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Stochastic Model for Predicting the Circulation of New Redesign Naira Notes and its Impact on Nigerian Cashless Economy

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Abstract. With the introduction of new re-design Naira note and setting limit on withdrawal to achieve the objectives of cashless policy, these create scarcity of Cash at hand of individuals. The circulation of a new redesign currency is dependent on several factors, including the level of public acceptance, the efficiency of the financial and banking systems, and the government's ability to effectively circulate the new currency. Redesign of currency in Nigeria comes with some little challenges or implications, including political, practical, and economic implications. By considering these implications, we proposed and analyzed a stochastic model that can help in monitoring and control of circulation of the new redesign naira note and its impact on Nigerian Cashless economy. The model will served as a starting point for policy direction and thereby forecasting the future trend of cashless policy in Nigeria.

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1. Introduction

Currency redesign refers to the process of revising the physical or digital appearance of money, such as banknotes or coins. Redesigning currencies is an activity for sovereign nations. According to Ajayi (2014), a cashless economy is referred to as an environment in which money is spent without being physically carried from one place to another. He argued that by increasing the use of cashless banking instruments, monetary policy effectiveness is strengthened and further stated that the present level of e-money usage is not yet posing a threat to the stability of the financial system and cautioned that if the government does not run a responsible fiscal policy, the central banks may eventually lose control over monetary policy.
According Paul (2023), Initiatives for cashless policies have received a lot of attention in recent years and are now being implemented in several nations, including Nigeria. The switch from a mostly cash-based to a cashless economy has generated a lot of discussion among economists, decision-makers, and scholars.

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While launching the new Naira, President Muhammadu Buhari was quoted as saying, ‘‘A cycle of banknote redesign is generally aimed at achieving specific objectives, including but not limited to: improving security of banknotes, mitigating counterfeiting, preserving the collective national heritage, controlling currency in circulation, and reducing the overall cost of currency management.” When the Governor of the Central Bank of Nigeria (CBN), Mr. Godwin Emefiele, announced the decision of the apex bank to redesign the Naira, on October 26, 2022, he left no one in doubt that one key objective of the exercise was to enable the CBN take control of the currency in circulation,(CBN,2022).

He said that the exercise would affect the three highest denominations of the nation’s currency: N200, N500, N1000 notes. According to him, about 85 percent of nation’s currency in circulation was outside the banking system and that the CBN would not allow the situation to continue because it was adversely affecting monetary policies of the CBN. The apex bank boss added that the worsening shortage of clean and fit banknotes with attendant negative perception of the CBN and increased risk to financial stability as well as increasing ease and risk of counterfeiting evidenced by several security reports were reasons for redesigning the notes, (CBN,2022).

According to Vanguard (2022), the activities of currency hoarders have become evident as very dirty, smelly Naira notes have been in circulation, especially since political activities heightened across the country-an indication that such notes must have been hoarded in damp places and for a long period of time.

According Iwedi et.al, (2023) their study discovered that there are both positive and negative sides to Naira redesign which includes the fact that Naira redesign could lead to reduction in the level of cash insecurity and money laundering, huge deficit cost to the economy, a rise in price level and the mitigation of counterfeiting in the economy. They suggest that the redesign of Naira may not be the antidote to the consistent depreciation of the country’s currency and the focus of the Central Bank of Nigeria should be the stabilization of Naira. The study concludes that Naira redesign is not the best thing to be done currently in the economy as it could lead to more challenges and so the Government of Nigeria should attend to more pressing issues

According to Adebayo (2022) the introduction of new redesign Naira and setting limit on withdrawal to achieve the objectives of cashless policy, these create scarcity of Cash at hand of individuals. The spread of a new redesign currency is dependent on several factors, including the level of public acceptance, the efficiency of the financial and banking systems, and the government's ability to effectively circulate the new currency. Redesign of currency can have a range of implications, including political, practical, and economic implications. By considering these implications, the model can help in taking measures to minimize their impact; governments can ensure a successful and efficient circulation of redesign of their currency with control of some parameters. According to Taiwo (2022), the success of a new redesign currency can be impacted by the availability and accessibility of new currency notes and coins. For example, if the new currency is not widely available in circulation, or if it is difficult for individuals and businesses to obtain the new currency, its use may be limited.

