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STOCHASTIC MODEL OF STOCK MARKET PRICE MOVEMENT IN THE ASSESSMENT OF TWO SELECTED COMPANIES IN TIME-VARYING INVESTMENTS

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Abstract

This paper examined the stochastic analysis of stock market prices of Dangote Cement and Bua Cement PLCs respectively, using Markov chain formation in finite states. The stock price data of the two companies were subjected to a 3-step transition probability matrix, while the mean data of Oct-Dec of each year (i.e. 2017-2021) were calculated and used as column vectors. This gave us a precise condition for obtaining variations of future price changes for both companies. From the stochastic analysis, it was discovered that Dangote Cement PLC has the highest rate of return: 137.4371 and also has the best probability of price reduction in the near future: 34% and a 32% chance of no change in price. This permeates an investor about stock price movement for the decision making. Recommendations includes stochastic control in modeling of stock price assessment in the further study.

Keywords: *Markov chain and investment, Stock price, companies, stochastic analysis*

Introduction

In an investment, decision-making is one of the major tools that affect investors either positively or negatively. When proper decisions are taken, the financial strength of the investments will increase, but when wrong decisions are taken, the business will crumble. So, the vital decision an investment will make is how to properly allocate its funds at every point in time due to the instability in stock market prices. Therefore, the above constraints need a viable mathematical model that guides investors in decision-making. However, a lots scholars has written extensively on the modelling stock prices using the Markov chain and results obtained in various ways. For instance, Agwuegbo et al., (2010) examined stock market prices due to their fluctuations and influences on the financial lives and economic health of a country. Their findings showed that stock prices are random and no investor can alter the fairness and unfairness of a stock price as defined by expectation. Lakshmi et al., (2020) studied the Markov process of stock market performance. In their result, oil prices in India exhibit a higher chance of being stable with no significant increase or decrease. Davou et al., (2013) considered the Markov chain model on share price movement. The result showed GT Bank shares changing hands more than FB Bank. Agbam and Udo (2020) examined the Markov chain model for forecasting stock prices in Nigeria. In their results, the Markov chain model was determined based on the probability transition matrix. Amadi et al., (2022) explored the stochastic analysis of the Markov chain in finite states. Their work replicated the use of a 3-state transition probability matrix, which enables them to propose precise conditions for obtaining the expected mean rate of return of each stock. , Mettle et al., (2014) considered a stochastic analysis of share prices. Results showed the precise condition of determining the expected mean return time for stock prices; improving investment decisions based on the highest transition probabilities. In the same manner, Amadi et al., (2022) studied the behavior of

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the stock market using the Markov chain. From the study, the iteration remained the same all through steady state probability of share prices. Adeosun et al., (2015) forecasted stock market trend using Markov chain. The result showed a well effective analysis and prediction of stock market prices. In another dimension Davies et al., (2019) discovered that Nigerian banks share prices were relatively stable and further buttressed such analysis will be realistic for investors for the purpose of profit making. Ofomata et al., (2017) analysed the share prices of eight Nigerian banks for long run trading assessments using Markov chain. The limiting distribution probability matrix of the share prices was found to be useful to investors. In this paper, stochastic analysis of the Markov chain was applied to Dangote and Bua Cement PLC using stock prices from 2017-2021. The stock price data was transformed into 3-step transition probability matrix solution, where the variations of stock price changes were obtained. The two return rates of the companies were also compared accordingly.

This paper aims to first present the stock price movement using the Markov chain in finite states, and then vary the stock price future changes of the two companies for the period a year ahead, thereby giving insight into future investments of Dangote cement Nigeria PLC and Bua Cement Nigeria PLC.This paper is arranged as follows: section 2 presents the mathematical preliminaries; the problem formulation is seen in subsection 2.1. Results are presented in section 3 and the paper is concluded in section 4.

Mathematical Preliminaries

A stochastic process is a collection of random variables, its requirement are similar to those for random vectors. It can also be seen as a statistical event that evolves over time in accordance to probabilistic laws. Mathematically, a stochastic process may be defined as a collection of random variables which are ordered in time and defined at a set of time points, which may be continuous or discrete.

