ON THE HEDGING CHARACTERISTICS OF GOLD AGAINST EXCHANGE RATE (NGN-USD) USING MARKOV APPROACH

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ABSTRACT

The removal of pegs on the exchange rate by the Central Bank of Nigeria has exposed the Nigerian currency (Naira) to a wobbly trend in recent times. A direct consequence of currency depreciation is the loss of wealth and purchasing power by those whose income and assets are in the devalued currency. One of the ways to safeguard against the possible losses is to hedge with commodity-related assets and other precious metals that have the potential to appreciate or at worst, remain stable during currency depreciation. This study investigated the impact of exchange rate (NGN-USD) on gold price using Markov chain modelling approach. A three-state Markov chain model which classified the state as Increase (I), Decrease (D) and Stable (S) was used to model the stochasticity of each of exchange rate (NGN-USD) and gold price (USD). Thereafter, the impact of exchange rate on gold price was examined using a three-state Markov Chain with classification: positive impact, negative impact, and no impact. The study considered daily time-series data of exchange rates and gold prices sourced from the Central Bank of Nigeria (CBN) and World Gold Council (WGC) bulletins, respectively from year 2001 to 2024. The long-run distribution of exchange rate (NGN-USD) was obtained as 13% for increase, 11% for decrease, and 76% for stable states, while the gold price has a long-run distribution of 51% for increase, 46% for decrease, and 3% for stable states. Further results revealed that exchange rate has a 7% positive impact, a 5% negative impact, and 88% no impact on gold price, with mean occurrence times of 15 days, 20 days, and 1 day respectively. The study established that investment in gold can serve as a hedge against exchange rate (USD-NGN) fluctuations.

Keywords: Exchange Rate, Gold price, Markov Chain, Currency Depreciation, Investment.

1.0 Introduction

The removal of pegs on the exchange rate by the Central Bank of Nigeria (CBN) on June 14, 2023 has plunged the Naira into depreciation as the value of the currency is now determined by market forces, making the value of the Naira experience a wobbly trend in recent times. Depreciation of a currency connotes a decline in the value of a currency relative to its exchange rate with other currencies. A lower-valued currency makes a country's imports more expensive and its exports less expensive in foreign markets (Onyekpere, 2023). A direct consequence of currency depreciation is the loss of wealth and purchasing power by those whose income and assets are in the devalued currency.

One of the ways to safeguard against these losses is to hedge with commodity related assets and other precious metals that have the potential to appreciate or at worse remain stable during currency depreciation. Gold is considered the leader in the precious metal market as a rise in

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its price appears to occasion a parallel trend in the price of other precious metals (Sari et al, 2010). According to Nair, et al. (2015), the major reason behind the relationship of gold and US Dollar (USD)/ Indian rand (IRN) exchange rate is that gold is considered as a hedge against the adverse exchange value of dollar. Gold exhibited a tremendous appreciation in price during the global financial crises (GFC) of 2007-2008, further presenting itself as a precious metal with some hedging characteristics and hence making it more attractive to investors (Aftab et al. 2018). Erdoğdu (2017) reported that gold has the capacity to sustain its value over time while Sukri et al. (2015) noted the increase in demand for gold for two basic purposes: firstly, the "use demand" for gold in the production of jewelry, medals, coins, electrical components and also in dentistry and secondly, the "asset demand" for gold where it is used by governments, fund managers and individuals as an investment.

The asset demand for gold is traditionally associated with the view that gold is an effective "hedge" as it is used to represents a value stored that investors believe will insulate them against inflation and other forms of uncertainty. In Adewuyi, *et al.* (2019) while gold was an effective hedge against stock exposure in Nigeria, the contrary was the case in South Africa. The high volatility of the stock markets and persistent fluctuations in exchange rates portend that an understanding of the dynamics of a particular exchange rate fluctuations vis-a-vis a hedging commodity like gold is invaluable.

The aim of this paper is to assess the stochasticity of exchange rate (NGN-USD) in relationship with the hedging characteristics of gold using the Markov approach. Results obtained in this paper will provide additional information on the hedging characteristics of gold against exchange rate (NGN-USD) fluctuations.

2.0 Literature Review

The effect of exchange rate and some macroeconomic variables on trade and investment is a common theme in research. According to Rao and Ramachandran (2016), modeling and prediction of time-varying volatility on financial markets cannot be undermined because these models are fundamental tools in risk management. Sattayatham *et al*. (2012) earlier posited that all stock markets possess characteristics of uncertainty, which is related with their short and long-term price state; a feature which is undesirable to investors but is also unavoidable whenever the stock market is the investment tool.

