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PROBABILITY MODELING OF EXCHANGE RATE FLUCTUATION IN NIGERIA

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ABSTRACT: *The Naira's value has continued fluctuating in comparison with other currencies due to its depreciation. Because of this fluctuation, returns are difficult to forecast. The core objective of this study is to find a unified probability distribution for modelling the exchange rate in Nigeria and this will contribute immensely to the existing body of knowledge. The continuous nonnegative exchange rate data from 1970 to 2021 was used for this research paper. Previous studies have demonstrated different probability distributions from others in the real sense. Therefore, the selection of appropriate probability distributions is of great importance. This study adopted ten continuous probability distributions. The graph of the probability density function and Chi-square goodness of fit statistics show that the probability distributions fit the exchange rate data. Meanwhile, the log-likelihood value and the AIC show that Fatigue Life (3P) distribution is best done compared with fitted probability models. Therefore, the Fatigue Life (3P) is Nigeria's unified probability distribution for the modelling exchange rate.*

KEYWORDS: Exchange rate, Probability models, Fatigue Life (3P) distribution, AIC, Log-Likelihood.

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INTRODUCTION

When discussing the global economy, the exchange rate is an important topic to bring up (Etuk et al., 2016). The dynamics of exchange rates are critical in modern macroeconomics (Medel et al., 2015). Forecasting and modelling of exchange rates are critical for policy development (Hina & Qayyum, 2015). This is because exchange rates significantly affect macroeconomic fundamentals, including oil prices, interest rates, wages, unemployment, and the pace of economic expansion; they must be predicted (Ramzan et al., 2012). With trade occurring around-the-clock and trillions of dollars in various currencies changing hands every day, foreign exchange markets are among the most significant and essential financial markets in the world (Khashei & Bijari, 2011). The relative cost of one currency to another is determined by the exchange rate (Nwankwo, 2014). Economic prices are significantly influenced by the exchange rate (Klein & Shambaugh, 2012). It determines how much a local currency is worth about a world basket of goods or prices (Gourinchas, 1999). It affects how much the external sector engages in international trade and how much cheaper domestically produced goods are compared to import ones (Mohammed & Abdulmuahymin, 2016). The most widely utilized and crucial component in the settlement of international invoices and transactions is foreign exchange (Oleka et al., 2014). The Naira to US dollar conversion rate determines how much money is needed to buy one US dollar (Jhingan, 2005; Campbell, 2010; Omojola & Gbadebo, 2014).

A country's economy, like that of Nigeria, depends on the cost of foreign currency to operate at its maximum level of production (Ogiogio, 1996). Exchange rates are among the most significant expenses in global financial markets (Rahim et al., 2018). They affect economic activity, international trade, and income disparity between countries (Tan, 2009). The stability of the exchange rate now provides a firm platform for all economic activities (Taiwo & Adesola, 2013). Exchange rates are essential in creating this strategy since price stability is the main objective of monetary policy in the majority of countries (Adeoye & Saibu, 2014). Therefore, central banks need to monitor currency prices and exchange rates carefully (Dilmaghani & Tehranchian, 2015). The primary goals of Nigeria's currency rate policy are to maintain adequate foreign exchange reserves and a stable value for the Naira (Oleka & Okolie, 2016). Nigeria's central bank attempts to maintain the stability of the Naira to achieve its goal of preserving price stability because domestic prices (inflation and interest rates) are particularly sensitive to exchange rate swings (CBN, 2016). Nigeria is hardly an exception when it comes to nations prioritising economic growth as one of their main macroeconomic policy goals (Nyoni & Bonga, 2018). Nigeria wants its economy to rank among the top twenty in the world by 2020 and among the top twelve by 2050 (CBN, 2019). The aggressive pursuit of quick and sustained economic growth and development through a thoroughly determined exchange rate policy is one of the best ways to accomplish the aforementioned objective (Obi et al., 2016). The capacity of a nation to make investments and utilize its resources wisely and efficiently is a prerequisite for long-term economic success (Nyoni & Bonga, 2017). Exchange rates significantly affect economic growth, according to several academics, including Korkmaz (2013), Ahmad et al. (2013), Uddin et al. (2014), and Chipeta et al. (2017). According to researchers like Rasaq (2013), and Eze and Okpala (2014), efficient exchange rate management is necessary for Nigeria's economy to continue growing. Besides, different works in the past have applied probability distributions to air pollutants, leaving a significant gap because no work has modelled probability distributions to macroeconomic

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variables such as exchange rates, making this work extremely important. Therefore, the key objective is to find a unified probability distribution that can model the exchange rate fluctuation in Nigeria, and achieving this will significantly contribute to the existing body of knowledge.