Definition 1: A stochastic process $X(t)$ is a relation of random variables $\{X_t(\gamma), t \in T, \gamma \in \Omega\}$, i.e., for each t in the index set T, $X(t)$ is a random variable. Now we understand t as time and call $X(t)$ the state of the procedure at time t

Definition 2: A stochastic process X is said to be a Markov chain if Markov property is satisfied :

$$P\left(X_{n+1} = j / X_0, X_1, \cdots, X_n\right) = P\left(X_{n+1} = j / X_n\right) \qquad (1.1)$$

For all $n \geq 0$ and $i, j \in S$ (state space) **.**

It is sufficient to know that the Markov property given(1.1) is equivalent to easy of the following for each $j \in S$.

$$P\left(X_{n+1} = j / X_{n1}, X_{n2}, \cdots, X_{nk}\right) = P\left(X_{n+1} = j / X_{nk}\right) \qquad (1.2)$$

$\left(\text{for any } n_1 < n_2 <, \cdots, n_k \leq n\right)$

Assuming $X_n = i$ implies that the chain is in the ith state at the nth step.it can also be said that the chain' having the value i' or ' being in state i'. The idea behind the chain is described by its transition probabilities:

$$P\left(X_{n+1} = j / X_n = i\right) \qquad (1.3)$$

They are dependent on i, j and n.

Definition 3: The chain X is said to be homogeneous if the following are stated below

$$P\left(X_{n+1}=j/X_n=i\right)=P\left(X_1=j/X_0=i\right) \qquad (1.4)$$

For all $n,i,j.$

The transition matrix $\mathrm{P}=\left(P_{ij}\right)$ is $n\times n$ matrix of transition probabilities.

$$P_{ij}=P\left(X_{n+1}=j/X_n=i\right) \qquad (1.5)$$

Hence, the transition probabilities with homogenous Markov chain are always stationary at a point.

Theorem 1: Suppose P is a stochastic matrix which implies the following:

i) P has non-negative entries or $\mathrm{P}_{ij}\geq 0$ (ii) $\sum_j P_{ij}=\sum_j P\left(X_{n+1}=j/X_n=i\right)=\sum_j P\left(X_1=j/X_0=i\right)$

which is stationarity or point of convergence.

Proof:(i) each associated entry in P is a transition probability P_{ij} and being probability $P_{ij}\geq 0$.

(ii) $\sum_j P_{ij}=\sum_j P\left(X_{n+1}=j/X_n=i\right)=\sum_j P\left(X_1=j/X_0=i\right)$

Which is stationarity.

$P\left(X_i\in S/X_0=i\right)=1.$

Theorem 2 :(Chapman-Kolmogorov Equations).

$P_{ij(m+n)}=\sum_{r=i}^{n}P_{ir(m)}\,P_{rj(n)}$ Since $\mathrm{P}_{m+n}=\mathrm{P}_m\mathrm{P}_n$ and so on $\mathrm{P}_n=\mathrm{P}^n$ the *nth* power of P .

$$P_{ij(m+n)}=P\left(X_{m+n}=j/X_0=i\right)$$

Proof: $\sum_r P\left(X_{m+n}=j,X_m=r/X_0=i\right)$

$$\sum_r P\left(X_{m+n}=j/X_m=i/X_0=i\right)P\left(X_m=r/X_0=i\right)$$

Using the following in probability rule:

$P\left(A\cap B/C\right)=P\left(A/B\cap C\right)P\left(B/C\right)$ and setting $A=\left\{X_{m+n}=j\right\},\mathrm{B}=\left\{X_m=r\right\},\text{and }\mathrm{C}=\left\{X_0=i\right\}$

Using Markov property yields

$$P_{ij(m+n)}=\sum_r P\left(X_{m+n}=j/\mathrm{X}_m=r\right)P\left(X_m=r/\mathrm{X}_0=i\right)$$

$$\sum_r P_{rj(n)}P_{ir(\mathrm{m})}$$

$$\sum_r P_{1r(\mathrm{m})}P_{r1(\mathrm{n})}$$

Hence $\mathrm{P}_{m+n}=\mathrm{P}_m\mathrm{P}_n$ and so $\mathrm{P}_n=\mathrm{P}^n$, the power *of* P.