The best that is expected is to reduce the uncertainty which is possible via stock market analysis and forecasting. Joy (2011) and Wang et al, (2021) tested the hypothesis of dynamic hedging characteristics of gold against exchange rate using a time varying parameter vector error

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correction model. The study considered a panel data which consists of 15 countries from 2009-2020. Results obtained from Wang et al, (2021) revealed that gold can hedge against currency depreciation in the long run. Similarly, Chen et al. (2017), earlier posited that most commodity-money advocates choose gold as a medium of exchange because of its intrinsic properties.

Olabisi et al. (2019) investigated the effect of currency depreciation on the financial performance of Nigerian Deposit Bank using the Generalized Least Square (GLS) method with the conclusion that interest and inflation rates have negative significant impacts on the return on assets at 0.05 level of significance.

In Kim and Dilts (2011), the causal relationship between the value of Dollar and the prices of gold and oil was examined using monthly data from January, 1970 to July, 2008. Results revealed that there exists causal relationship between the value of Dollar and prices of gold and oil; that gold and oil are safe havens from dollar fluctuations. Earlier, Smith (2001) and also Sjaastad (2008) investigated the relationship between gold price and stock exchange price index using daily, weekly and monthly data beginning from 1991 to 2001. Four gold prices and six stock exchange indices were considered in the study. The short-run correlation between returns on gold and returns on US stock price indices is small and negative and for some series and time periods insignificantly different from zero. During the examined period, gold prices and US stock price indices were not cointegrated. Granger causality tests finds evidence of unidirectional causality from US stock returns to returns on the gold price set in the London morning fixing and the closing price.

Seemuang and Romprsert (2013) explored the relationship between the movement of gold value and dynamic macroeconomic variables namely: Inflation rate, US real GDP, value of Dollar, US money supply in the United States. Correlation analysis was used to explore the correlation between each of the variables. After a regression analysis, it was found that inflation rate significantly affected the gold price and the US Real GDP had a positive correlation with gold price. Ibrahim et al., (2014) investigated the factors that affected the price of gold in Malaysia from 2003 to 2012 using Multiple Linear Regression model. The study found a negatively significant relationship between inflation rates and exchange rates on gold prices.

Arfaoui and Rejeb (2017) examined in global perspective the oil, gold, US dollar and stock prices interdependencies and to identify instantaneous direct and indirect linkages among them from a period of 1995 to 2015. The simultaneous equation system was used and the result showed that price of gold was observed to be concerned by changes in oil, USD and stock markets. The US dollar was negatively affected by stock market and significantly by oil and

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gold price. Another study by Altarturi *et al.* (2018) revealed that USD exchange rate negatively influenced the price of gold in the short and medium term.

Bapna *et al*. (2012) analyzed the impact, causal effect of macroeconomic variables on gold price using quarterly data from 2002 to 2012. The study employed the unit root test, regression and granger causality test to further specify the probability of change in the variables studied and also to examine weather gold price contained any additional significant information about macroeconomic trends. It was shown that macroeconomic variables such as exchange rate, fiscal deficit, FOREX reserve, inflation rate independently affected gold prices.

Nguyen et al (2020) investigated the safe-haven feature of gold against Japanese Yen (JPY), US Dollar (USD) and Euro (EUR) using the multivariate Copula theory with the conclusion that gold possesses a substantial hedging characteristic against currency depreciation while Bahmani-Oskooee and Hajile (2010) validated the link between currency depreciation and domestic investment with some empirical results which involved time series data of 50 countries. Findings revealed that there exists a short run relationship between currency devaluation and investment.

Based on the literature that have been reviewed so far, it is obvious that there exists relationship between exchange rate fluctuations and investment in general. However, as opined by Ozturk (2006), the nature of relationship is mixed and greatly influenced by the choice of models, sample period and geographical location of empirical information. It is therefore imperative to investigate the hedging characteristic of gold against (NGN-USD) exchange rate fluctuation.

3.0 Methodology

A secondary data which consists of daily exchange rate of Naira (NGN) to US dollar (USD) accessed from the Central Bank of Nigeria (CBN) Statistical Bulletin 2024 and the daily price of gold (per troy ounce) in US dollar sourced from the World Gold Council for a period of 23 years (2001 – 2024) were used for the study. Figures 1 and 2 present graphical description of the data on exchange rate and gold prices respectively.