METHODOLOGY

Continuous probability distributions are used in this work to model the exchange rate fluctuation in Nigeria. Secondary data were explored for this study and were collected via World Bank online publication (data.worldbank.org) spanning from 1970 to 2021. It is suitable for continuous probability distributions because it is a non-negative value. The statistical software adopted for the analysis of this research work is Easyfit version 5.6. Each of the adopted probability distributions concept and their probability density functions will be described accordingly as follows:

1. Fatigue Life distribution can also be referred to as Birnbaum-Saunders distribution and it applies a great deal to model the lifetime of a device suffering from fatigue. For example, it is suitable for modelling time between events such as insurance claims, shocks to a market, macroeconomic fluctuation, etc. Fatigue Life (3P) was adopted for this study with parameters: α, β and ɣ. The probability density function can be expressed below with α = μ.

$$f(x) = (\frac{\sqrt{\frac{x-\mu}{\beta}} + \sqrt{\frac{\beta}{x-\mu}}}{2\gamma(x-\mu)})\phi(\frac{\sqrt{\frac{x-\mu}{\beta}} - \sqrt{\frac{\beta}{x-\mu}}}{\gamma}) \qquad x > \mu; \gamma, \beta > 0$$

2. The continuous probability distribution known as the Weibull distribution can match a wide variety of distribution forms. The Weibull distribution defines the probability connected with continuous data, much like the normal distribution does. However, it can also model skewed data, unlike the normal distribution. In fact, because of its incredible flexibility, it can model data that is skewed both left and right. In addition, it models time in terms of events such as fatigue life distribution. The Weibull distributions can be of two parameters with α and β as well as three parameters (3P) with α, β and ɣ. The probability density functions for the generalized three parameters Weibull distribution can be expressed as:

$$f(x) = \frac{\gamma}{\alpha}(\frac{(x-\mu)}{\alpha})^{\gamma-1} exp^{(-(\frac{(x-\mu)}{\alpha})^{\gamma})} x \geq \mu; \gamma, \alpha > 0$$

3. When μ = 0 in the Weibull (3P), it becomes two parameters Weibull which can be expressed as:

$$f(x) = \frac{\gamma}{\alpha}(\frac{(x)}{\alpha})^{\gamma-1} exp^{(-(\frac{(x)}{\alpha})^{\gamma})} x \geq 0$$

4. The generalized Pareto distributions also belong to the family of continuous probability distributions.

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It can be used to model distributions of incomes and other macroeconomic variables like exchange rate, inflation, etc. The probability density function of a Gen. Pareto distribution can be expressed as:

$$f(x) = \begin{cases} \frac{1}{\sigma}\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1-1/\xi}, & \xi \neq 0 \\ \frac{1}{\sigma}\exp\left(-\frac{x-\mu}{\sigma}\right), & \xi = 0 \end{cases}$$

where ξ can also be represented with K as the case maybe. The three parameters are μ, ƴ and ξ.

5. Cauchy distribution also belongs to the family of a continuous probability distribution which is similar to normal distributions, with parameters σ and μ. The Cauchy probability density function can be expressed as:

$$f(x) = \left(\pi\sigma\left(1+\left(\frac{x-\mu}{\sigma}\right)^2\right)\right)^{-1}$$

6. Burr distribution is a continuous probability distribution which can model varieties of phenomena like household income, crop prices, macroeconomic fluctuations, etc. The probability density function of a Burr distribution with parameters σ, β and k can be written as:

$$f(x) = \frac{\alpha\beta k^{\alpha} x^{\beta-1}}{(k+x^{\beta})^{\alpha+1}}$$

7. Generalized extreme value distribution also belongs to the family of continuous probability distribution and it is developed within the extreme value theory. It helps to model extreme values among a large set of data. The probability density function of generalized extreme value with parameters σ, μ and ξ can be written as:

$$Q(x) = \begin{cases} \left(1+\xi\left(\frac{x-\mu}{\sigma}\right)\right)^{-1/\xi} & \xi \neq 0 \\ \exp\left(-\frac{x-\mu}{\sigma}\right) & \xi = 0 \end{cases}$$