2.1 Problem Formulation

Here, we study closing stock price data of Dangote Nigeria PLC and Bua Nigeria PLC in naira of five years selected be defined as three –state Markov process. Then a $N\times N$ data matrix associated with the two companies which measures the change in stock prices at time t ,where $t=0,1,2,\cdots,N$ and t is measured in weekly intervals $t\in T.$. Considering N stocks over N trading days, time horizon. For each of the three $D_{11},\ldots,D_{13}$ *and* $B_{11},\ldots,B_{13}$ is a as column vectors of the two companies which is the last three months of trading in each independent year which sum is given as $\sum_{i=1}^{N}S_{Di}$ and $\sum_{i=1}^{N}S_{Bi}$ where

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$i=1,2,3$. setting $ij=0,1,2 \text{ for} = 3$ Now, let each vector matrices denote Therefore, the ve is defined such that

To obtain an estimates of the transition probability as follows

$$P_{ij}=P\left(X_t=j/X_{t-1}=i\right),\ for\ \ j=0,1,2,3,\cdots,N \qquad (1.6)$$

$$P_{ij}=\begin{cases} P \text{ if } \ j=1+j \\ q=1-P \text{ if } \ j=i-j \\ 0 \ \text{ otherwise} \end{cases} \qquad (1.7)$$

where $k+1$ is the number of states.

$$\left.\begin{array}{l} n_{ij}=\sum_{i=1}^{n} P_{ij} \ \text{ for i j=0,2,3} \\ \dfrac{n_{ij}}{n_i} \ \text{ for } i\ j=0,1,\cdots k \end{array}\right\} \qquad (1.8)$$

and for the fact that we are considering two unique companies, we

$$\hat{P}_{Dangote}=\begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{02} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{23} \end{pmatrix} \qquad (1.9)$$

$$\hat{P}_{Bua}=\begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{02} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{23} \end{pmatrix} \qquad (1.10)$$

Let N_t represent the total months of sale in both companies; where $t=1,2,3,\ldots,12$,while K_t represent the number of years the trading took place, $t=1,2,3,\ldots,5$. However, we define the mean vector of both companies as:

$$\bar{V}_{Dandote}=\frac{1}{N_tK_t}\sum_{i=1}^{N} S_{Di}=\begin{pmatrix} D_{11} \\ D_{12} \\ D_{13} \end{pmatrix} \qquad (1.11)$$

$$\bar{V}_{Bua}=\frac{1}{N_tK_t}\sum_{i=1}^{N} S_{Bi}=\begin{pmatrix} B_{11} \\ B_{12} \\ B_{13} \end{pmatrix} \qquad (1.12)$$

Multiplying (1.9) and(1.11);(1.10) and(1.12) gives

$$\hat{P}_{ij}\,(\text{Dangote:price changes})=\begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{02} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{23} \end{pmatrix}\begin{pmatrix} D_{11} \\ D_{12} \\ D_{13} \end{pmatrix}=\begin{pmatrix} \beta_{11} \\ \beta_{12} \\ \beta_{13} \end{pmatrix} \qquad (1.13)$$

$$\hat{P}_{ij}(\text{Bua:price changes}) = \begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{02} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{23} \end{pmatrix} \begin{pmatrix} B_{11} \\ B_{12} \\ B_{13} \end{pmatrix} = \begin{pmatrix} \phi_{11} \\ \phi_{12} \\ \phi_{13} \end{pmatrix} \quad (1.14)$$

Assuming X_t has state space and transition probability matrix of (1.9) becomes, the limiting distribution for three-state chains with particular reference to definitions of the transition matrices which gives:

$$\left.\begin{matrix} \hat{P}_{Dangote} \\ \hat{P}_{Bua} \end{matrix}\right\} = \begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{02} \\ \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{02} \end{pmatrix} \quad (1.15)$$

The rate of return is determined for both companies as follows:

$$Rt = \frac{E_{It} - B_{It}}{B_{It}} \times \% \quad (1.16)$$

Rt represents rate of returns, E_{It} represents end of investment in particular trading year. B_{It} represents begining of investment in particular trading year. However, from(1.13) and (1.14) and taking their transpose yields

$$\left.\begin{pmatrix} \beta_{11} & \beta_{12} & \beta_{13} \end{pmatrix} \text{ and} \begin{pmatrix} \phi_{11} & \phi_{12} & \phi_{13} \end{pmatrix} \right\} \quad (1.17)$$

The chain follows the behavior of stock market, each as categorized as: increase . Decrease and, remains the same.

