STOCHASTIC MODELLING OF NIGERIA INFLATION RATE

Akintunde A. A., Agwuegbo S. O. N., Ampitan K.R., Ariyo, O. S. and Yusuff K. M.

Department of Statistics, Federal University of Agriculture, Abeokuta
Correspondence: akintundeaa@funaab.edu.ng; +2348134592275

ABSTRACT

Inflation rate is an essential economic variable. It gives a picture of the performance of an economy. Nigeria as a developing country needs to monitor the inflation rate with the other economic factors in order to ensure that the economy does not go out of control. The impact of the Corona Virus Disease 2019 (COVID-19) on the developing countries can be checked through such monitoring. This study examined the long run prediction of the dynamics of the Nigeria inflation rate using the Markov Modeling approach. The Nigeria inflationary system was considered as a three state Markov process and the system's distribution was determined at the steady state. Result shows that the long run probability of increased inflation rate is high. The study recommends the use of Markov approach for modelling the behaviour of dynamic systems and that reversion mechanism be put in place especially by the governments to mitigate inflation rate in Nigeria.

Keywords: Inflation rate, economic indicator, Markov Model, Stationary probability distribution

1.0 INTRODUCTION

Inflation rate is considered an essential indicator of an economy. It gives a picture of the performance of an economy. Nigeria as a developing country needs to monitor the inflation rate with the other economic factors in order to ensure that the economy does not go out of control. Inflation can be said to be a general increase in cost of purchasing goods and services which is always worrisome to all (individuals, households, managers, industries governments at all levels, marketers etc.) in an economy system. Inflation system can be considered as a stochastic recurrence process as it has a continuous tendency to repeat itself periodically or otherwise (Campêlo and Cribari-Neto, 2003, Sani-Bawa *et al*., 2016 etc.). As a result of this, the necessity of examining the process regularly cannot be over emphasized for adequate planning by all stakeholders in the economy (Dawodu *et al*., 2017). The plague of continuous and outrageous in inflation rate is much more in the developing countries like Nigeria where there are occurrences of economic shocks. The Corona Virus Disease 2019 (COVID-19) pandemic has left a great economic challenges to all countries of the world most especially, the developing countries like Nigeria. Therefore, this current work is important as it examines the inflation situation in Nigeria and make possible predictions of the nature of the system in the future for adequate awareness and planning for effective control by all stakeholders in the country. Business managers often require a regular prediction of inflation rate in order to avoid business pitfalls (Dawodu *et al.,* 2017). Many works has been done on modeling inflation systems. Such work include that of Atkeson and Ohanian (2001), Campêlo and Cribari-Neto

(2003), Ang et al (2007), Stock and Watson (2008), Groen *et al* (2010), Bocquet and Sakov. (2012), Maku and Adelowokan (2013), Shah *et al* (2014); Agwuegbo *et al*. 2014, Sani Bawa *et al*. (2016), Dawodu *et al*. (2017) and Cavallo (2020).

This study considered the inflation system as a stochastic dynamic process due to it random and time varying mechanisms. The system therefore has both stochastic components and random noise as we have for most dynamic systems. The system can therefore be modeled as stochastic models where the uncertainty of the system's operating environment is adequately captured. The underlying dynamical phenomenon is regarded as a Markov process. A Markov process is a stochastic process whose future behaviour depends on the present only.

Markov processes involve random chance or probability. They are probabilistic models that can be used to describe sequential data structure. They are good to use in the analysis of random occurrences that are dependent (Akintunde *et al*., 2017). For the mathematical theory of Markov processes see Dynkin (2006). A Markov process uses the movement from on state to another state within the system. This movement is referred to as transition.

Many researchers had studied the models of dynamic behaviour as finite state Markov models with discrete or continuous time. Such behaviours can be well examined using the Chapman-Kolmogorov equations in stochastic processes (Akintunde *et al*., 2008, 2015 and 2017). The Chapman-Kolmogorov equations give the conditions for the occurrences of transition densities. This work therefore examined the future behavior of the inflation rate using the theory of the Markov process with its state properties through the Chapman-Kolmogorov equation. A Markov process can be fully examined by looking at the distribution of the system conditionally (Agwuegbo *et. al* (2014). This present study applied the Chapman-Kolmogorov equations in modeling the future behavior of the Nigeria inflationary rate.