8. Generalized gamma distribution also belongs to the family of continuous probability distribution. It is very important because of its relation with normal and exponential distribution. It is suitable for survival analysis, modeling macroeconomic fluctuations, etc. The probability density function of the generalized gamma distributions with parameters k, σ and β can be written as:

$$f(x) = \frac{k}{\beta\Gamma(\alpha)}\left(\frac{x}{\beta}\right)^{k\alpha-1}\exp\left(-\left(\frac{x}{\beta}\right)^{k}\right)$$

9. Beta distribution belongs to the family of continuous probability distributions with two positive parameters, a and b. The probability density function can be expressed below as:

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$$f(x) = \frac{1}{B(a,b)} x^{a-1}(1-x)^{b-1}, x \in (0,1)$$

10. Log-Logistic distribution is also a family of continuous probability distribution with two parameters, α and β. The probability density function for a log-logistic probability distribution can be written as:

$$f(x) = \frac{\left(\frac{\beta}{\alpha}\right)\left(\frac{x}{\alpha}\right)^{\beta-1}}{\left(1+\left(\frac{x}{\alpha}\right)^{\beta}\right)^{2}}$$

RESULT AND DISCUSSION

Table 1: Summary Statistics of Official Exchange Rate in Nigeria (1970 to 2021).

Statistic	**Exchange rate**
Sample Size	52
Range	471.85
Mean	86.728
Std. Deviation	111.48

Table 1 shows that the average exchange rate in Nigeria under review (1970 to 2021) is about 87 Naira per dollar with variability of about 111 Naira per dollar, indicating a high level of fluctuation or variability in Nigeria's exchange rate. The range of the exchange rate in Nigeria is about 472 Naira per dollar, which agrees with the current bank rate of dollar to Naira.

Table 2: The Value of the Chi-square Statistics, Log-likelihood Functions, AIC and the Rank of the Fitness

Prob. Distribution	Chi-Square Statistic	Log-Likelihood	AIC	Rank
Fatigue Life (3P)	2.0677	-58.96	4.72	1
Weibull (3P)	2.3192	-65.82	6.05	2
Weibull	3.1545	-69.07	7.23	3
Gen. Pareto	3.716	-71.60	7.53	4

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Cauchy	3.7527	-74.13	7.85	5
Burr	5.2408	-79.18	8.40	6
Gen. Extreme Value	5.2481	-85.88	8.90	7
Gen. Gamma	6.5601	-88.58	9.18	8
Beta	7.7104	-89.53	9.33	9
Log-Logistic	7.76	-91.28	9.48	10

Table 2 shows that the log-likelihood values of the Fatigue Life (3P) are higher than those of Weibull (3P), Weibull, Gen.Pareto, Cauchy, Burr, Gen.Extreme Value, Gen. Gamma, Beta and Log-logistic distribution. In the same vein, we can also see that Fatigue Life (3P) has the lowest Akaike information criteria (AIC) compared with the rest of the distributions. This suggests that the Fatigue Life (3P) performs better than the other fitted probability distributions to the exchange rate in Nigeria.

Table 3: Chi-square Estimation Parameters of the Fitted Probability Distributions

Prob. Distribution	Parameters estimation
Fatigue Life (3P)	α=5.7832, β=3.9922, γ=0.52953
Weibull (3P)	α=0.3387, β=23.416, γ=0.54678
Weibull	α=0.44235, β=50.318
Gen. Pareto	κ=0.12968, σ=91.745, μ=−18.688
Cauchy	σ=23.584, μ=9.8489
Burr	κ=302.44, α=0.50976, β=3.7105E+6
Gen. Extreme Value	κ=0.32093, σ=54.489, μ=30.28
Gen. Gamma	κ=0.7741, α=0.55406, β=143.3
Beta	α=0.54678, β=472.4
Log-Logistic	α=0.62468, β=14.547

Table 3 shows the parameter estimations of the ten fitted probability distributions to the exchange rate in Nigeria.