The Technology Acceptance Model (TAM) and Diffusion of Innovation (DOI) Theory by Davis (1985). TAM is an information systems theory that models how users come to accept cashless policy and use a technology that will enhance the performance of Deposit money Banks in Nigeria. TAM is one of the models that have been developed to provide a better understanding of the usage and adoption of information technology which is the base of cashless policy that will promote the performance of Deposit money Banks in Nigeria.

DOI theory seeks to explain how, why, and at what rate new ideas and technology spread through cultures. Innovation Diffusion Theory (IDT) consists of six major components: innovation characteristics, individual user characteristics, adopter distribution over time,

diffusion networks, innovativeness and adopter categories, and the individual adoption process which are the bases of cashless policy that promote the performance of commercial banks in Nigeria.

If well implemented, the redesign supporting the cashless policy would help in no small measure the anti-corruption crusade in the country.

2. Methodology

We formulate a stochastic model describing the impact of cashless policy on circulation of new redesign Naira notes. From the model, the circulation/flow of the new redesign Naira currency is considered as random. This randomness is modeled as stochastic Continuous-Time Markov Process satisfying X(t), where X(t) represent a stochastic process and the model was formulated via the schematic or model diagram below:

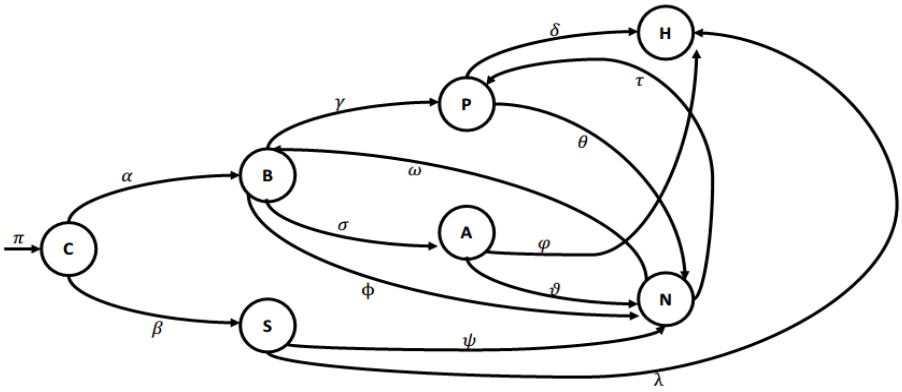

Figure 1.Circulation of New Redesign Naira Notes Model diagram

From the model above, we first derived our various transitions and probabilities by letting X = (X1 = C, X2 = B, X3 = S, X4 = A, X5 = P, X6 = N, X7 = H) be a set of random variables representing the amount new currency in Central Bank of Nigeria (CBN), Deposit Money Banks, Cash Swap Agents, Automated Teller Machines (ATMs), Super Bank Agents (POS Operators), Non- Hoarders and Hoarders respectively. Let the transition intensities and probability be represented in the table below;

