	20.5	21.35	21.35
S_3	21.50	21.50	21.05	22.15
S_4	19.90	19.90	15.05	15.05

Table 14.

S_1	19	19	19	19.5
S_2	21.35	21.35	21.35	21.35
S_3	22.15	22.15	22.15	22.15
S_4	15.05	15.05	15.05	15.05

Table 15.

S_1	19.5	19.5	19.5	19.5
S_2	21.35	21.35	21.35	21.35
S_3	21.1	21.5	22.5	22.5
S_4	15.05	15.05	15.05	15.05

Appendix 2: Matlab codes for solving systems of non linear SDE

```
>> eqn1=0.2486*dw1+0.1122*dw2+0.1503*dw3+0.0624*dw4==0.7843;
>> eqn2=0.1122*dw1+0.1039*dw2+0.0616*dw3+0.0849*dw4==0.1294;
>> eqn3=0.1503*dw1+0.0616*dw2+0.0894*dw3+0.1323*dw4==0.4654;
>> eqn4=0.0624*dw1+0.0849*dw2+0.1323*dw3+0.37*dw4==6.5328;
>> [A,B]=equationsToMatrix([eqn1,eqn2,eqn3,eqn4],[dw1,dw2,dw3,dw4]);
>> x=linsolve(A,B)
```

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