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A Markov Chain Model in Finite State And the impact of Time Delay on Nigerian Current Account Net for Capital Markets

[1]Okoro, J.C, [2]Amadi, I.U, and [3*]Howard C.C

[1] Department of Mathematics, Federal College of Education Technical, Omoku, Rivers State, Port Harcourt, Nigeria.

email: joyceadaobi@fcetomoku.edu.ng

[2]Department of Mathematics & Statistics, Captain Elechi Amadi Polytechnics, Port Harcourt, Nigeria.

email: innocent.amadi@portharcourtpoly.edu.ng

[3*]Department of Mathematics & Computer Science, University of Africa, Toru-Orua, Bayelsa State,

*corresponding author email: howardchioma@gmail.com

ABSTRACT

A mathematical model which captures Nigerian Current Account (NCA) net movements were examined in short and long-term future investments plans, since each finite state communicates. In particular, this paper considered a Markov chain model and time-dependent delay parameter to study Nigeria Current Account net movements, which could be used for decision making. The 3-steps transition probability matrices were considered for NCA data for each group, where movements of NCA net were known. The stochastic matrix solution revealed that group-D had the highest probability of increase in the near future with 179% and has the highest probability of reducing by 43% and finally has the highest probability of no change by 90%. Also, the effects of time delay in each independent group were considered to note changes in commodity prices or global demand for Nigeria exports. Consequently, the impacts of surface view profile of highest covariance matrix and the effect of relevant parameters were discussed for the purpose of this paper.

Keywords: Markov Chain, Time Delay, Transition Matrices, Capital Market, and NCA Net.

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1. INTRODUCTION

The financial capital market plays a crucial role in the economic advancement and progress of developing economies, including Nigeria. This market consists of various financial entities that engage in providing long-term loans for investments. By doing so, they facilitate the connection between long-term lenders and investors. The term loans often span more than two years. Key players in this sphere are insurance firms, issuing authorities, development banks, investment banks, investment trusts, building societies, mortgage banks, finance corporations, savings banks, and stock exchanges. In the realm of the capital market, which is utilized for funding long-term projects, key financial tools include stocks and shares, corporate bonds, and government bonds This market can be segmented into two main categories: the primary market, which focuses on the exchange of newly issued securities, and the secondary market, which is concerned with the trading of securities that are already in circulation. The latter is primarily controlled by the Stock Exchange. At its core, the capital market encompasses the challenges and opportunities associated with equity investments. This includes the issuance and trading of shares, bonds, and debentures, facilitated by brokers, dealers, and underwriters. The capital market serves as the conduit for making these transactions possible.

The financial capital market plays a crucial role in the economic advancement and progress of developing economies, including Nigeria. This market consists of various financial entities that engage in providing long-term loans for investments. By doing so, they facilitate the connection between long-term lenders and investors. The term loans often span more than two years. Key players in this sphere are insurance firms, issuing authorities, development banks, investment banks, investment trusts, building societies, mortgage banks, finance corporations, savings banks, and stock exchanges. In the realm of the capital market, which is utilized for funding long-term projects, key financial tools include stocks and shares, corporate bonds, and government bonds. This market can be segmented into two main categories: the primary market, which focuses on the exchange of newly issued securities, and the secondary market, which is concerned with the trading of securities that are already in circulation. The latter is primarily controlled by the Stock Exchange. At its core, the capital market encompasses the challenges and opportunities associated with equity investments. This includes the issuance and trading of shares, bonds, and debentures, facilitated by brokers, dealers, and underwriters. The capital market serves as the conduit for making these transactions possible. However, the most significant challenge has been a lack of long-term funding. Capital investments are funds invested in a firm with the expectation that the return rates will be sufficient to meet day-to-day trade expenditures. An investor may require greater capital assets in order to boost its trading results. Therefore, capital expenditures are determined on the basis of: acquiring additional capital assets for expansion, allowing the business to grow its unit production, create new product ideas, or even add value to the business; and exploring innovations in technology in order to increase efficiency, reduce costs, and replace worn-out assets. Without capital investments, trade businesses will struggle to get started.