Table 1: Cumulative Transition Markov's Chain of the Model

EVENT	VARIABLES	TRANSITIONS
$\pi\Delta(t) + o(\Delta t)$	x1+1, x2, x3, x4, x5, x6, x7	1, 0, 0, 0, 0, 0, 0
$m_{12}\Delta(t) + o(\Delta t)$	x1 – 1, x2 + 1, x3, x4, x5, x6, x7	-1, 1, 0, 0, 0, 0, 0
$m_{13}\Delta(t) + o(\Delta t)$	x1 – 1, x2, x3 + 1, x4, x5, x6, x7	-1, 0, 1, 0, 0, 0, 0
$m_{24}\Delta(t) + o(\Delta t)$	x1, x2 – 1, x3, x4 + 1, x5, x6, x7	0, -1, 0, 1, 0, 0, 0
$m_{25}\Delta(t) + o(\Delta t)$	x1, x2 – 1, x3, x4, x5 +1, x6, x7	0, -1, 0, 0, 1, 0, 0
$m_{26}\Delta(t) + o(\Delta t)$	x1, x2 – 1, x3, x4, x5, x6 + 1, x7	0, -1, 0, 0, 0, 1, 0
$m_{27}\Delta(t) + o(\Delta t)$	x1, x2 – 1, x3, x4, x5, x6, x7 +1	0, -1, 0, 0, 0, 0, 1
$m_{46}\Delta(t) + o(\Delta t)$	x1, x2, x3, x4 – 1, x5, x6 + 1, x7	0, 0, 0, -1, 0, 1, 0
$m_{47}\Delta(t) + o(\Delta t)$	x1, x2, x3, x4 – 1, x5, x6, x7 +1	0, 0, 0, -1, 0, 0, 1
$m_{56}\Delta(t) + o(\Delta t)$	x1, x2, x3, x4, x5 – 1, x6 + 1, x7	0, 0, 0, 0, -1, 1, 0
$m_{62}\Delta(t) + o(\Delta t)$	x1, x2 + 1, x3, x4, x5, x6 – 1, x7	0, 1, 0, 0, 0, -1, 0
$m_{65}\Delta(t) + o(\Delta t)$	x1, x2, x3, x4, x5 + 1, x6 – 1, x7	0, 0, 0, 0, 1, -1, 0
$m_{36}\Delta(t) + o(\Delta t)$	x1, x2, x3 – 1, x4, x5, x6 + 1, x7	0, 0, -1, 0, 0, 1, 0
$m_{37}\Delta(t) + o(\Delta t)$	x1, x2, x3 – 1, x4, x5, x6, x7 + 1	0, 0, -1, 0, 0, 0, 1

The probabilities of an event taking place due to transitions are obtained by set of difference equation known as Kolmogorov forward equations. For continuous time stochastic process, we have;

$$
\begin{aligned}
&p_{x_1,x_2,x_3,x_4,x_5,x_6,x_7}\ (t+\Delta t) = P\pi\Delta t p_{x_1+1}(t) + m_{12}(x_1-1)(x_2+1)\Delta t p_{x_1-1,x_2+1}(t)\\
&+m_{13}(x_1-1)(x_3+1)\Delta t p_{x_1-1,x_3+1}(t) + m_{24}(x_2-1)(x_4+1)\Delta t p_{x_2-1,x_4+1}(t)\\
&+m_{25}(x_2-1)(x_5+1)\Delta t p_{x_2-1,x_5+1}(t) + m_{26}(x_2-1)(x_6+1)\Delta t p_{x_2-1,x_6+1}(t)\\
&+m_{27}(x_2-1)(x_7+1)\Delta t p_{x_2-1,x_7+1}(t) + m_{46}(x_4-1)(x_6+1)\Delta t p_{x_4-1,x_6+1}(t)\\
&+m_{47}(x_4-1)(x_7+1)\Delta t p_{x_4-1,x_7+1}(t) + m_{56}(x_5-1)(x_6+1)\Delta t p_{x_5-1,x_6+1}(t)\\
&+m_{57}(x_5-1)(x_7+1)\Delta t p_{x_5-1,x_7+1}(t) + m_{62}(x_6-1)(x_2+1)\Delta t p_{x_6-1,x_2+1}(t)\\
&+m_{65}(x_6-1)(x_5+1)\Delta t p_{x_6-1,x_5+1}(t) + m_{36}(x_3-1)(x_6+1)\Delta t p_{x_3-1,x_6+1}(t)\\
&+m_{37}(x_3-1)(x_7+1)\Delta t p_{x_3-1,x_7.+1}(t) -\\
&\begin{bmatrix}1 + P\pi + (m_{12}+m_{13})(x_1+1)\\ +(m_{24}+m_{25}+m_{26}+m_{27})(x_2+1)\\ +(m_{46}+m_{47})(x_4+1) + (m_{56}+m_{57})(x_5+1)\\ +(m_{62}+m_{65})(x_6+1) + (m_{36}+m_{37})(x_3+1)\end{bmatrix}
\end{aligned}
\qquad (1)
$$