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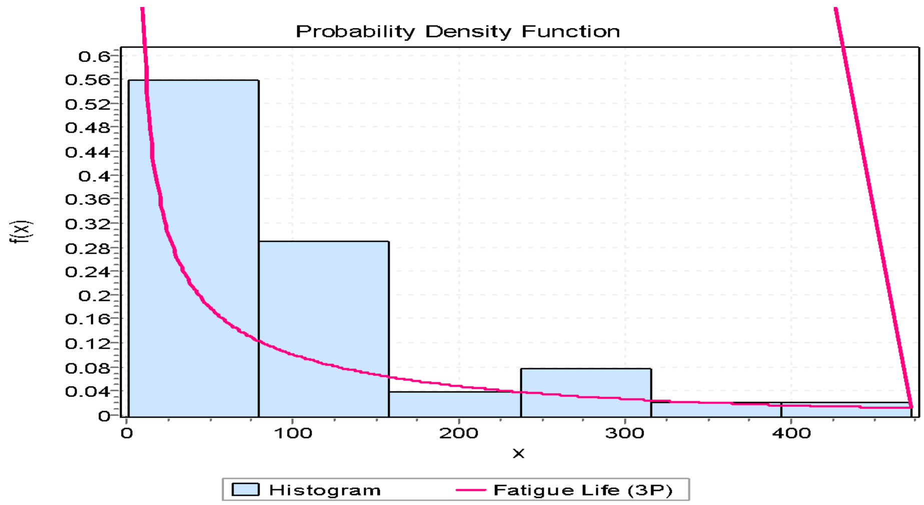

Figure 1: Probability Density Plot of Fatigue Life (3P) Distribution

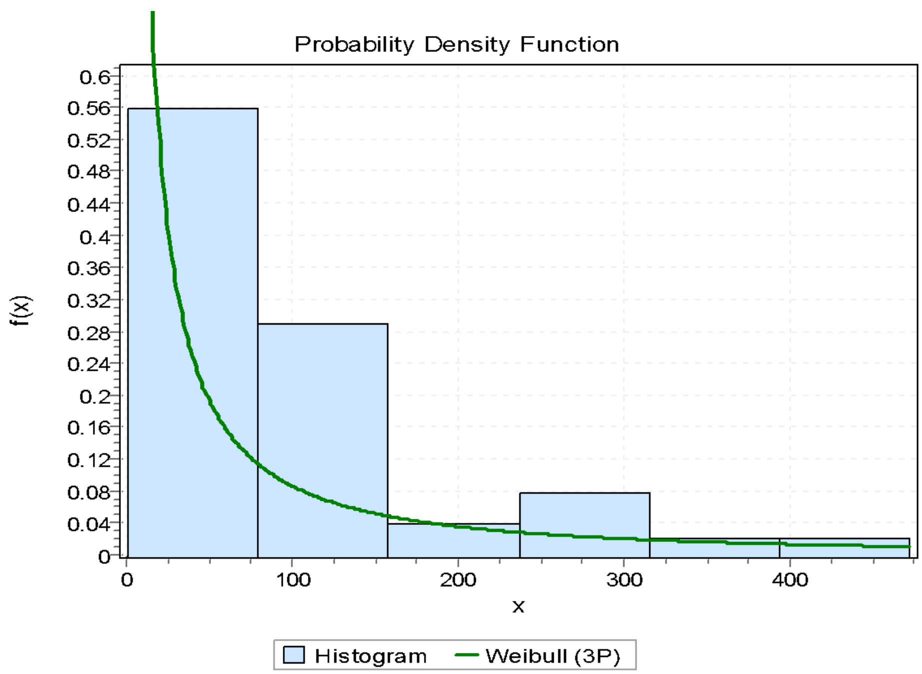

Figure 2: Probability Density Plot of Weibull (3P) Distribution

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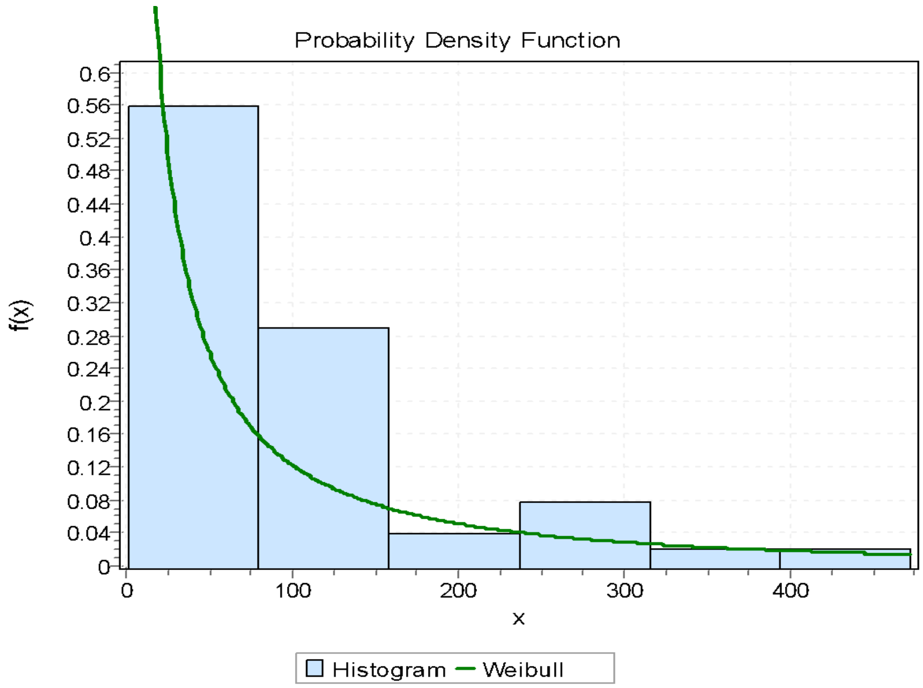