2.0 MATERIALS AND METHODS

Let X_t be the inflation rate at month *t*. X_t is a stochastic process that moves randomly as a random walk, with unit steps at a time in a manner that cannot be predicted. If the system is considered to change relatively as it evolves in time, then let $\{C_t\}$ equals a series of the change and let

$$C_t = X_t - X_{t-1} \tag{1}$$

and

$$C_t = \begin{cases} -1 & for\ X_t < X_{t-1}, with\ probability\ q \\ 0 & for\ X_t = X_{t-1}, with\ probabilityb\ r \\ +1 & for\ X_t > X_{t-1}, with\ probabilityb\ p \end{cases} \tag{2}$$

The system can be in any of the states C_1, C_2, C_3 whose sequence forms a discrete time Markov chain. For all t= $1,2,\ldots$) and all possible values of the random variables, C_t, then

$$P(C_t = j | C_{t-1} = i_{t-1}, C_1 = i_1, C_2 = i_2, \ldots, C_0 = i_0) = P(C_t = j | C_{t-1} = i_{t-1}) \tag{3}$$

Equation (3) is the one step transition probability which is a homogeneous Markov chain defined as

$$p_{ij} = P(C_t = j | C_{t-1} = i) \tag{4}$$

This is the probability of the system moving from state i to state j after a unit time step.

The inflation system is considered as an ergodic Markov chain. This is because the states communicate, are recurrent and aperiodic. An ergodic Markov chain tends towards or converges to an equilibrium level or what is referred to as a steady state or absolute probability distribution. The steady state probability distribution gives the long run probability distribution of the system and so the prediction of the future behavior of the system at the long run. From (4), we can define the $n - step$ transition probabilities as

$$p_{ij}^{(n)} = P(C_{t+s} = j|C_t = i) \quad (5)$$

Such that

$$p_{ij}^{(n)} = \sum_l \; p_{il}^{(n-1)} p_{lj} \qquad n = 2,3,\dots \quad (6)$$

Also,

$$p_{ij}^{(n+m)} = \sum_l \; p_{il}^{(n)} p_{lj}^{(m)} \qquad n, m = 1,2,3,\dots \quad (7)$$

Equation (7) is a Chapman-Kolmogorov equation for process in discrete time and it shows that there is a possibility of the decomposition of the probability of the transition. In view of the decomposing property highlighted by the Chapman-Kolmogorov equations, we can obtain the long run probability distribution of the chain given the initial probability distribution and transition probability matrix P. For a k-states Markov chain, P is a square matrix given as

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1k} \\ p_{21} & p_{22} & \cdots & p_{1k} \\ \vdots & \vdots & \ddots & \vdots \\ p_{k1} & p_{12} & \cdots & p_{kk} \end{pmatrix} \quad (8)$$

2.1 Long Run Probability Distribution

At the long run the ergodic Markov chain converges to position of statistical equilibrium which is are independent of the starting conditions. Ergodicity defines the equilibrium probability distribution or steady state probabilities given as:

$$\lim_{n\to\infty} P^n = \pi \quad (9)$$

Such that

$$\pi P = \pi \quad (10)$$

where $\pi = (\pi_i, i = 1,2 \dots k)$ is the steady state probability distribution and P is the transition probability matrix for $\sum_i^k \pi_i = 1$

it is however easy to obtain the distribution of the system using Chapman-Kolmogorov equation (Akintunde et al., 2008). If p_i^0 is the initial probability distribution then the stationary probability distribution is given as

$$p^n \;= p_i^0 P^n \quad (11)$$

Equation (11) can be obtained using the recursive relation, for $n = 1,2,3,\dots n$, defined in equation (12) as

$$p^n \;= p^{n-1} P \quad (12)$$

p^n is the stead state distribution at t_n. Each row of the equilibrium probability matrix, P^n is p^n.

3.0 RESULTS AND DISCUSSION

The study examined the Nigeria monthly inflation rate data between January, 2011 and Mar., 2021. The data was obtained from the website of Central Bank of Nigeria. R statistical software was used for the analysis.

3.1 Descriptive/Exploratory Analysis

Table 1 shows the descriptive statistics of the data. Figure 1 shows the time plot of the data which indicates the dynamics of the Nigeria inflation rate as non-stationary with dramatic upward and downward jumps in the system. The change of political powers in 2015 is obvious in the upward movement seen in Figure 1 that resulted in amendments and introduction of new policies. Figure 2 shows that the Nigeria inflation rate is a random walk and can be modeled as a Markov Chain.