Differentiating equation (1) using first principle, this gives us our Kolmogorov Forward Differential Equation below:

$$
\begin{aligned}
&\frac{dp_{x_1,x_2,x_3,x_4,x_5,x_6,x_7}(t)}{dt} = P\pi + m_{12}(x_1-1)(x_2+1)p_{x_1-1,x_2+1}(t)\\
&+m_{13}(x_1-1)(x_3+1)p_{x_1-1,x_3+1}(t) + m_{24}(x_2-1)(x_4+1)p_{x_2-1,x_4+1}(t)\\
&+m_{25}(x_2-1)(x_5+1)p_{x_2-1,x_5+1}(t) + m_{26}(x_2-1)(x_6+1)p_{x_2-1,x_6+1}(t)\\
&+m_{27}(x_2-1)(x_7+1)p_{x_2-1,x_7+1}(t) + m_{46}(x_4-1)(x_6+1)p_{x_4-1,x_6+1}(t)
\end{aligned}
$$

$$+m_{47}(x_4-1)(x_7+1)p_{x_4-1,x_7+1}(t)+m_{56}(x_5-1)(x_6+1)p_{x_5-1,x_6+1}(t)$$
$$+m_{57}(x_5-1)(x_7+1)p_{x_5-1,x_7+1}(t)+m_{62}(x_6-1)(x_2+1)p_{x_6-1,x_2+1}(t)$$
$$+m_{65}(x_6-1)(x_5+1)p_{x_6-1,x_5+1}(t)+m_{36}(x_3-1)(x_6+1)p_{x_3-1,x_6+1}(t)$$
$$+m_{37}(x_3-1)(x_7+1)p_{x_3-1,x_7.+1}(t)$$
$$-\begin{bmatrix}(m_{12}+m_{13})(x_1+1)+(m_{24}+m_{25}+m_{26})(x_2+1)+(m_{46}+m_{47})(x_4+1)\\+(m_{56}+m_{57})(x_5+1)+(m_{62}+m_{65})(x_6+1)+(m_{36}+m_{37})(x_3+1)\end{bmatrix}$$
$$p_{x_1,x_{xcccc2},x_3,x_4,x_5,x_6,x_7}(t) \quad (2)$$

Equation (2) is a full dynamics and it can be simplified or converted with the aid of multivariate probability generating function. We will then obtain the sets of the following differential equations for expectation below:

$$\frac{dE[X_1(t)]}{dt}=E[P\pi]-m_{12}E[X_1(t)X_2(t)]-m_{13}E[X_1(t)X_3(t)]$$
$$\frac{dE[X_2(t)]}{dt}=m_{12}E[X_1(t)X_2(t)]-m_{24}E[X_2(t)X_4(t)]-m_{25}E[X_2(t)X_5(t)]$$
$$-m_{26}E[X_2(t)X_6(t)]-m_{27}E[X_2(t)X_7(t)]$$
$$\frac{dE[X_3(t)]}{dt}=m_{13}E[X_1(t)X_3(t)]-m_{36}E[X_3(t)X_6(t)]-m_{37}E[X_3(t)X_7(t)]$$
$$\frac{dE[X_4(t)]}{dt}=m_{24}E[X_2(t)X_4(t)]-m_{46}E[X_4(t)X_6(t)]-m_{47}E[X_4(t)X_7(t)]$$
$$\frac{dE[X_5(t)]}{dt}=m_{25}E[X_2(t)X_5(t)]-m_{56}E[X_5(t)X_6(t)]-m_{57}E[X_5(t)X_7(t)]$$
$$\frac{dE[X_6(t)]}{dt}=m_{26}E[X_2(t)X_6(t)]+m_{56}E[X_5(t)X_6(t)]-m_{62}E[X_6(t)X_2(t)]$$
$$-m_{65}E[X_6(t)X_5(t)]$$
$$\frac{dE[X_7(t)]}{dt}=m_{27}E[X_2(t)X_7(t)]+m_{37}E[X_3(t)X_7(t)]+m_{47}E[X_4(t)X_7(t)]+$$
$$m_{57}E[X_5(t)X_7(t)] \quad (3)$$