Nonetheless, [1] examined the variations in the share price of Access Bank. They used the stochastic model of the Markov chain. According to their findings, Access Bank has the highest chance of lowering in the future by 21%. [2] Investigated stochastic analysis of Markov Chains with finite states. For their study, they examined Nigeria's current account net statistics.

The solution matrix of the stochastic analysis revealed that 2004-2012 had the highest likelihood of lowering payments by 72%. [3] Investigated the impact of the Markov Chain and the characteristics of the primary component. They employed the Markov chain and the principle component to determine that share prices established by the two merging banks were given, and the analytical solution of the principal component was used to anticipate future stock price fluctuations. [4] Investigated the stochastic analysis of Markov chains in finite states. They converted stock price data into a 3-state transition probability matrix for prediction.

Based on the stochastic analysis of the problem, the features of the basic matrix were investigated in forecasting various commodity price processes. [5] Examined the stochastic analysis of Markov chains in three selected firms' closing stock prices. Based on the problem's empirical solution, NASCO Nigeria's prices are likely to rise in the near future. As a result, major researchers have published significantly on stochastic analysis of Markov chains, including [6-13].

Entrepreneurs and policymakers have substantial challenges in making sound judgments when dealing with Nigeria's current account concerns. These issues might be the result of poor government policies or preconceptions. The forecast of probable states of payments in commodities and services is more difficult due to the stock market's inherent stochastic effectiveness, which occasionally builds shortages and excesses in the Nigerian Current Account (NCA). As a result, the NCA, which represents both imports and exports of goods and services, must be examined in order to successfully understand the dynamics of Nigerian net income and basically improve accurate forecasting for the sake of empirical proof and the country's economic outcomes. To address the aforementioned ideas, stochastic analysis of Markov chains and covariance matrices are required to effectively evaluate the fluctuation of payments in NCA, which is defined by shortages and surpluses in import and export payments, as well as pointing out their time delay effects on Nigeria as a nation.

Nevertheless, owing to the economy fallen which causes instability on NCA net. In this scenario, Markov Chain were highly used to examine NCA net. The NCA data were formulated in 3-steps transition probability matrices in order to recover the number of each group in the study were found. Also, time delay parameter was introduced in the transition probability matrices in each independent group to examine adequately NCA net formation for the purpose of investments. To this end, paper extends the work of [2] by incorporating time delay parameter in assessing the movements of NCA net; hence, is the novelty of this study.

The paper is set as follows: Section 2 is Mathematical preliminaries; Section 3 presents analysis of results and discussion of findings, while the paper is concluded in Section 4.

2. MATHEMATICAL PRELIMINARIES

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

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

For all $n \geq 0$ and $i, j \in S\left(\text{state space}\right)$.

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

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

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

Suppose $X_n = i$ means 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 impression behind the chain is stated by its transition probabilities as follows:

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

They are dependent on i, j and n.

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

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

For all n, i, j.

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

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

Therefore, the transition probabilities with homogenous Markov chain are always stationary at every point.

Theorem 1.3. let P represents stochastic matrix which implies the follows:

I) P has non-negative entries or $\mathrm{P}_{ij} \geq 0$ (II)

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

which is stationarity or point of convergence.

Proof:(I) Each corresponding entry in P is a transition probability matrix P_{ij} and is a 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 stationary.

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

2.1. Problem Formulation

To illustrate the NCA net data performances in finite states using a Markov chain model and by adopting time delay in the transition probability matrices of NCA net. The dataset is grouped from A-D.: hence, we have an estimate of the transition probability as follows:

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

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

Where $k+1$ is the number of finite states?

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

Though, for $k = 3$ is an estimate of the transition matrix solution.