Figure 3: Probability Density Plot of Weibull Distribution

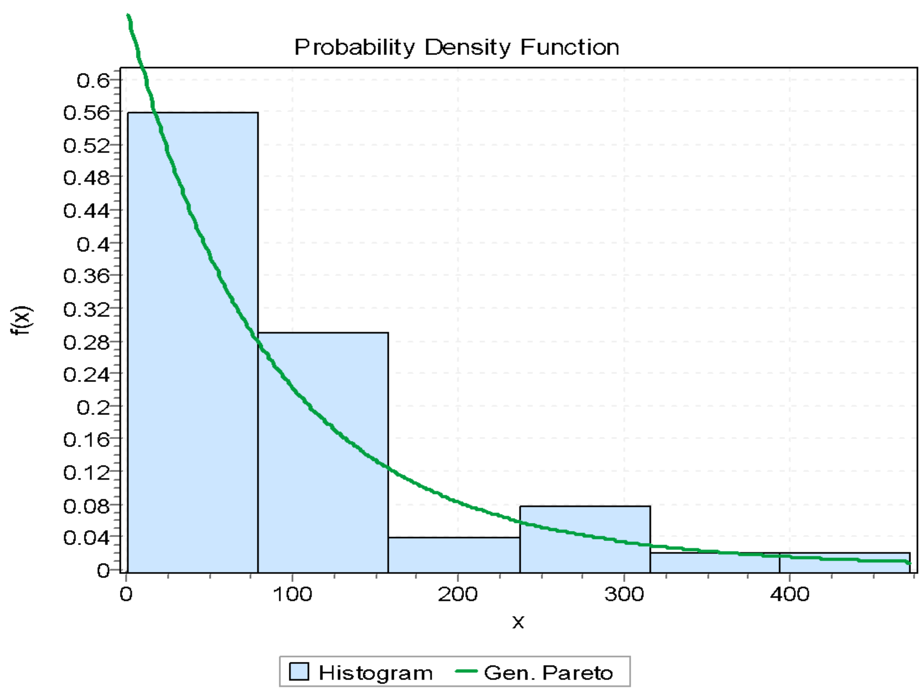

Figure 4: Probability Density Plot of Generalized Pareto Distribution

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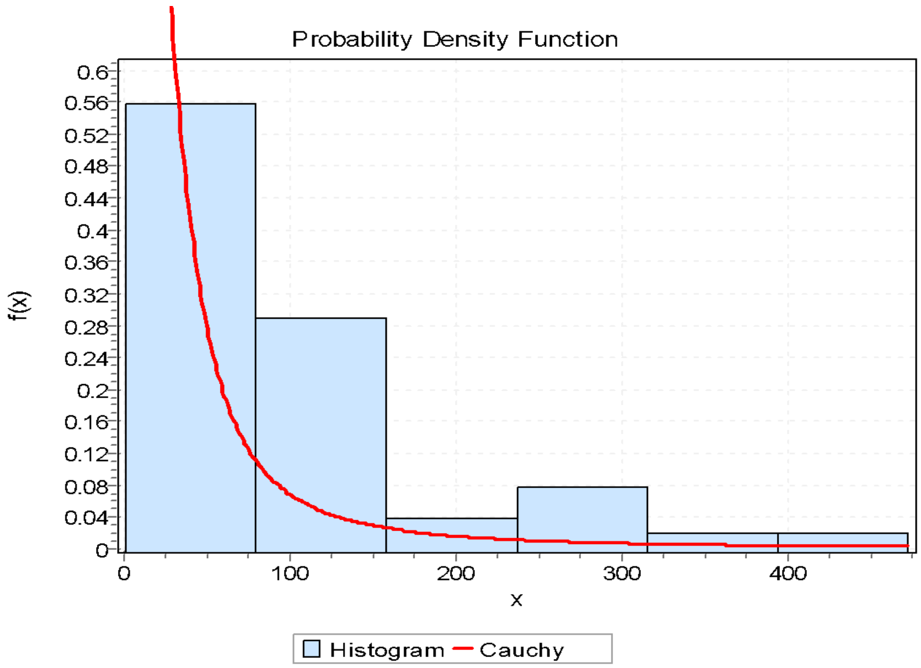

