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# Copula Analysis of Dependencies Between Extreme Exchange Rates and NSE20 Price Index

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**Abstract:** Exchange rates within an economy affect international trade as they influence the price of goods and services sourced from another country and the attractiveness of the local produce to international consumers. This brings forth an interdependence relationship between exchange rates and market value of share products listed in Security Exchange Markets. This study evaluates the dependence structure between extreme exchange rates of the Kenyan Shilling against the US Dollar and the Nairobi Securities 20 price index using archimedean copulas. The Peak Over Threshold method was used to determine extreme values of the daily log returns of the KSH/USD exchange rate whose dependence structure was analyzed against the NSE20 price index. Parameter Estimation was via the Maximum log-Likelihood Estimation technique. Descriptive statistics showed that the minimum and maximum Ksh/Usd exchange rates were at Ksh. 79.44 and Ksh. 116.07 respectively. The highest NSE 20 price index was at Ksh.5500 with the lowest value of Ksh. 1724. This study found a negative correlation between Ksh/Usd extreme exchange rate data and the NSE20 price index. The Clayton copula was found as the best archimedean copula in modeling the dependence structure as it had the lowest standard error and a parameter estimate close to zero.

**Keywords:** Extreme Value, Copula Analysis, Exchange Rates, NSE20 Price Index, Clayton Copula, Archimedean Copula

## 1. Introduction

According to the Oxford dictionary, the exchange rate is defined as the value of one country's currency converted in terms of another country's currency. Over the years we have observed improved technology the most significant advancement been the internet which is leading to the evolution of E-commerce, an essential part for most business recently been online presence. This has made the foreign exchange market even more important as businesses are competing at global level. In the recent decades we have also noted increased volatility of the financial market this is influenced by the changing dynamics of economic performance, political stability and terms of trade across different countries. Foreign exchange markets have been on the increase across the years, in April 1998 it averaged to USD 1.5 trillion per day and had risen to USD 5 trillion in April 2016 we also note a further increase to USD 6.6 trillion in April 2019, [1]. Risk management is thus a very important area of research for financial regulators, co-operations, organizations and business that are involved in trade at global level [2].

The (NSE20) Nairobi Securities Exchange 20 Share Index is a benchmark that tracks the performance of best performing listed companies in the Nairobi Stock Exchange. It represents the geometric mean of share prices of the NSE's 20 top stocks. It was introduced in 1964 and later in February 2006 the NSE All Share Index (NASI) was introduced that looks at the total market value of all the stocks traded in a day.

This study focused on analyzing the relationship between the extreme currency exchange rate relative to the extreme mean NSE 20 index of stocks and securities traded at the Nairobi Securities Exchange market. The study used the data of the USD/KSH exchange rates and NSE 20 price index during the period June 2010 to May 2022. Extreme value theory and Copula analysis were used for the analysis.

*Motivation for the Study*

The stock market provides platforms for government and organizations to raise funds that result in growth, It thus plays a big role in promoting the growth of a country's economy. Investors keep track of the stock market performance to make informed decisions on whether and when to invest [3, 4]. This makes this area of study very important, but a look into different studies that have been done in Kenya on the effect of exchange rate volatility against stock exchange showed that contraction has been on normal exchange rates time series data thus there is a gap in the study of the effect of extreme exchange rate returns on NSE stock exchange.

The findings from this study will be used by the government to come up with policies that influence macroeconomic aggregate impacting exchange rates to influence GDP and country development. Investors will also benefit from this as they will be able to make informed decisions on how to trade even when volatility is at an extreme level.

# 2. Literature Review

A study was done that modeled production efficiency and greenhouse gas objectives of dairy farms using copula models [5]. They attributed that correlations among multiple variables must be considered in reliably assessing risks of improving the environmental performances of farms. The conventional dairy farms data survey in France was used to describe the relationship among farm characteristics, the characteristics they considered were dry forage production, greenhouse gas that was emitted and milk production. The copula models identified the farm characteristics joint distributions in estimating probabilities of reaching the goal in milk production or not exceeding the regulated greenhouse gas emission limit this was modeled as a function of forage production which farmers make trade-offs.