(1.10) $$\hat{P}ij = (\text{NCA}) : \text{A} = \begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

(1.11) $$\hat{P}ij = (\text{NCA}) : \text{B} = \begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

(1.12) $$\hat{P}ij = (\text{NCA}) : \text{C} = \begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

(1.13) $$\hat{P}ij = (\text{NCA}) : \text{D} = \begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

Adopting time-dependent delay in (3.10-3.13) gives the following:
However, for $k = 3$.

(1.14) $$\hat{P}ij : \mathrm{A}-_{DELAY} = (t-\tau)\begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

(1.15) $$\hat{P}ij : \mathrm{B}-_{DELAY} = (t-\tau)\begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

(1.16) $$\hat{P}ij : \mathrm{C}-_{DELAY} = (t-\tau)\begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

(1.17) $$\hat{P}ij : \mathrm{D}-_{DELAY} = (t-\tau)\begin{pmatrix} \hat{P}_{00} & \hat{P}_{01} & \hat{P}_{03} \\ \hat{P}_{10} & \hat{P}_{11} & \hat{P}_{12} \\ \hat{P}_{20} & \hat{P}_{21} & \hat{P}_{22} \end{pmatrix}$$

Where t represent time acting on the delay parameter and τ represents delay parameter .

2.2. Constructing Markov Chain Model for NCA Net Movements

To provide adequate precision of the Markov chain model for future occurrences, it must be constructed for the forecast of NCA payments flow. The first payment must be in three finite states, as indicated:
R: implies the probability of NCA payment reducing in the future
I: implies the probability of NCA payment increasing in the future
NO-change: implies the probability of NCA payment not changing in the future

In contrast, the probability of transition matrix accurately describes the Markov chain. Each member in the matrix communicates, thus we may build three states of the Markov process, as shown in the table below.

2.3. Transition Probability Matrix

$$\begin{pmatrix} State & I & II & III & Total \\ I & P_{11} & P_{12} & P_{13} & T_1 \\ II & P_{21} & P_{22} & P_{23} & T_2 \\ III & P_{31} & P_{32} & P_{33} & T_3 \end{pmatrix}$$

Each item P_{ij} specifies how many times a state change occurs from i to j. The transition matrix is calculated by dividing every element in each row by the sum of each row. Nonetheless, this research examines NCA payment data obtained from the statistics bulletin.

3. ANALYSIS OF RESULTS AND DISCUSSION OF FINDINGS

This is secondary data obtained from a statistics journal. To determine the Nigerian Current Account net flow in certain states. The data ranges from 2004 to 2023. We divided the data into four categories A-D.

Transition Probability Matrices of NCA net for Group A -D

Group-A:

$$NCA-NET:\mathrm{A}=(P)=\begin{pmatrix}0.4801 & 0.37010 & 0.1489\\ 0.6998 & -0.2863 & 0.5865\\ 0.4039 & 0.2751 & 0.3209\end{pmatrix}$$

Forecast of Transition Probability Matrix for Group-A: NCA net portrays in predicting from one state to other:

NCA: 48% Probability of price decline: this states that there is likelihood that the NCA net will decrease in the near future. 0.37% probability of price increase: is a likelihood that the NCA net will rise in the near future. 15% probability of price stability: this implies that there is a chance that the price of NCA net will not change over a given period of time. 0.70% probability of bearish market: it indicates a high chance that the overall market sentiment will be negative, which could lead to price reductions for many assets. -0.29% probability of bullish market: this indicates that there is high chance that the overall market sentiment will be positive which could lead to price increases. 59% probability of price equilibrium: this suggest that there is a likelihood that the forces of supply and demand are in balance, resulting in no change in price. 40% probability of downward trend: this suggest that the price of the NCA is likely to trend downwards in the near future. 28% probability of upward trend: this suggest that the price of the NCA is likely to trend upwards, and 32% Chance of no change in payments of the NCA net.