Table 1: Exploratory Analysis

Statistic	**Value**
Sample size	123
Min.	7.70
Max.	18.72
Quartile 1	9.30
Quartile 3	13.28
Mean	11.90
Median	11.38
Variance	9.362

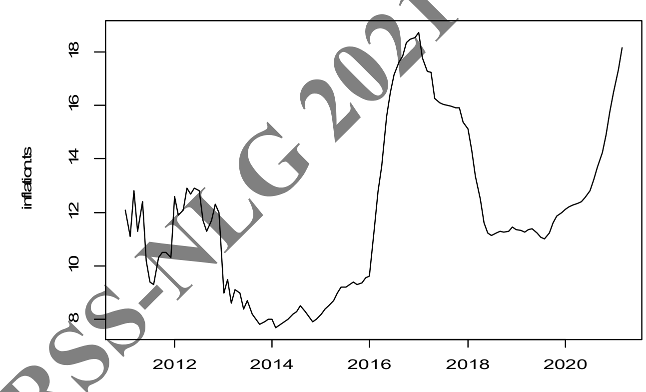

Figure 1: Time plot of the Nigeria Inflation rate (Jan., 2011 to Mar., 2021)

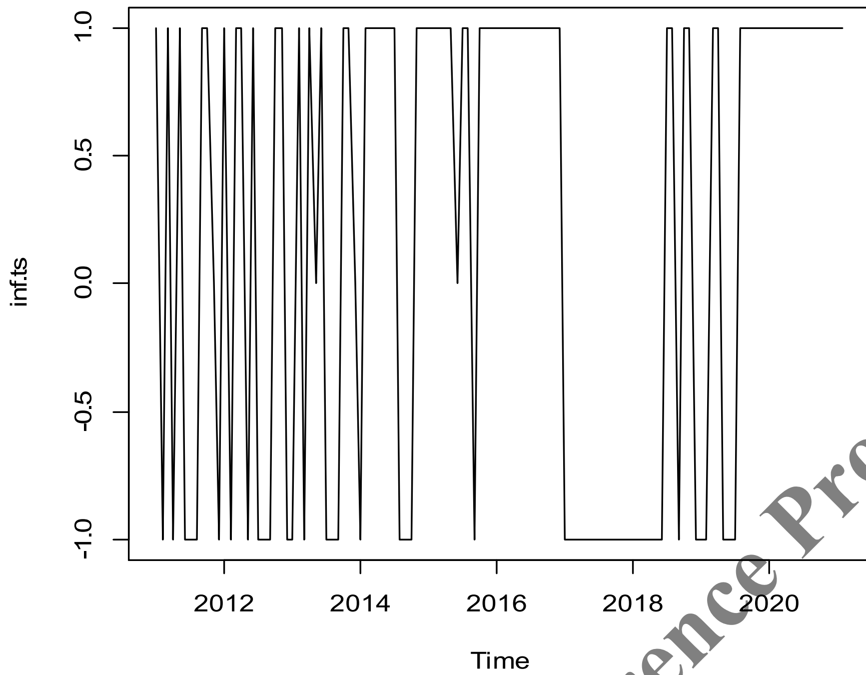

Figure 2: Continuous Sample path of Nigeria Inflation rate

3.2 Fixed Point Distribution

The model is a Random Walk with probability distributions given as:

$$p^{(0)} = (0.579 \quad 0.024 \quad 0.397) \tag{13}$$

$$P_{ij} = \begin{pmatrix} 0.64 & 0.00 & 0.36 \\ 0.67 & 0.00 & 0.33 \\ 0.24 & 0.04 & 0.72 \end{pmatrix} \tag{14}$$

$$p^n = (0.4161 \quad 0.0225 \quad 0.5614) \tag{15}$$

and

$$P^n = \begin{pmatrix} 0.4161 & 0.0225 & 0.5614 \\ 0.4161 & 0.0225 & 0.5614 \\ 0.4161 & 0.0225 & 0.5614 \end{pmatrix} \tag{16}$$

Equations (13) and (15) are initial and fixed distributions respectively while (14) and (16) are transition and fixed probability matrices respectively. This shows that the probability of increasing inflation is 56%. The chance of having increasing inflation rate is higher than having decreasing inflation rate. All stakeholders should be prepared for this unless drastic measures are put in place by the policy makers to revert the process.