Figure 5: Probability Density Plot of Cauchy Distribution

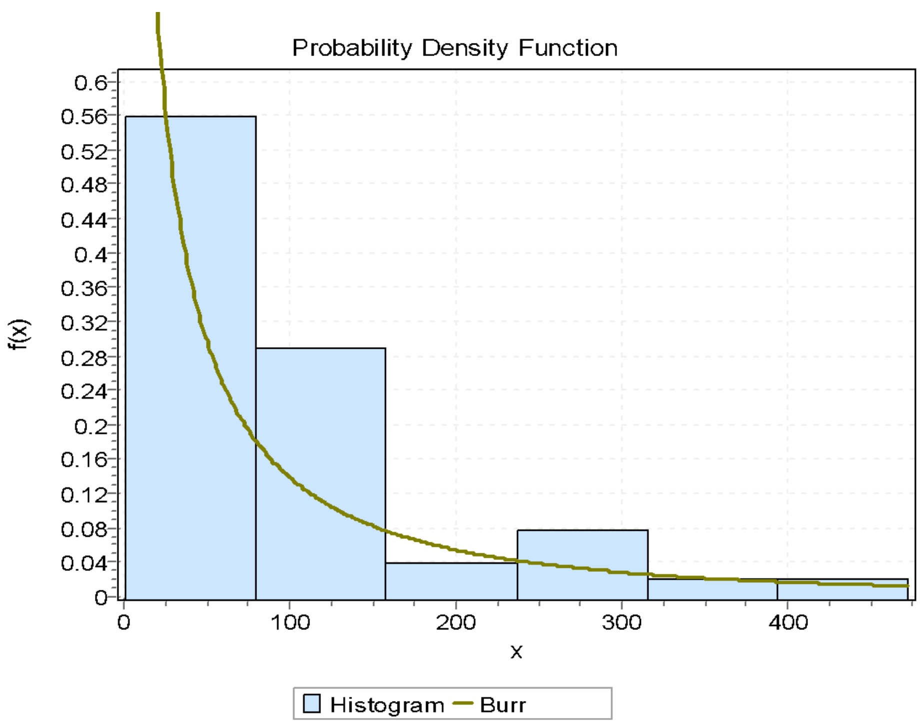

Figure 6: Probability Density Plot of Burr Distribution

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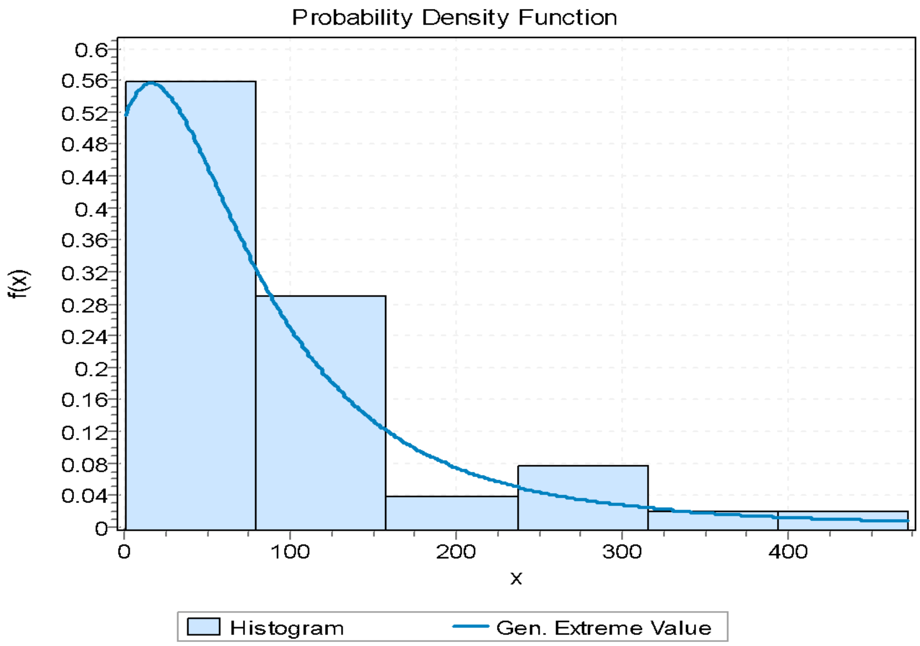