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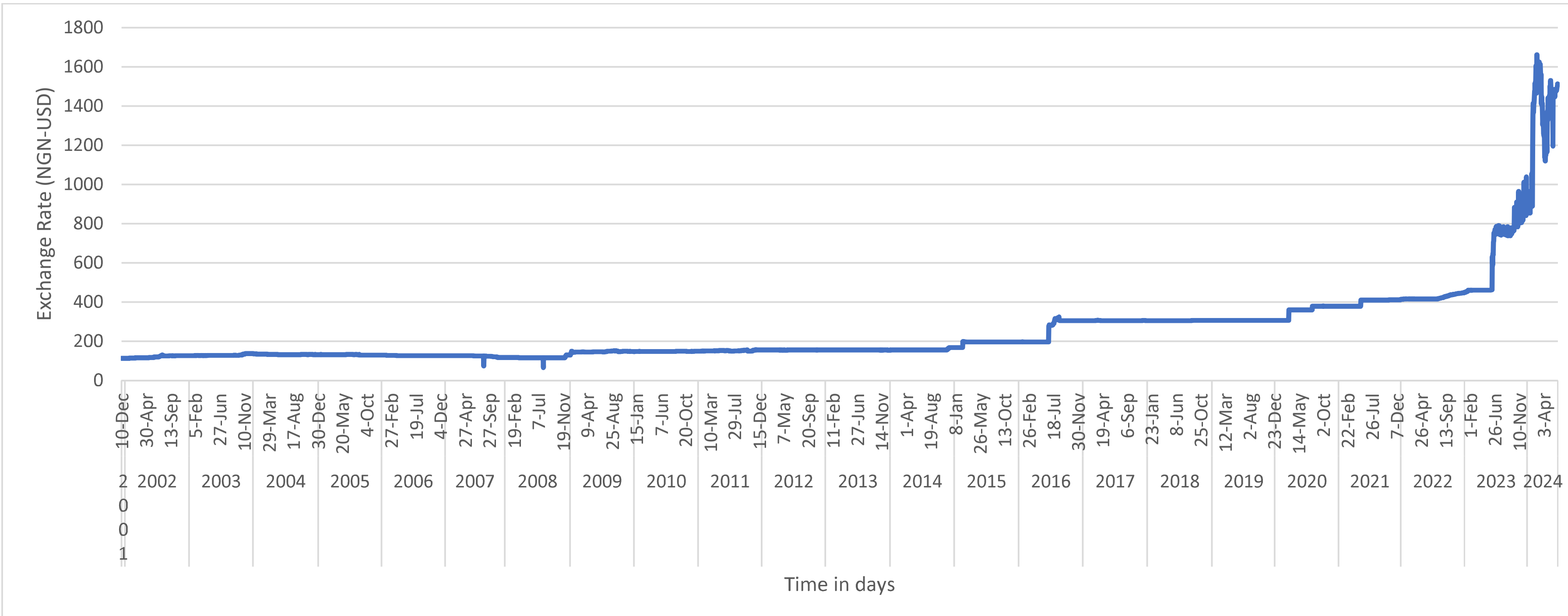