Replacing X1 = C, X2 = B, X3 = S, X4 = A, X5 = P, X6 = N and X7 = H

$$\frac{dC(t)}{dt}=P\pi-m_{12}C(t)B(t)-m_{13}C(t)S(t)$$
$$\frac{dB(t)}{dt}=m_{12}C(t)B(t)-m_{24}B(t)A(t)-m_{25}B(t)P(t)-m_{26}B(t)N(t)$$
$$-m_{27}B(t)H(t)$$
$$\frac{dS(t)}{dt}=m_{13}C(t)S(t)-m_{36}S(t)N(t)-m_{37}S(t)H(t)$$
$$\frac{dA(t)}{dt}=m_{24}B(t)A(t)-m_{46}A(t)N(t)-m_{47}A(t)H(t)$$
$$\frac{dP(t)}{dt}=m_{25}B(t)P(t)-m_{56}P(t)N(t)-m_{57}P(t)H(t)$$
$$\frac{dN(t)}{dt}=m_{26}B(t)N(t)+m_{36}S(t)N(t)+m_{46}A(t)N(t)+$$
$$m_{56}P(t)N(t)-m_{62}N(t)B(t)-m_{65}N(t)P(t)$$
$$\frac{dH(t)}{dt}=m_{27}B(t)H(t)+m_{37}S(t)H(t)+m_{47}A(t)H(t)+m_{57}P(t)H(t) \quad (4)$$

3. Result

In this Section, the stochastic model on circulation of new redesigned naira where analyzed

using values for state variables and transition parameters in Table 2. The numerical solutions of equation (4) are also display from Fig. 2-8.

Table 2: Parameters description, source and their values (

Variables/ Parameters	Descriptions	Value	Source
C	Total currency from Central Bank of Nigeria	N800B	CBN
B	Total currency in Banks	N500B	Estimated
S	Total currency with Cash Swap Agents	N10B	Estimated
A	Total currency in ATMs	N10B	Estimated
P	Total currency with Bank Super Agents (POS)	N10B	Estimated
H	Total currency with Hoarders	N200B	Estimated
N	Total currency with Non-Hoarders	N80B	Estimated
π	Production rate		Estimated
α	The rate at which CBN disburse the new Naira to Banks	0.9	Estimated
β	The rate at which CBN disburse the new Naira to Cash Swap Agents	0.1	Estimated
γ	The rate at which Super POS Agent withdraw the new Naira from Banks	0.2	Estimated
σ	The rate at which Bank load the new Naira to ATM Machines	0.7	Estimated
δ	The rate at which Hoarders of new Naira withdraw the new Naira from POS Agents	0.9	Estimated
θ	The rate at which Non-Hoarders of new Naira withdraw their money from POS Agents	0.1	Estimated
τ	The rate at which Individual not likely to Hoard new Naira deposit the new Naira to POS Agent	0.1	Estimated
φ	The rate at which Non-Hoarders withdraw their new Naira from ATM Machines	0.8	Estimated
ϑ	The rate at which Non-Hoarders withdraw their new Naira from POS Agents.	0.1	Estimated
ψ	The rate at which Non-Hoarders new deposit their new Naira to Banks	0.1	Estimated
ω	The rate at which Cash Swap Agent disburse the new Naira to Non- Hoarders.	0.025	Estimated
ϕ	The rate at which Cash Swap Agent disburse the new Naira to individual likely to Hoarders.	2	Estimated
λ	Rate at which Cash Swap Agent disburse to Horders	0.7	Estimated