3. Data Analysis and Results

To demonstrate the closing stock market price performance of Dangote cement and Bua cement in finite states using Markov chain model. The daily prices covers from 2017-2021 retrievable from Nigeria Stock Exchange (NSE). From Jan.-Sept. of each year were used to form transition probability matrix while from Oct.-Dec. of each year were used to form a mean column vectors all for both companies:

Therefore, the 3-Step transition probability matrix and mean vector of Dangote cement Nigeria, PLC.

$$Pij_{(Dangote)} = \begin{pmatrix} 0.3278 & 0.3327 & 0.3395 \\ 0.4093 & 0.1580 & 0.4327 \\ 0.3432 & 0.3308 & 0.3259 \end{pmatrix}, \bar{V}_{Dandote} = \begin{pmatrix} 15.3405 \\ 43.2975 \\ 15.0863 \end{pmatrix}$$

The 3-Step transition probability matrix and the mean vector of Bua cement Nigeria, PLC.

$$Pij_{(Bua)} = \begin{pmatrix} 0.3335 & 0.3257 & 0.3408 \\ 0.3308 & 0.3291 & 0.3401 \\ 0.3295 & 0.3329 & 0.3376 \end{pmatrix}, \bar{V}_{Bua} = \begin{pmatrix} 97.8088 \\ 970.0202 \\ 963.5911 \end{pmatrix}$$

Using equations (1.13) and (1.14) gives the following

$$\hat{P}_{ij}(\text{Dangote:price changes}) = \begin{pmatrix} 24.5570 \\ 19.6496 \\ 24.5058 \end{pmatrix}, \quad \hat{P}_{ij}(\text{Bua:price changes}) = \begin{pmatrix} 97.8088 \\ 970.0202 \\ 963.5911 \end{pmatrix}$$

Using (1.15) gives the following limiting distributions of the companies

$$\left.\begin{matrix} \hat{P}_{Dangote} \\ \hat{P}_{Bua} \end{matrix}\right\} = \begin{pmatrix} 0.3278 & 0.3327 & 0.3395 \\ 0.3335 & 0.3257 & 0.3408 \end{pmatrix}$$

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Table 1: Variation of Stock Market Process changes of Dangote Cement Plc.

Year (t)	β_{11}	β_{12}	β_{13}	Mean (μ)	Max	Min
1	24.5570	19.6496	24.5058	22.904	24.5570	19.6496
2	49.114	39.2992	49.0116	45.808	49.114	39.2992
3	73.671	58.9488	73.5174	68.712	73.671	58.9488
4	98.228	78.5984	98.0232	91.616	98.228	78.5984
5	122.785	98.248	122.529	114.521	122.785	98.248
6	147.342	117.8976	147.0348	137.425	147.342	117.8976
7	171.899	137.5472	171.5406	160.329	171.899	137.5472
8	196.456	157.1968	196.0464	183.233	196.456	157.1968
9	221.013	176.8464	220.5522	206.137	221.013	176.8464
10	245.57	196.496	245.058	229.041	245.57	196.496
11	270.127	216.1456	269.5638	251.945	270.127	216.1456
12	294.684	235.7952	294.0696	308.183	294.684	235.7952

Table 2: Variations of stock market prices changes of Bua Cement PLC.

Year (t)	ϕ_{11}	ϕ_{12}	ϕ_{13}	Mean (μ)	Max	Min
1	97.8088	970.0202	663.5911	677.140	970.0202	97.8088
2	195.6176	1940.0404	1927.1822	1354.280	1940.0404	195.6176
3	195.6176	2910.0606	2890.7733	1998.817	2910.0606	195.6176
4	391.2352	3880.0808	3854.3644	2708.560	3880.0808	391.2352
5	489.044	4,850.101	4817.9555	3385.700	4850.101	489.044
6	586.8528	5820.1212	5,781.5466	4062.840	5820.1212	586.8528
7	684.6616	6790.1414	6745.1377	4739.980	6790.1414	684.6616
8	782.4704	7760.1616	7708.7288	5417.120	7760.1616	782.4704
9	880.2792	8730.1818	8672.3199	6094.260	8730.1818	880.2792
10	978.088	9700.202	9635.911	6771.400	9700.202	978.088
11	1075.8968	10670.2222	10599.5021	7448.540	1075.8968	10599.5021
12	1173.7056	11640.2424	11563.0932	8125.680	1173.7056	11563.0932