Figure 1: Graph of Daily Exchange Rate (NGN/USD) from 2001-2024

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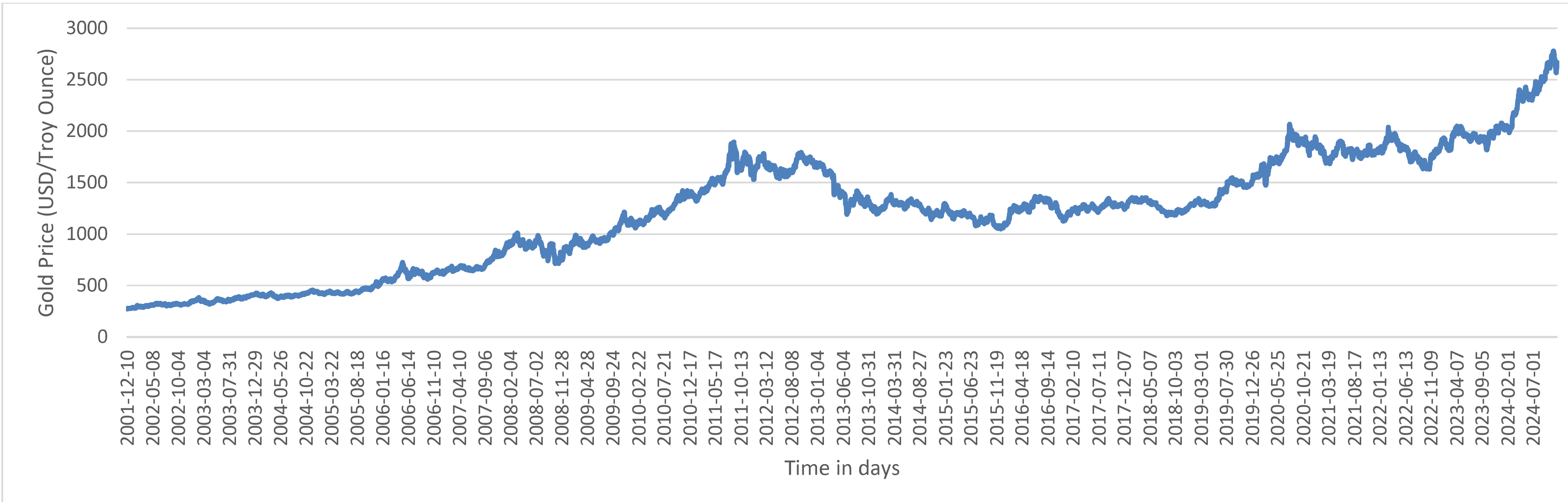

Figure 2: Daily Gold Prices from 2001-2024

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3.1 The Markov Chain Model

A Markov chain $\{X_n : n = 0, 1, 2 \ldots.\}$ is a stochastic process with countable states such that for each state $i_0, i_1, \ldots \ldots i_n, j$;

$$P(X_{n+1} = j | X_0 = i_0, X_1 = i_1, \ldots \ldots, X_{n-1} = i_{n-1}, X_n = i_n) = P(X_{n+1} = j | X_n = i_n) \quad (1)$$

For a Markov chain, the conditional distribution of any future state X_{n+1} given the past state $X_0, X_1, \ldots\ldots, X_{n-1}$ and the present state X_n is independent of the past values but it depends only on the present state.

3.3 Transition Probability Matrix

Let E be the set consisting of the possible states of the Markov chain; $E = \{E_1, E_2, \cdots, E_m\}$. The process starts in one of these states and moves successively from one state to another. Each of these successive moves is called a transition. If the chain is currently in state E_i then it moves to state E_j with a probability denoted P_{ij}, where P_{ij} is the transition probability from state i to state j.

The general form for an $(n \times n)$ transition matrix is given as;

$$P = \begin{bmatrix} P_{11} & P_{12} & P_{13} & \cdots & P_{1n} \\ P_{21} & P_{22} & P_{23} & \cdots & P_{2n} \\ \vdots & \vdots & \vdots & & \vdots \\ P_{n1} & P_{n2} & P_{n3} & \cdots & P_{nn} \end{bmatrix} \quad (2)$$

The elements P_{ij} are also called stationary probabilities which is defined as

$$P(X_n = j | X_{n-1} = i) = P_{ij} \quad (3)$$

3.4 N-Step Transition probability matrix

For any value of n (n = 2, 3, …), the n^{th}power; P^n of the matrix P in equation (2) above which specify the probability P_{ij}^n that the chain will be in state j after n-steps given that it begins in state i is called the n-step probability matrix. In general, the n-step transition probability matrix is given as in Equation (4).

$$P^{(n)} = P^{n-1}P\,;\; n \geq 1. \quad (4)$$

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This shows that if P^n denotes the matrix of n-steps transition probability, then P^n can be obtained by multiplying the matrix P by itself n times (Ross, 2010).

3.5 Steady State Probabilities and Mean Recurrence Time

Consider a Markov chain with r-states and row vector $\pi = (\pi_1 \ \pi_2 \ ... \ \pi_r)$

Such that $\pi_i \geq 0$ and $\sum_{i=1}^{r} \pi_i = 1$

Then,

$$\pi_j = \lim_{n\to\infty} P_{ij}^n \tag{5}$$

where P_{ij} is defined in Equation (2), then $(\pi_1 \ \pi_2 \ ... \ \pi_r)$ is called a steady state vector of the Markov chain. This means that as n→ ∞, the probability that the chain will transit from state x_i to a state x_j is independent of the initial state x_i . π can be obtained by solving the relation

$$\pi_j = \sum_{i=1}^{r} \pi_j P_{ij} \ ; \ j \geq 0 \tag{6}$$

These limiting probabilities, which also represent the proportion of the time that the process spends in state i over a long period, will enable us forecast the long-term behavior of the Markov chain (Grinstean and Snell, 1998).