4.0 CONCLUSION

The dynamics of the inflation rate is stochastic. Markov chain model was used in the present work to model inflation rate in Nigeria. The rate followed a Random Walk with three state

Markov model. The absolute probability distribution was obtained using the Chapman relation. Results indicate that dynamics of inflation in Nigeria follow an ergodic Markov chain with the steady state probability distribution given as $(0.4161 \quad 0.0225 \quad 0.5614)$. This shows that an increasing inflation rate is inevitable in Nigeria with a probability of 0.56 if necessary control measures are not put in place by the governments.

REFERENCES

Agwuegbo, S.O.N., Adewole, A.P., Olayiwola, O.M and Apantaku, F.S. (2014). "State-Dependent Model for the Analysis of Inflationary Rates". Journal of Mathematical Theory and Modeling, Vol.4, No 7, pg. 84-89.

Akintunde, A.A., Asiribo, O.E., Adebanji, A.O., Adelakun, A.A. and Agwuegbo, S.O.N. (2008). "Stochastic Modeling of Daily Precipitation of Daily Precipitation in Abeokuta". Proceedings of International Conference on Science and National Development by College of natural Sciences COLNAS., UNAAB, Abeokuta, pg. 108-118.

Akintunde, A.A., Agwuegbo, S.O.N., Asiribo, O.E., Waheed, M.A. and Olayiwola, O.M. (2015) "Modeling Nonlinear Dynamical Systems". Annals Computer Science Series, Vol. 13, No. 1, pg. 30-38.

Akintunde, A.A., Agwuegbo, S.O.N, and Olayiwola O.M. (2017). "Markov Models for the Analysis of Dynamical Systems". Journal of Natural Science, Engineering and Technology, Vol. 16 Vol. 1, pg. 35-49.

Ang, A, Bekaert, G., and Wei, M. (2007). "Do Macro Variables, Asset Markets, or Surveys Forecast Inflation Better?" Journal of Monetary Economics Vol. 54, pg. 1163-1212.

Atkeson, A. and Ohanian, L. (2001). "Are Phillips Curves Useful for Forecasting Inflation?" Federal Reserve Bank of Minneapolis Quarterly Review Vol. 25 pg. 2-11.

Bocquet, M. and Sakov, P. (2012). "Combining inflation-free and iterative ensemble Kalman filters for strongly nonlinear systems". Nonlinear Processes in Geophysics Vol.19 pg. 383–399

Campêlo, A.K. and Cribari-Neto, F. (2003). "Inflation Inertia and Inliers: The Case of Brazil". *RBE Rio De Janeiro*. Vol. 57, No. 4, pg. 713-739

Cavallo A. (2020). "Inflation with COVID Consumption Baskets. National Bureau of Economic" Research Working Paper No. 27352

Dawodu, G.A., Akintunde, A.A., Ariyo, S.O. (2017). "Stochastic prediction of monthly inflation rates through Kalman Filtering". Journal of Natural Science, Engineering and Technology, Vol. 16, No. 2, pg. 11-25.

Dynkin, E.B. (2006). "Theory of Markov Processes". Dover Publications Inc. Mineola, New York

Groen, J, Paap, R. and Ravazzolo, F. (2010). "Real-time Inflation Forecasting in a Changing World". Federal Reserve Bank of New York, Statistical Report Number 388.

Maku, A. O. and Adelowokan, O A. (2013). "Dynamics of Inflation in Nigeria: An Autoregressive Approach". European Journal of Humanities and Social Sciences Vol. 22, No. 1 pg. 1175-1184.

Sani Bawa1, Ismaila S. Abdullahi and Adamu Ibrahim (2016). "Analysis of Inflation Dynamics in Nigeria (1981 – 2015)". CBN Journal of Applied Statistics, Vol. 7, No. 1(b) pg. 255 -276

Shah, M. A. A., Arshed, N. and Jamal, F. (2014). "Statistical Analysis of the factors affecting Inflation in Pakistan". International Journal of Research, Vol. 1, No.4.

Stock, J., Watson, M. (2008). "Phillips Curve Inflation Forecasts". NBER Working Paper No. 14322.