Table 3: The return rate, total rate of return and mean rate of return of Dangote cement Nigeria,PLC

Year	End of investment	Beginning of Investment	Return Rate%
2017	170	156	8.9744
2018	173.78	128.91	34.8072
2019	230	166.11	38.4625
2020	189.9	270	29.6667
2021	141.5	190	25.5263
Total Rate of Return			**137.4371**
Mean Rate of Return			**27.48742**

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Table 4:The return rate, total rate of return and mean rate of return of Bua cement Nigeria,PLC

Year	End of investment	Beginning of Investment	Return Rate%
2017	860	800.25	7.4664
2018	810	739.99	9.4609
2019	1555.99	727	114.0289
2020	1485.00	1435.30	3.4627
2021	1469.90	1440.00	2.0764
	Total Rate of Return		**136.4953**
	Mean Rate of Return		**27.2991**

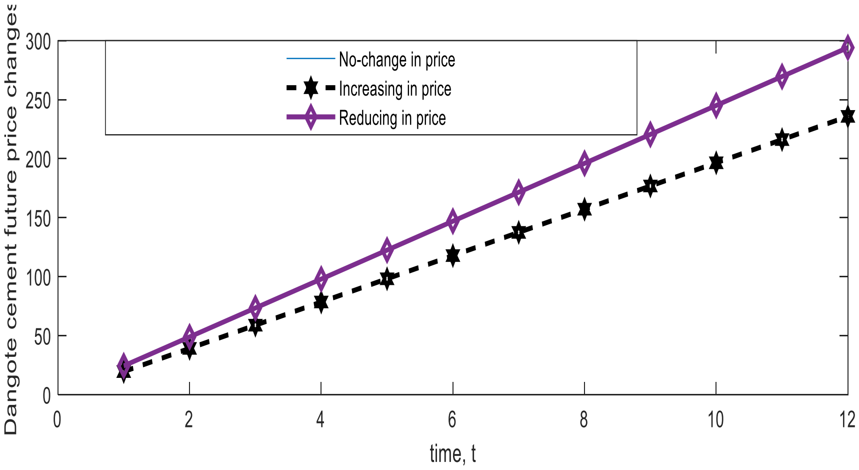

Figure 1: Plot of future price changes of Dangote cement Nigeria, PLC.

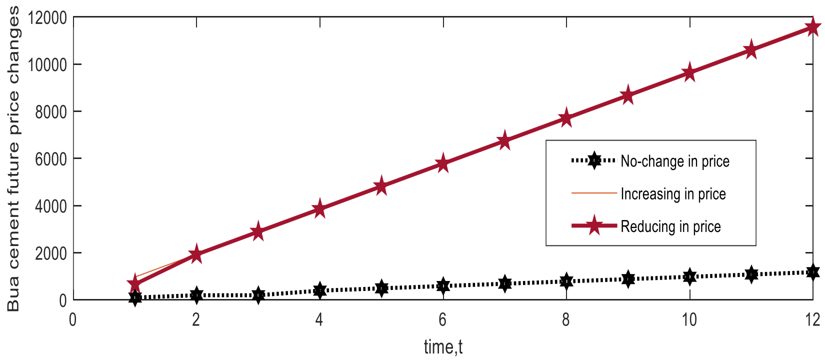

Figure 2: Plot of future price changes of Bua cement Nigeria, PLC.