Group-B :

$$NCA-NET:B=(P)=\begin{pmatrix}0.3414 & 0.2712 & 0.3874\\ 0.7216 & 0.2028 & 0.07557\\ 0.4072 & 0.1307 & 0.4621\end{pmatrix}$$

Forecast of Transition probability matrix for Group-B: the analysis shows the probability of NCA net: reducing by 34%; 27% chance of increasing in NCA net in the near future; 20% chance of no change in NCA net. Also, in the same situations, 72% chance of reducing its NCA net; 20% chance of increasing it NCA net and 7% chance of no change in NCA in the near future.

To conclude, 41% chance of reducing its NCA net, a 13% chance of increasing, and 47% chance of no change in NCA net payments.

Group-C:

$$NCA-NET:\mathrm{C}=(P)=\begin{pmatrix}0.2971 & 0.2990 & 0.4039\\ 0.6392 & 0.2687 & 0.09207\\ 0.1091 & 0.2264 & 0.6645\end{pmatrix}$$

Forecast of Transition probability matrix for Group-C: 30% probability of price decline: this states that there is likelihood that the NCA net will decrease in the near future. 30% probability of price increase: this stating that there is a likelihood that the NCA net will rise in the near future. 40% probability of price stability: this implies that there is a chance that the price of NCA net will not change over a given period of time. 64% probability of bearish market: it indicates that there is a high chance that the overall market sentiment will be negative, which could lead to price reductions for many assets. 21% probability of bullish market: this indicates that there is high chance that the overall market sentiment will be positive, which could lead to price increases for many assets.9% probability of price equilibrium: this suggest that there is a likelihood that the forces of supply and demand are in balance, resulting in no change in price. 11% probability of reducing in NCA net trend, 23% probability of increasing in its NCA net trend, and 66% chance of no change in NCA net payments.

Group-D:

$$NCA-NET:\mathrm{D}=(P)=\begin{pmatrix}0.3637 & 0.3471 & 0.2891\\ 0.4262 & 0.4667 & 0.1071\\ -1.7125 & 1.7923 & 0.9203\end{pmatrix}$$

The above matrices describes the probability movements of NCA net in the near future.

net movements: $$NCA-NET_{D}(P)=\begin{pmatrix}0.3637 & 0.3471 & 0.2891\\ 0.4262 & 0.4667 & 0.1071\\ -1.7125 & 1.7923 & 0.9203\end{pmatrix}$$

The above matrix shows the group highest transition probability matrix solution of NCA net.

Forecast of Transition probability matrix for Group-D: presents the probability NCA net reducing by 36%; 35% chance of increasing its NCA net payments in the near future; 29% chance of no change in NCA net payments.
Correspondingly, in the same situations, 43% chance of reducing its NCA net; 47% chance of increasing NCA net payments, and 11% chance of no change in NCA net payments. In general, -1.7% chance of reducing its imports NCA net payments; 1.8% chance of increasing its NCA net payments, and 3.3% chance of no change in NCA net payments. The above assessments describe the level of surplus made in NCA net the -1.7% connotes shortages in NCA. Hence, the predicted results shows significant improvements for the purpose of decision-making.

3.1. The Effects of Time Delay Parameter in Analyzing the Nigerian Current Account Net

Group-A:

$$NCA-NET:A:(P)=(.5)\begin{pmatrix}0.4801 & 0.37010 & 0.1489\\ 0.6998 & -0.2863 & 0.5865\\ 0.4039 & 0.2751 & 0.3209\end{pmatrix}=\begin{pmatrix}0.2401 & 0.1851 & 0.07445\\ 0.3499 & -0.1432 & 0.2933\\ 0.20195 & 0.1376 & 0.1605\end{pmatrix}$$

Group-B:

$$NCA-NET:B=(P)=(.5)\begin{pmatrix}0.3414 & 0.2712 & 0.3874\\ 0.7216 & 0.2028 & 0.07557\\ 0.4072 & 0.1307 & 0.4621\end{pmatrix}=\begin{pmatrix}0.1707 & 0.1356 & 0.1937\\ 0.3608 & 0.1014 & 0.037785\\ 0.2036 & 0.06535 & 0.0032675\end{pmatrix}$$