The dependence between extreme prices of selected agricultural products on the derivative market was modeled using the linkage function [6]. They selected 3 products (Corn, soybean and wheat). They analyzed the dependency between extreme price values on the selected futures, this was done using five models of two-dimensional extreme value copulas; the Husler Reiss copula, the Galambos copula, the Gumbel copula, the t-EV copula and the Tawn asymmetric copula. They assessed the correlation of the different copulas using Kendall coefficients. From the research they determined that Copulas can sufficiently assess returns on agricultural products.

Gree Electric and Midea Group daily return data were analysed using copula theory [7]. The dependence of the stock risk was analyzed using copula theory by establishing the correlation structure model of the stock market and they were found to be better simulated. The results showed that the binary Gaussian Copula function and the binary t -Copula function can simulate the daily return data of the stock market very well.

Kamal and Hague [8] analyzed the dependence structure between the stock market and foreign exchange in South Asia. They used the Copula-Garch approach from this the correlation was computed using Kendall's tau and Spearman's rho which revealed the presence of a linear dependence. Copula functions were applied to obtain marginal distributions of stationary uni-variate daily return series. The fitted copula models indicated the existence of asymmetric dependence that had upper tail dependence for all pairs in the markets. They established that Copula-based dependence measures can be used by foreign investors and countries to come up with strategies and policies that lead to maximization of utility.

# 3. Research Methodology

### 3.1. Study Area and Data

The area of study is Kenya, which is a country located in the continent of Africa particularly in East Africa. The data used was obtained from the Central bank of kenya portal https://www.centralbank.go.ke on monthly average USD/KSH exchange rates value from 2010 to 2022 and the NSE 20 shares price index for the same period.

### 3.2. Extreme Value Theory Modeling

This study used the Extreme value theory to assess the extreme deviations from the median of probability distributions for exchange rates in Kenya. The foundations of the Extreme Value theory were set by Fisher and Tipett (1928) [9], who proved that the distribution of the extreme values of an independent and identically distributed sample from a cumulative distribution function $F$, when adequately rescaled has been shown to converge to Frechet, Negative Weibull or Gumbel family of distributions.

Two main approaches have been pointed out in determining extreme values in real data. These approaches are Block Maxima which considers the maximum/minimum values that a variable takes over successive periods of identical length blocks, The second approach is Peaks over Threshold (POT) which focuses on events exceeding a given level. This study used the POT approach, which relies on the Generalized Pareto Distribution to analyze dependence structure between foreign exchange rates and NSE 20 price index.

#### 3.2.1. Peak Over Threshold (POT) Model

The Fisher-Tippet [9] theorem, the Balkema De Haan results [10] and Pickands [11] are the foundations for the Peak Over Threshold model in which exceedances over a high level $u$ can be estimated using Generalized Pareto Distribution. This study considered a POT model composed of a Poisson process for the number of events above the obtained threshold. The dispersion index and the Chi-Square tests were used to check the adequacy of the used distribution function for modeling exchange rates.

Let $Y_n$ be a sequence of iid (independent, identically distributed) random variables with marginal distribution $F$, an interest is in estimating the distribution function $F_u$ of values of $Y$ that exceed a certain threshold $u$. The distribution function $F_u$ is the conditional excess distribution function and is defined as;

$$F_u(y) = P(Y - u \leq x/y > u), \;\; 0 \leq x \leq y_F - u \quad (1)$$

where $u$ is a given threshold, $x = y - u$ is termed the excess and $y_F \leq \infty$ is the right endpoint of the distribution function $F$. The conditional excess distribution function $F_u$ represents the probability that the value of $Y$ exceeds the threshold by at least a quantity $X$ given that $Y$ exceeds the threshold $u$.