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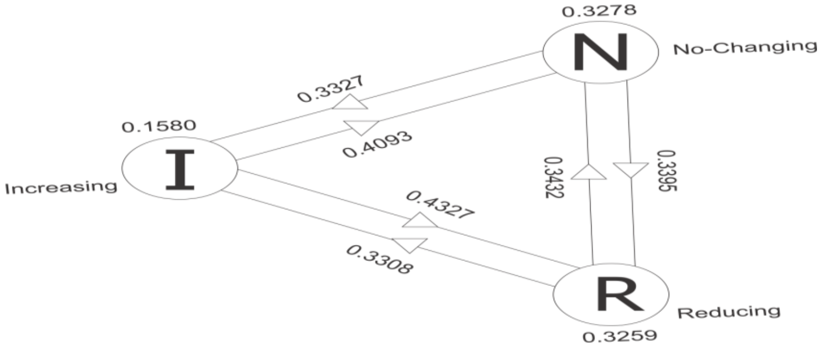

Figure 3: Diagraph transition probability matrix of Dangote cement

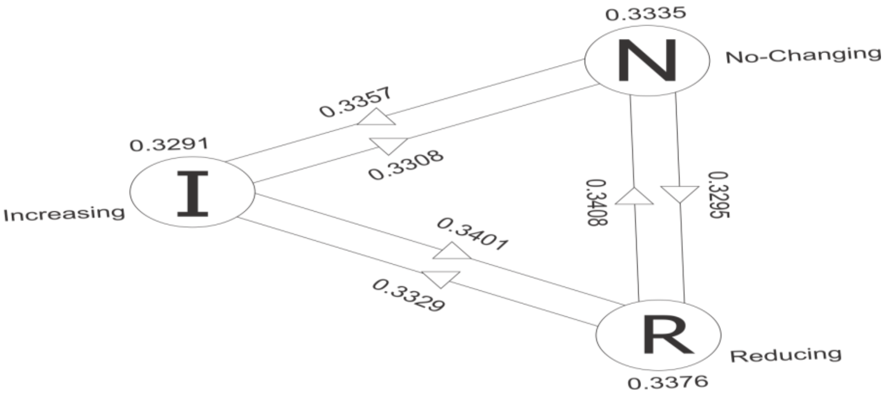

Figure 4: Diagraph transition probability matrix of Bua cement

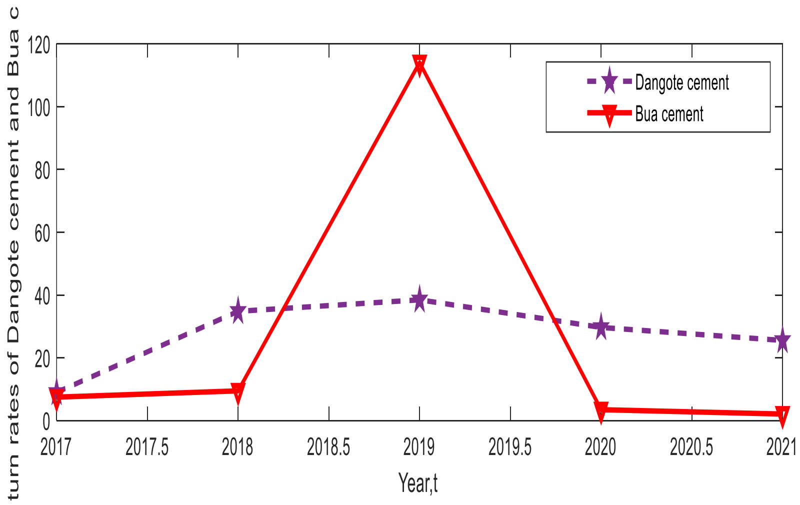

Figure 5: Plots of Dangote cement and Bua cement rate of returns

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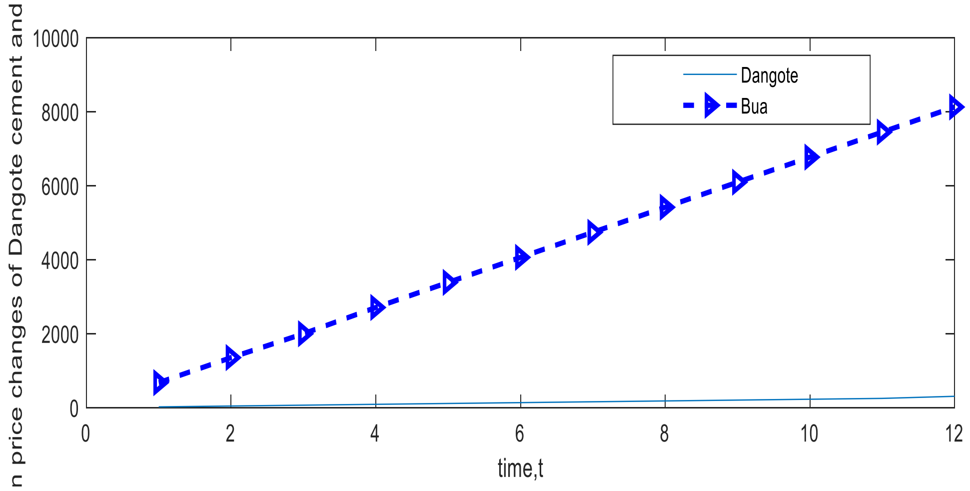