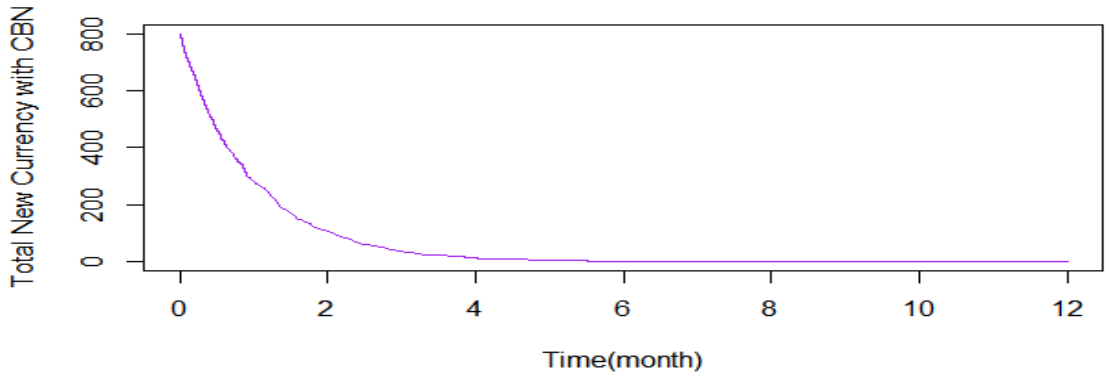

Figure 2: Sample path showing Total New Currency with CBN over time

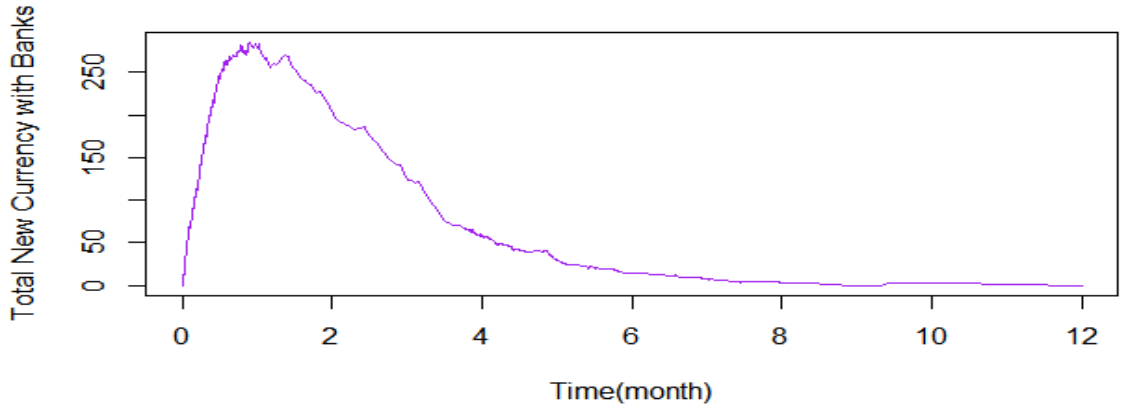

Figure 3: Sample path showing Total New Currency with Banks over time

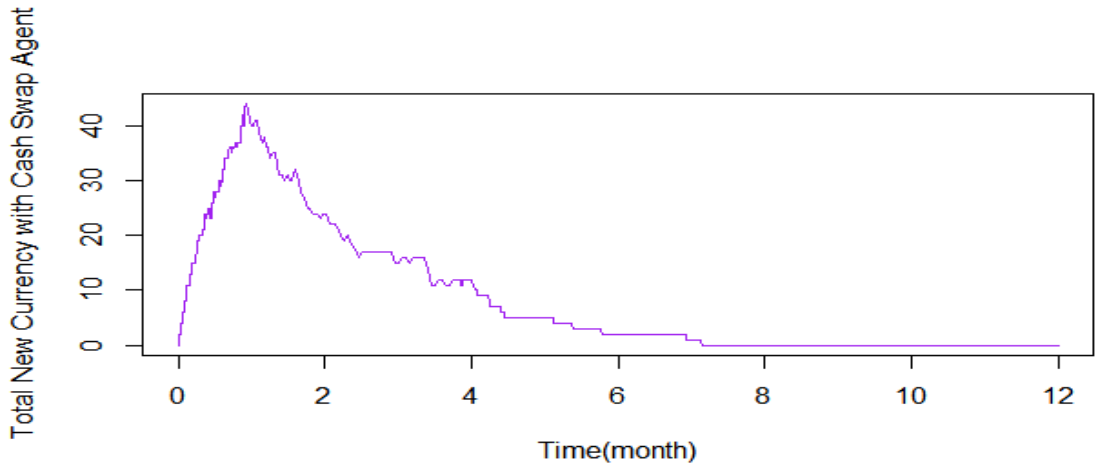

Figure 4: Sample path showing Total New Currency with Cash Swap Agents over time