Group-C:

$$NCA-NET:\mathrm{C}=(P)=(.5)\begin{pmatrix}0.2971 & 0.2990 & 0.4039\\ 0.6392 & 0.2687 & 0.09207\\ 0.1091 & 0.2264 & 0.6645\end{pmatrix}=\begin{pmatrix}0.14855 & 0.1495 & 0.20195\\ 0.3196 & 0.13435 & 0.046035\\ 0.05455 & 0.1132 & 0.33225\end{pmatrix}$$

Group-D:

$$NCA-NET:\mathrm{D}=(P)=(.5)\begin{pmatrix}0.3637 & 0.3471 & 0.2891\\ 0.4262 & 0.4667 & 0.1071\\ -1.7125 & 1.7923 & 3.2639\end{pmatrix}=\begin{pmatrix}0.18185 & 0.17355 & 0.14455\\ 0.2131 & 0.23335 & 0.05355\\ -0.85625 & 0.89615 & 0.46015\end{pmatrix}$$

The matrices above are the effects of time delay on Nigeria Current Account net movements.

The delay in the transition matrix implies that the current account is more sensitive to external shocks, such as changes in commodity prices or global demand for Nigeria exports. This is because the current account will take longer to adjust to these shocks, and this may prolong their effects on the economy. It also could mean that policy measures to address current account imbalances will take longer to have an effect. This description informs investors more reliable and effective ways of decision-making in terms of imports and exports of goods and services.

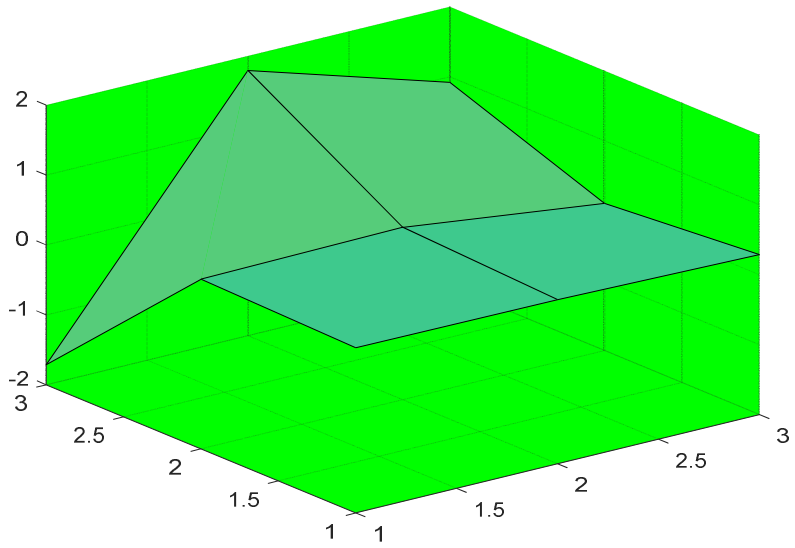

Figure 1. The surface view profile of group highest probability transition matrix for NCA net.

The profile of surface view in Figure 1 portrays the changes in Nigeria Current Account net; the transition probabilities would represent the likelihood of the net changing from positive and negative. The profile shows the highest probability in a three-dimensional plot.

4. CONCLUSIONS

Current Account net is a vital indicator of an economy that cannot be over emphasized due to its economic benefits. Therefore, this paper examined the applications of Markov chain and the impact of time delay in assessing Nigeria Current Account (NCA) net movements. The 3-steps probability transition matrices were formulated in each independent group. From the stochastic analysis of results shows that group-D has the largest probability transition matrix, and the impact of time delay shows significantly in explaining NCA net for our economic purposes.

However, the yearly variations of percentages on the predicted NCA net to determine levels of import, export goods, and services is well recommended, and therefore, introducing a control parameter will help to improve significantly.

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