This conditional probability is given as;

$$\begin{aligned} F_u(x) &= \frac{F(u+x) - F(u)}{1 - F(u)} \\ &= \frac{F(y) - F(u)}{1 - F(u)} \end{aligned} \quad (2)$$

with the majority of the values of the random variable $Y$ lies between 0 and $u$ thus aiding in the estimation of $F_u$.

#### *3.2.2. Threshold Determination (Mean Residual Life Plot)*

The main objective of threshold selection is to ensure we select enough events that reduce the variance but also ensure that they are not too much such that we pick events coming from the central part of the distribution thus inducing bias.

Note that the mean residual life plot has been shown to be founded on the theoretical mean of the Generalized Pareto Distribution. Let $X$ be a random variable distributed as GPD $(u, \sigma, \xi)$. Then, theoretically, we have;

$$E(X) = u + \frac{\sigma}{1 - \xi} \quad \text{for} \;\; \xi < 1 \quad (3)$$

when $\xi \geq 1$, the theoretical mean is infinite. In practice, if $X$ represents excess over a threshold $u_0$ and if approximation by a GPD is good enough, we have;

$$E(X - u_0/X > u_0) = \frac{\sigma_{u_0}}{1 - \xi} \quad (4)$$

For all new threshold $u_1$ such that $u_1 > u_0$, excesses above the new threshold are also approximate by a GPD with updated parameters. Thus;

$$E(X - u_1/X > u_1) = \frac{\sigma_{u_1}}{1 - \xi} = \frac{\sigma_{u_0} + \xi_{u_1}}{1 - \xi} \quad (5)$$

The quantity $E(X - u_1/X > u_1)$ is linear in $u_1$ or is simply the mean of excesses above the threshold $u_1$ which can easily be estimated using the empirical mean. A mean residual life plot consists in representing points;

$$\left\{ \left( u, \frac{1}{n_u} \sum_{i=1}^{n_u} x_{i,n_u} - u \right); u \leq x_{max} \right\} \quad (6)$$

where $n_u$ is the number of observations $X$ above the threshold $u$, $x_{i,n_u}$ is the $i^{th}$ observation above the threshold $u$ and $x_{max}$ is the maximum of the observation $x$. Confidence intervals can be added to this plot as the empirical mean can be supposed to be normally distributed.

### *3.3. Dependence Structure Modeling*

In order to study the dependence structure analysis of exchange rates, the study used copulas which were first introduced by Sklar 1959 [12]. For this purpose, a copula is a multivariate cumulative distribution function where by the marginal probability distribution for each variable is uniform on the interval [0, 1]. In probabilistic terms, $C : [0,1]^d \rightarrow [0,1]$ is a d-dimensional copula when C is a joint cumulative distribution function of a random vector with d-dimensions on the unit cube $[0,1]^d$ with uniform marginals. In analytic terms, $C : [0,1]^d \rightarrow [0,1]$ is a d-dimensional copula if $C(u_1, \ldots, u_{i-1}, 0, u_{i+1,\ldots,u_d)=0}$, the copula is zero if any one of the arguments is zero,$C(1, \ldots, 1, u, 1, \ldots, 1) = u$ the copula is equal to u if one argument is u and all others 1. C is d-non-decreasing, i.e., for each hyper-rectangle $B = \prod_{i=1}^{d} [x_i, y_i] \subseteq [0,1]^d$ the C-volume of B is non-negative;

$$\int_B \mathrm{d}C(u) = \sum_{\mathbf{z} \in \prod_{i=1}^{d} \{x_i, y_i\}} (-1)^{N(\mathbf{z})} C(\mathbf{z}) \geq 0 \quad (7)$$

where the $N(\mathbf{z}) = \#\{k : z_k = x_k\}\}$

#### *3.3.1. Archimedean Copula Analysis*

Archimedean copulas were chosen as they have shown to be of diverse copula structures which gives them much flexibility for modeling different kinds of data sets [13]. The Archimedean copulas chosen for this case are Gumbel Copula, Frank Copula and Clayton Copula. Also, when models are constructed using Archimedean copulas the resulting expression of the log-likelihood facilitate maximum likelihood estimation thus a good model for estimation of dependency [14]. The three were also considered because they also cater for tail dependences.