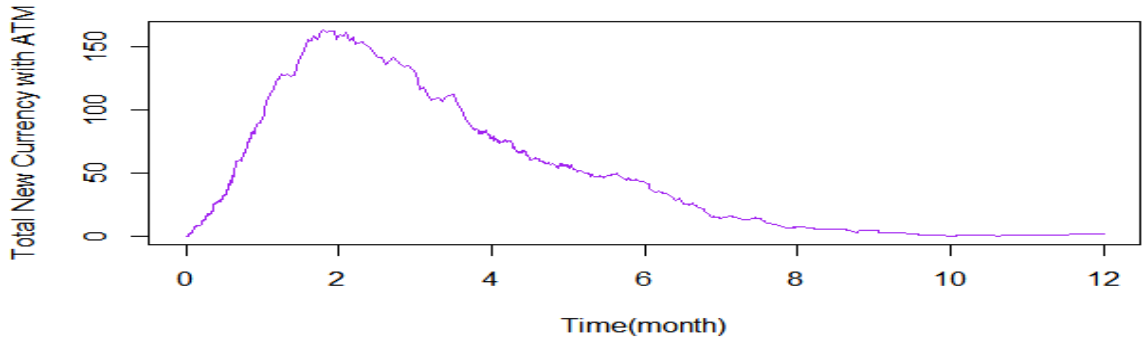

Figure 5: Sample path showing Total New Currency with ATM over time

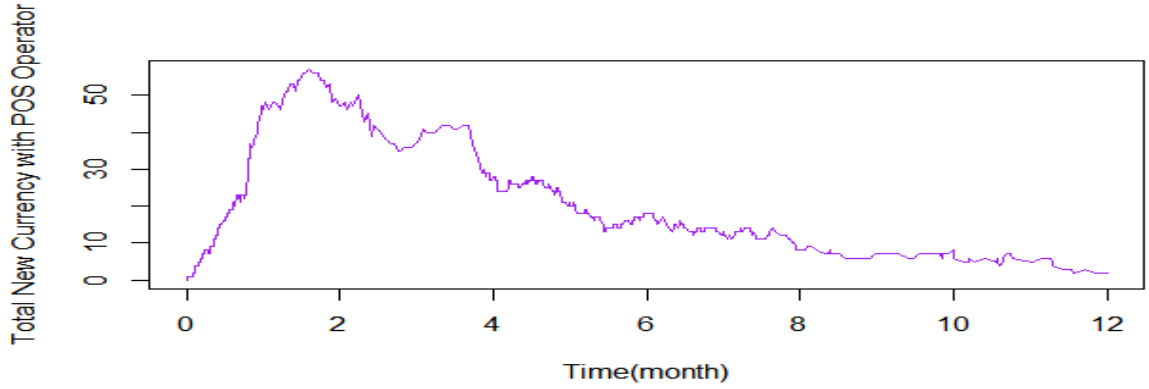

Figure 6: Sample path showing Total New Currency with POS Operator over time

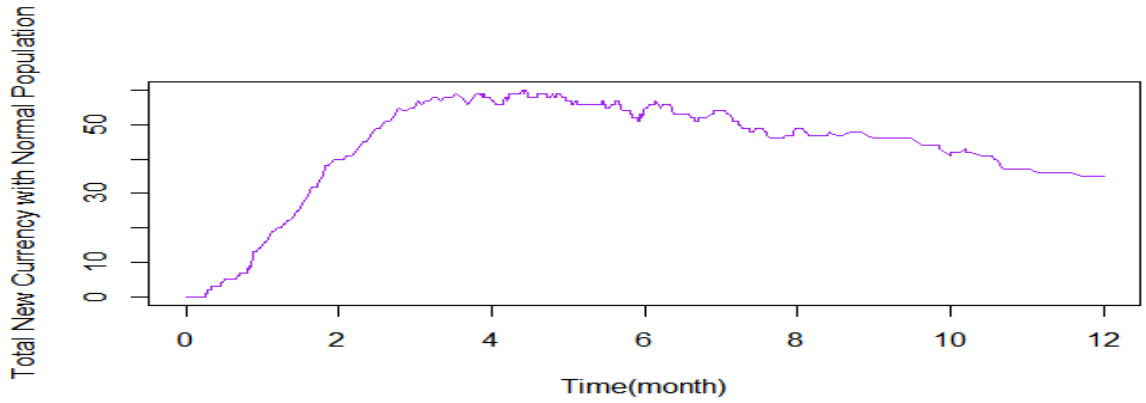

Figure 7: Sample path showing Total New Currency with Normal Individual over time