Figure 7: Probability Density Plot of Generalized Extreme Value Distribution

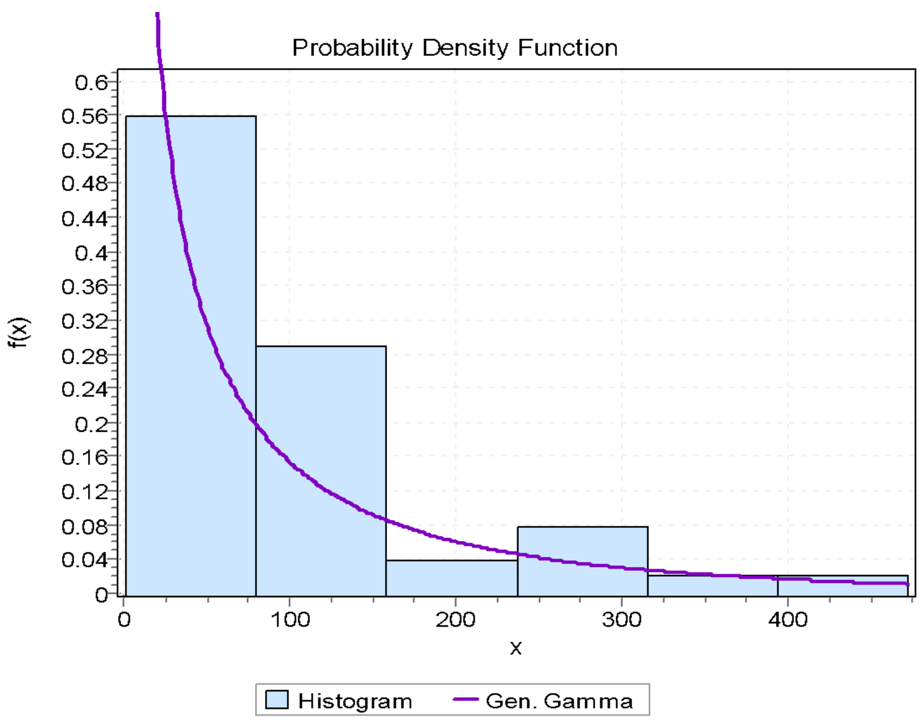

Figure 8: Probability Density Plot of Generalized Gamma Distribution

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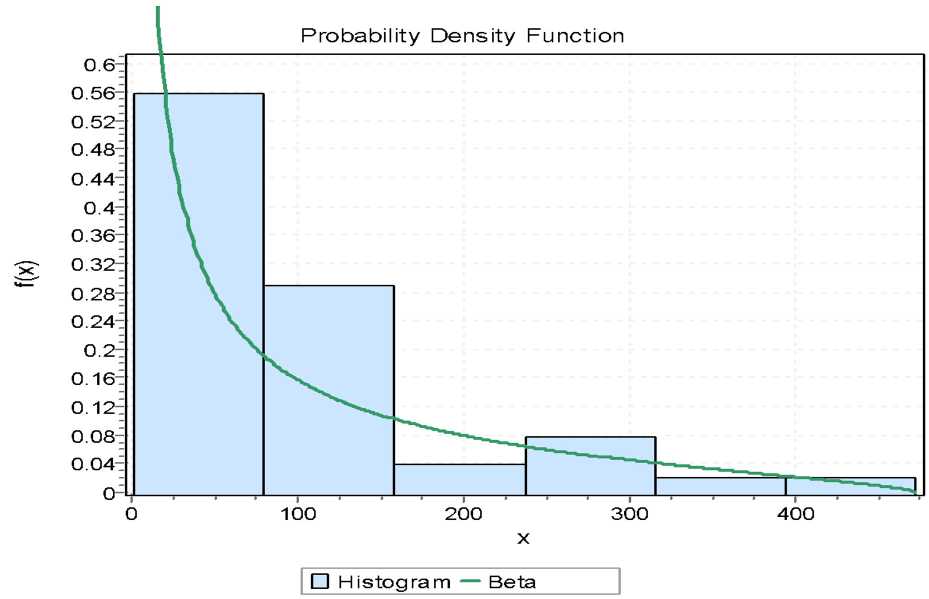