The mean recurrence time are computed as $(\frac{1}{\pi_1}, \frac{1}{\pi_2} \cdots \frac{1}{\pi_r})$ respectively. It is the time it takes the chain to return to its initial state.

3.6 Markov Chain Modelling of the Stochastic Sequence of Gold Price and Exchange Rate

Consider an indicator function; G_k which is used to define a stochastic sequence of gold price for a 3-state Markov Chain as follows: for any k^{th} day, a random variable G_k is defined to represent the state of the process with the realization; 1, if the price of gold increases compared to the previous day, -1 if it decreases compared to the previous day and 0 if it is stable compared to the previous day.

Mathematically,

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$$G_k = \begin{cases} 1; & \text{if} \quad G_{k-1} < G_k \\ 0; & \text{if} \quad G_{k-1} = G_k \\ -1; & \text{if} \quad G_{k-1} > G_k \end{cases} \tag{7}$$

where k = 1, 2, …… nth (days)

Consider an indicator function; E_k which defines the stochastic sequence of exchange rate on day k for a 3-state Markov Chain as follows: E_k represents the state of the process with realization 1, if exchange rate increases compared to the previous day, -1 if it decreases when compared to the previous day and 0 if it remains stable.

Mathematically,

$$E_k = \begin{cases} 1; & \text{if} \quad E_{k-1} < E_k \\ 0; & \text{if} \quad E_{k-1} = E_k \\ -1; & \text{if} \quad E_{k-1} > E_k \end{cases} \tag{8}$$

where k = 1, 2, …… nth (days)

Using Equations (7) and (8), the observed frequency matrices for gold price and exchange rate could be obtained as in Table 1.

Table 1: Observed Frequency for exchange rate and gold prices

		Current Day (j)			Total
		Increase (1)	Decrease (2)	Stable (3)	
Previous Day (i)	Increase (1)	f_{11}	f_{12}	f_{13}	F_1
	Decrease (2)	f_{21}	f_{22}	f_{23}	F_2
	Stable (3)	f_{31}	f_{32}	f_{33}	F_3

The maximum likelihood estimators of P_{ij} ; $(i, j = 1, 2, 3)$ in Equation (2) is given by Equation (9)

$$\hat{p}_{ij} = \frac{f_{ij}}{\sum_{j=i}^{3} f_{ij}} \quad ; \qquad \text{where } i, j = 1, 2, 3 \tag{9}$$

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3.7 Markov Chain Modelling of the Impact of Exchange Rate on Gold Price

Consider an indicator; I_k which represents the impact of exchange rate on gold price on a K^{th} day;

$$I_k = \begin{cases} 1; & \text{if impact is positive} \\ 0; & \text{if} \quad \text{no impact} \\ -1; & \text{if impact is negative} \end{cases} \tag{10}$$

The impact of exchange rate on gold price was classified into three (3) states namely, positive, negative and neutral (no-impact). From Table 2, the conditions that could result in positive impact are: if exchange rate increase when gold price also increases, if exchange rate decrease when gold price equally decreases and if exchange rate is stable when gold price is also stable. A negative impact could emerge if: exchange rate increases when gold price decreases, exchange rate decreases and when gold price increases. Lastly it could result to a neutral or no-impact if: change rate increases when gold price is stable, exchange rate decreases when gold price is stable, exchange rate is stable when gold price increases and exchange rate is stable when gold price decreases.

Table 2: Classification of the impact of exchange rate on gold price

States	Conditions
Positive Impact (1)	$E_{k-1} < E_k$ and $G_{k-1} < G_k$ $E_{k-1} > E_k$ and $G_{k-1} > G_k$ $E_{k-1} = E_k$ and $G_{k-1} = G_k$
Negative Impact (-1)	$E_{k-1} < E_k$ and $G_{k-1} > G_k$ $E_{k-1} > E_k$ and $G_{k-1} < G_k$
No-Impact/Neutral (0)	$E_{k-1} < E_k$ and $G_{k-1} = G_k$ $E_{k-1} > E_k$ and $G_{k-1} = G_k$ $E_{k-1} = E_k$ and $G_{k-1} < G_k$ $E_{k-1} = E_k$ and $G_{k-1} > G_k$

Table 3 presents the observed frequencies for the impact of exchange rate on gold prices.