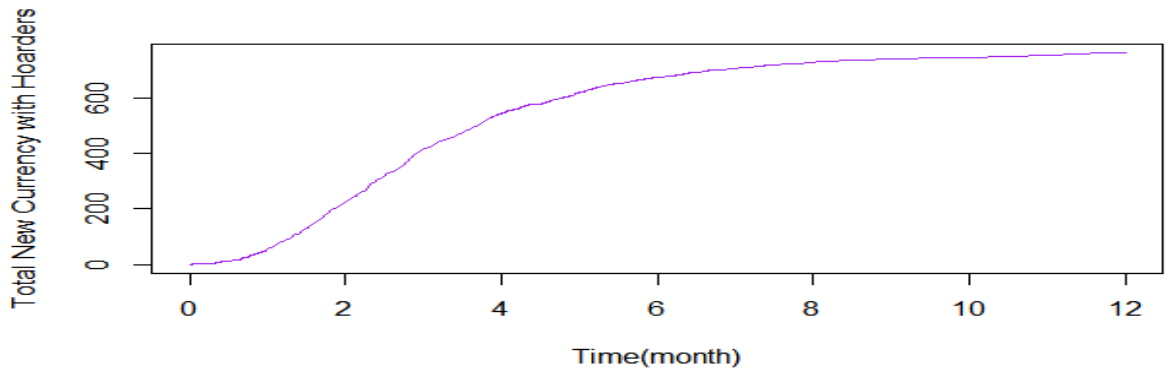

Figure 8: Sample path showing Total New Currency with Hoarders over time.

4. Discussion

Figure 2-8 are stochastic realizations curves representing the circulation of the new redesign naira notes. From Figure 2, the total amount of new currency notes release from the APEX bank tends to decrease exponentially. This was as a result of too much demands of the new currency and termination of the old currency notes. Figure 3 reveals that the total amount of new currency notes with the Banks raises rapidly as soon as the Bank received the new currency note and then tends to decline as the banks disbursed the money. This was as a result of much of demands on them and slow adoption of the policy due to level of literacy. Figure 4 shows that the total amount of new currency notes with the Cash Swap Agent initially raises as the APEX release money to them but later on decline slowly. This decline was as a result of people in rural areas don't have access to Bank Account from the commercial banks and this lead higher demand of cash of new currency notes to run their businesses. Figure 5 shows an increase in the amount of new naira notes on ATMs as the commercial banks make provisions, transactions restriction and later keep declining over time. This decline was also as a result of people waits/queue to withdraw the new currency Naira notes on ATMs due to lack of adoption of the policy and scarcity of them. Figure 6 shows Total new currency notes with POS Operators goes up as got money from the bank and later tends to decline over time as a result of people are hoarding the money. Figure 7 shows a rapid raise as the money became available from cash swap agents, ATMs and POS agents. Figure 8 shows that the hoarders also continuous to get their new naira notes from cash swap agents, ATMs and POS agents due to failure to adopt the policy.

5. Conclusion

In this paper, a stochastic model for the circulation of new redesign naira notes were proposed and analyzed. The result shows that failure to adopt the policy were as a result of literacy level, lack of awareness before introducing the policy, high level of fraudulent activities, poor network connectivity, level of public acceptance, the efficiency of the financial and banking systems, and the government's ability to effectively circulate the new currency. Redesign of currency can have a range of implications, including political, practical, and economic implications. The model will served as a starting point for policy direction and thereby forecasting future trend of cashless policy in Nigeria. We therefore recommend a need for government increase awareness prior to implementation of the policy.

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