Figure 9: Probability Density Plot of Beta Distribution

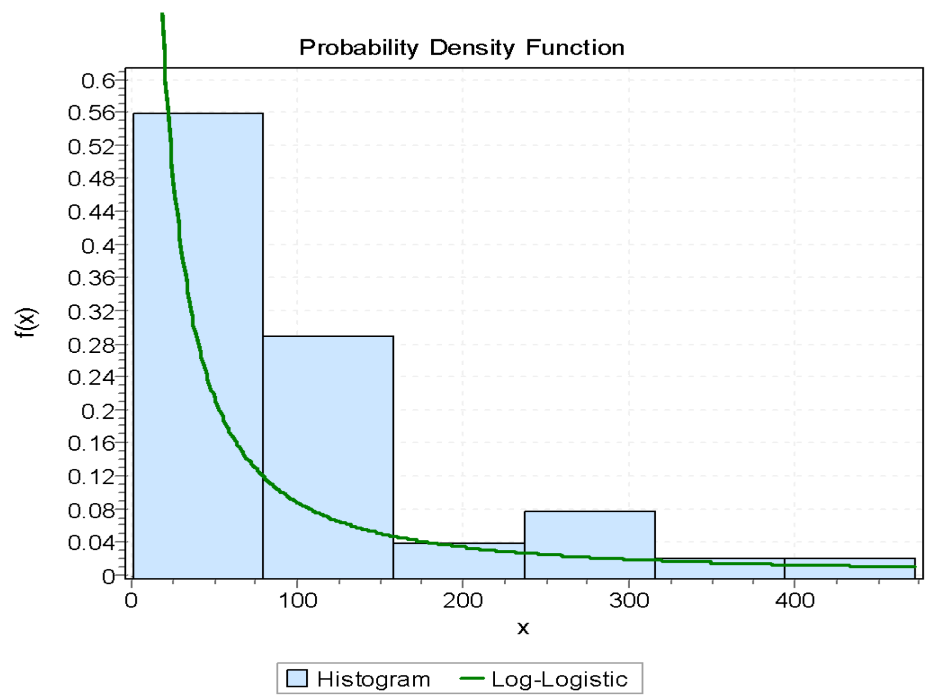

Figure 10: Probability Density Plot of Log-Logistic Distribution

Figure 1 to Figure 10 show the probability density function graphs of the fitted probability distributions to the exchange rate fluctuation in Nigeria.

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DISCUSSION OF FINDINGS

Based on the analysis of this study, the following notable findings were deduced:

The average exchange rate for Nigeria throughout the period under consideration (1970 to 2021) is around 87 Naira per dollar, with a variability of approximately 111 Naira per dollar. This high amount of variation or variability in Nigeria's currency rate is shown in Table 1. The range of the dollar to Naira exchange rate in Nigeria is approximately 472, which is in line with the current bank rate.

Table 2 demonstrates that the Fatigue Life (3P) has greater log-likelihood values than the Weibull (3P), Weibull, Gen. Pareto, Cauchy, Burr, Gen. Extreme Value, Gen. Gamma, Beta, and Log-Logistic distributions. In a similar vein, we can see that, when compared to the other distributions, Fatigue Life (3P) has the lowest Akaike information criterion (AIC). According to this, the Fatigue Life (3P) outperforms the other probability distributions that were fitted to the exchange rate in Nigeria.

Besides, the probability density function graphs of the fitted probability distributions to the exchange rate fluctuation in Nigeria are shown in Figures 1 through Figure 10.

CONCLUSION

Exchange rate fluctuation in Nigeria has resulted in depreciation in the value of the Naira when compared to the other currencies. This study emphasizes probability distribution modelling of exchange rate fluctuation in Nigeria as previous works have only demonstrated probability modelling on pollutant data. As shown in the result and discussion above, we can see that the Fatigue Life (3P) distribution is a better alternative to the other distributions. The graph of the probability density function and Chi-square goodness of fit statistics show that the probability distributions fit the exchange rate data. Meanwhile, the log-likelihood value and the AIC show that Fatigue Life (3P) distribution is best done compared with fitted probability models. Hence, the Fatigue Life (3P) distribution is a unified probability distribution for modelling the exchange rate in Nigeria.

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