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Table 3: Observed Frequency of the impact of exchange rate on gold price

		Current Day (j)			Total
		Positive (1)	Negative (2)	Neutral (3)	
Previous Day (i)	Positive (1)	f_{11}	f_{12}	f_{13}	F_1
	Negative (2)	f_{21}	f_{22}	f_{23}	F_2
	Neutral (3)	f_{31}	f_{32}	f_{33}	F_3

The maximum likelihood estimators of P_{ij} ; $(i, j = 1, 2, 3)$ in Equation (2) is given as in Equation (9).

3.8 Test of Goodness-of-fit of the Markov Model for the Impact of Exchange Rate on Gold Price

The Markovian assumption that current day's exchange rate impact on gold price depends on that of the previous day was tested using the Chi-Square test of independence (Raheem and Ezepue, 2016). The hypotheses are:

H_0: Impact of exchange rate on gold price on consecutive days is independent

H_1: Impact of exchange rate on gold price on consecutive days is not independent

The test Statistic is given as:

$$\chi^2 = \sum_{i,j}^{N} \frac{(f_{ij} - E_{ij})^2}{E_{ij}} \sim \chi^2_{(i-1)(j-1),\alpha} \qquad (11)$$

where E_{ij} represents the expected frequency using the formula: $\frac{F_{i+}\ F_{+j}}{F_{++}}$ with F_{i+} representing ith row marginal total, F_{+j} is the ith column marginal total, and F_{++} is the overall marginal total.

4.0 Results

This section presents numerical results which were obtained from the study.

4.1 Stochastic Modelling of Exchange Rate

Table 4 presents the frequencies of exchange rate transition from one state to the other. For instance, the transition of exchange rate from an increase-to-increase state occurred

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42 times. The highest case was that of transition from stable-to-stable state was 2370, which implies that exchange rate was mostly stable during the period under study.

Table 4: Exchange rate frequency values using Markov chain model

		Current Day			Total
		Increase (1)	Decrease (2)	Stable (3)	
Previous Day	Increase (1)	42	27	500	569
	Decrease (2)	29	39	393	461
	Stable (3)	498	395	2370	3263

Table 5 presents the transition probabilities of exchange rate fluctuations from one state to the other. In particular, the one-step transition probability result shows that the probability that an increase in the previous day will be preceded by an increase in the next day is 0.0700. the probability of transiting from a stable state exchange rate the previous day into a stable exchange rate the next day is 0.7300. Results for the 2nd, 3rd, 4th ……. 8th steps transition probabilities are also presented in Table 5. From the results in Table 5, it could be observed that a steady state process was achieved (attained) at the 8th-step. This result implies that the probability of exchange rate being at increase, decrease and stable states are 0.13, 0.11 and 0.76 respectively irrespective of the preceding state.

Table 5: N-Step transition probabilities for exchange rate

		Actual Day		
N- Steps transition prob.	Previous Day	Increase	Decrease	Stable
	Increase	0.0700	0.0500	0.8800
1st step	Decrease	0.0600	0.0800	0.8600
	Stable	0.1500	0.1200	0.7300
	Increase	0.139900	0.113100	0.747000
2nd step	Decrease	0.138000	0.112600	0.749400
	Stable	0.127200	0.104700	0.768100
	Increase	0.128629	0.105683	0.765688
3rd step	Decrease	0.128826	0.105836	0.765338
	Stable	0.130407	0.106908	0.762691

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4th step	Increase	0.130198	0.106769	0.763033
	Decrease	0.130169	0.106749	0.763083
	Stable	0.129946	0.106596	0.763458
5th step	Increase	0.129975	0.106615	0.763410
	Decrease	0.129979	0.106618	0.763403
	Stable	0.130011	0.106640	0.763349
6th step	Increase	0.130007	0.106637	0.763356
	Decrease	0.130006	0.106637	0.763357
	Stable	0.130002	0.106634	0.763365
7th step	Increase	0.130002	0.106634	0.763364
	Decrease	0.130002	0.106634	0.763364
	Stable	0.130003	0.106635	0.763363
8th step	Increase	0.130003	0.106634	0.763363
	Decrease	0.130003	0.106634	0.763363
	Stable	0.130003	0.106634	0.763363

Therefore, $\pi_1 = 0.130003$, $\pi_2 = 0.106634$, $\pi_3 = 0.76336$. The mean recurrence time for I = 7.692, D = 9.378, and S = 1.310.