Figure 6: Plots of mean of future price changes in Dangote cement and Bua cement

Discussion of Results

Clearly, in terms of predicting the future of Dangote and Bua cement investments, we interpret row-wise in each of the transition probability matrix. In Dangote cement:

Has 33% probability chance of reducing its price in the near future; 33% probability chance of increasing its price in future and 34% probability chance of no change in price. Also the investments has 41% probability chance of reducing its price; 12% probability chance of increasing its price in future and 43% probability chance of no change in price. Finally, has 34% probability chance of reducing its price; 33% probability chance of increasing its price in future and 33% probability chance of no change in price. However, In Bua cement: Has 33% probability chance of reducing its price in the near future; 33% probability chance of increasing its price in future and 34% probability chance of no change in price. Similarly the investments has 33% probability chance of reducing its price; 33% probability chance of increasing its price in future and 34% probability chance of no change in price. In conclusion, has 33% probability chance of reducing its price; 33% probability chance of increasing its price in future and 33% probability chance of no change in price.

It is observed that Dangote has the best probability of price increasing in the near future. This result will be beneficial to Dangote cement who deals in millions of naira to actually see their future today in terms of tomorrow so as to enable them take the best option in respect to decision making.

In Tables 1 and 2 are generated by multiplying each year, $t = 1, 2, 3, ..., 12$ to the 3-states of future price changes such as:24.5570, 19.6496,24.5058 and 97.8088,970.0202,963.5911 of Dangote cement and Bua cement respectively; which shows increase in the year ,increases 3-states of future price changes, this amounts to millions of naira of both capital investments. The yearly mean of future price changes are seen in column 5. Each yearly mean describes the performances of Dangote and Bua cement price changes over 2017-2021. In the same vain, the maximum and minimum future price changes are compared in the 3-states of each year; so the minimum values of future price changes are recommended to be better in this time varying investments ,see columns 6 and 7 of Tables 1 and 2.

Tables 3 and 4 are generated following equation (1.16) which is yearly rate of returns: that is the net gain or loss of an investment over 2017-2021. The total rate of return and mean rate of returns are: 137.4371, 27.48742 and 136.4953,27.2991 for both Dangote and Bua cements. The description of future price movement of Dangote is seen in Figure 1 which displays the probability of price reducing and at same time increasing in the near future is quite obvious. This remark is an eye opener to Dangote

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cement Nigeria PLC to be aware of the future prediction for the purpose of investments. It can be seen that the future price movement of Bua cement is very significant in the sense that the two plots grow in separate ways; meaning that the probability of price reducing is high more than the probability of price not changing in the near future, see Figure 2. Therefore, Figures 3 and 4 describes probability formations of stochastic process. The transition elements are not consistent but try to show the directions of 3-state space. In Figure 5, the rate of returns of Dangote cement moves upwardly almost at the mean level of its investment while Bua cement moves up and down movement and converges at a point. In all, Dangote cement rate of return is better.

Conclusion

Investors are normally faced with too many decisions on how to maximize profit in their investments due to the unstable nature of stock price movement. Therefore, this paper considered stochastic analysis of stock market prices of Dangote cement and Bua cement PLC using Markov chain formation in finite states. The stochastic analysis of problem showed that: (i) the variation of prices changes for both companies. (ii) Dangote Cement Nigeria Plc has the highest rate of return: 137.471. (iii)the best probability of price reducing in the near future: 34%: 32% chances of no change in price. (iv)Dangote Nigeria PLC is profit maximizing than Bua cement Nigeria PLC. (v) Dangote Nigeria PLC has the best transition probability matrix of limiting distribution than Bua cement. However, considering control theory in Markov chain will be an interesting study.

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