4.2 Stochastic Modelling of Gold Price

Table 6 presents the frequencies of gold price transition from one state to the other. For instance, the transition of gold price from an increase-to-increase state 1115 times. The transition was observed to be the highest case which implies that gold price was mostly increasing during the period under review. The lowest frequency was recorded at the transition from stable-to-stable state which was 7 times. This implies gold prices depicted a seldom stable trend throughout the period under review.

Table 6: Gold price frequency values using Markov chain model

		Current Day			Total
		Increase (1)	Decrease (2)	Stable (3)	
Previous Day	Increase (1)	1115	1020	60	2195
	Decrease (2)	1016	919	48	1983
	Stable (3)	64	44	7	3263

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Table 7 presents the transition probabilities of gold price transition from one state to the other. In the one-step transition probability of gold price, result shows that the probability of an increase in the previous day with an increase in the next day is 0.51. The probability of having an increased state in the previous day succeeded by stable state the next day was 0.03. this probability was observed to be same with the probability of decrease-to-stable state. The results of the 2nd, 3rd, 4th and 5th steps transition probabilities are also presented in Table 7. A steady state process was achieved (attained) at the 5th-step transition. The result in step 5 expressed that the probability of gold price being at increase, decrease and stable states are 0.51, 0.46 and 0.03 respectively. This implies that gold price experienced an increase 51% of the time irrespective of the previous state, also there is 46% chance that gold price decreased irrespective of the previous state and a 3% chance that gold price remained stable irrespective of its previous state.

Table 7: Markov chain transition probability values for gold price

		Actual Day		
N- Steps transition probability	Previous Day	Increase	Decrease	Stable
1st step	Increase	0.510000	0.460000	0.030000
	Decrease	0.510000	0.460000	0.030000
	Stable	0.560000	0.380000	0.060000
2nd step	Increase	0.511500	0.457600	0.030900
	Decrease	0.511500	0.457600	0.030900
	Stable	0.513000	0.455200	0.031800
3rd step	Increase	0.511545	0.457528	0.030927
	Decrease	0.511545	0.457528	0.030927
	Stable	0.511590	0.457456	0.030954
4th step	Increase	0.511546	0.457526	0.030928
	Decrease	0.511546	0.457526	0.030928
	Stable	0.511548	0.457524	0.030929
5th step	Increase	0.511546	0.457526	0.030928
	Decrease	0.511546	0.457526	0.030928
	Stable	0.511546	0.457526	0.030928

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Therefore, $\pi_1 = 0.511546, \quad \pi_2 = 0.457526, \quad \pi_3 = 0.030928$ and the recurrence time for I = 1.955, D = 2.186, S = 32.333.

4.3 Modelling of the Impact of Exchange Rate on Gold Price

Table 8 presents the frequencies of impact assessment of exchange rate on gold price transition from one state to the other. For instance, the transition from positive impact to negative impact is 8 times. The highest case was that of transition from a no-impact to no-impact with 3310 times, which implies that exchange rate mostly had no-impact on gold price during the period of study.

Table 8: Frequency values for impact of exchange rate on gold price

		Current Day (j)			Total
		Positive (1)	Negative (-1)	No-impact (0)	
Previous Day (i)	Positive (1)	12	8	268	288
	No-Impact (0)	271	201	3310	3782
	Negative (-1)	5	15	203	223

Table 9 presents the transition probabilities of the impact of exchange rate on gold price from one state to the other. In particular, the one step transition probability result showed that the probability that a negative impact in the previous day will be preceded by a positive impact the next day is 0.02. The probability of having a no-impact state the previous day succeed a no-impact state the next day is 0.88. The result of the 2nd, 3rd, 4th and 5th step transition probabilities are also presented in Table 9. It could also be observed that a steady state process was achieved (attained) at the 5th step. The result in step 5 implies that the probability of the impact of exchange rate on gold price being positive, negative and no-impact are approximately 0.07, 0.05 and 0.88 respectively. This implies that there is approximately 7% chance that exchange rate positively impacted gold price irrespective of its previous state, 5% chance that exchange rate

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negatively impacted gold price irrespective of the previous state and 88% chance that exchange rate had no-impact on gold price irrespective of its previous state. This result is in line with Nair et al., (2015) findings on the impact of US dollar/Indian Rand (IRN) exchange rate on gold price with the conclusion that gold could be used as a hedge against the adverse exchange rate fluctuations. Again, the convergence of transition probabilities in Table 9 to its limiting values in just 5-steps (5-days) suggest that gold can be considered as an edge against exchange rate (NGN-USD) fluctuations even in the short-run.

Table 9: N-Step transition probabilities for the impact of exchange rate on gold price

		Actual Day		
N- Steps transition prob.	Previous Day	Positive	Negative	No-Impact
1st step	Positive	0.040000	0.030000	0.930000
	Negative	0.020000	0.070000	0.910000
	No-Impact	0.070000	0.050000	0.880000
2nd step	Positive	0.067300	0.049800	0.882900
	Negative	0.065900	0.051000	0.883100
	No-Impact	0.065400	0.049600	0.885000
3rd step	Positive	0.065491	0.049650	0.884859
	Negative	0.065473	0.049702	0.884825
	No-Impact	0.065558	0.049684	0.884758
4th step	Positive	0.065553	0.049683	0.884764
	Negative	0.065551	0.049685	0.884768
	No-Impact	0.065549	0.049683	0.884768
5th step	Positive	0.065549	0.049683	0.884768
	Negative	0.065549	0.049683	0.884768
	No-Impact	0.065549	0.049683	0.884768

Therefore, $\pi_1 = 0.065549$, $\pi_2 = 0.049683$, $\pi_3 = 0.884768$

And the recurrence time for Positive = 15.256, Negative = 20.128, Neutral = 1.130

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4.4 Test of Goodness-of-fit Test of Markov Independence Assumption

Results in Table 10 present the Chi Square test of independence with the null hypothesis; H_0: Impact of exchange rate on gold price of consecutive days are independent at 0.05 level of significance. The Pearson chi-square statistic is 16.074 (p-value = 0.003) and the Likelihood ratio chi-square is 19.397 (p-value = 0.001). Since both p-values are less than 0.05 we reject the null hypothesis (H_0) that the impact of exchange rate on gold price of consecutive days are independent at 0.05 level of significance. This result validates the Markov property which states that the impact of exchange rate on gold price on a certain day depends only on that of the immediate past day.

Table 10: Chi-Square Test of Independence

	Chi-Square	DF	P-Value
Pearson	16.074	4	0.003
Likelihood Ratio	19.397	4	0.001

4.5 Mean Recurrence Time

Table 11 presents the result of mean recurrence time of exchange rate, gold price, and impact of exchange rate on gold respectively. This result reveal that the mean recurrence time for exchange rate to increase, decrease and remain stable are approximately 8 days, 9 days and 1 day respectively. The mean recurrence time for gold price to increase, decrease and remain stable are approximately 2 days, 2days and 32 days respectively. Lastly, the mean recurrence time for the impact of exchange rate on gold price to be positive, negative, and no-impact are approximately 15 days, 20 days and 1day respectively.

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Table 11: Mean recurrence Time (days)

Data	States	Recurrence time
Exchange rate	Increase	7.692
	Decrease	9.378
	Stable	1.310
Gold price	Increase	1.955
	Decrease	2.186
	Stable	32.333
Impact of Exchange Rate on Gold Price	Positive	15.256
	Negative	20.128
	No-impact	1.130

5.0 Conclusion

This paper presented a stochastic analysis of exchange rate (NGN-USD), gold price and the impact of exchange rate on gold price using the Markov chain model. The probability of having exchange rate increase, decrease and stable in the long run are 0.13, 0.11 and 0.76 with mean recurrence time of 8 days, 9 days and 1 day respectively. The probability of having increase, decrease and stable gold price in the long run are 0.51, 0.46 and 0.03 with mean recurrence time of 2 days, 2 days and 32 days respectively. The probability of exchange rate having positive, negative and zero (no-impact) impact on gold price in the long run are approximately 0.07, 0.05 and 0.88 with mean recurrence time of 15 days, 20 days and 1 day respectively. Since no-impact of exchange rate on gold price has the highest probability of 0.88 (88%), it implies that exchange rate has minimal chance of impact on gold price. Hence, gold can serve as a good hedge against (NGN-USD) exchange rate fluctuation. This result supports the view of Nair et al. (2015) and Wang et al. (2021) which stated that gold could be used as a hedge against adverse exchange rate fluctuations. Further research is recommended to isolate other macroeconomic variables which may influence gold prices in Nigeria.

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