***(i). Gumbel Copula***

This an asymmetric archimedean copula with a greater dependence in the positive tail and is given by;

$$C_n(u, v) = exp\left( - \left[ (-ln\ u)^n + (-ln\ v)^n \right]^{\frac{1}{n}} \right) \quad (8)$$

and its generator is given by;

$$\beta_n(t) = (-ln\ t)^n \quad \text{where} \quad n \in [1, \infty)$$

The $n$ parameter of this copula is related to the Kendall's tau $\tau$ as;

$$\hat{n} = \frac{1}{1 - \tau} \quad (9)$$

***(ii). Frank Copula***

This is a symmetric archimedean copula defined as;

$$C_n(u,v) = -\frac{1}{n} ln\left(1 + \frac{(e^{-nu}-1)(e^{-nv}-1)}{(e^{-n}-1)}\right) \tag{10}$$

and its generator is;

$$\beta_n(t) = -ln\left(\frac{exp(-nt)-1}{exp(-n)-1}\right) \quad \text{where} \quad n \in (-\infty,\infty) \setminus (0)$$

The $n$ parameter of this copula is related to the Kendall's tau $\tau$ as;

$$\tau = 1 + \frac{4}{\theta}(D_1(n)-1) \quad \text{where} \quad D_1(n) = \frac{1}{n}\int_0^n \frac{t}{e^t-1}dt \tag{11}$$

***(iii). Clayton Copula***

This is an asymmetric archimedean copula that exhibits greater negative tail dependence. It is given by;

$$C_n(u,v) = max\left(\left[u^{-n}+v^{-n}-1\right]^{-\frac{1}{n}}, 0\right) \tag{12}$$

and its generator is;

$$\beta_n(t) = \frac{1}{n}(t^{-n}-1) \quad \text{where} \quad n \in [-1,\infty) \setminus (0)$$

The $n$ parameter of this copula is related to the Kendall's tau $\tau$ as;

$$\hat{n} = \frac{2\tau}{1-\tau} \tag{13}$$

### *3.3.2. Copula Estimation and Selection*

For copula parameter estimation, we define a vector of two random variables $(X,Y)$ with joint distribution $H$ and marginal distributions $F$ and $G$ respectively. Each marginal distribution depends only on the parameter $\phi_i$ for $\phi = (\phi_1,\phi_2,\theta)$ where $\theta$ is the vector of parameters for the copula $\{ C_\theta, \theta \in \Theta \}$. $C_\theta$ is completely known except for the parameter $\theta$ hence by Sklar's theorem [12];

$$H(x,y) = C\left(F(x;\phi_1), G(y;\phi_2);\theta\right) \tag{14}$$

thus the joint distribution function $H$ is completely specified by the parameter vector $\phi = (\phi_1,\phi_2,\theta)$.

In order to obtain the density function $h$, we defined $f$ and $g$ as density functions associated with the marginal distributions $F$ and $G$ and differentiated to obtain;

$$h(x,y) = c\left(F(x),G(y)\right) f(x)g(y) \tag{15}$$

where $c$ is the copula density defined as;

$$c(u,v) = \frac{\partial^2 c(u,v)}{\partial u \partial v} \tag{16}$$

Based on this copula density, the log-likelihood function is;

$$l(\phi) = \int_{t=1}^{T} ln\, c\left(F(x,t;\phi_1), G(y,t;\phi_2),\theta\right) + \int_{t=1}^{T} \left(in\, f(x,t;\phi_1) + ln\, g(y,t;\phi_2)\right) \tag{17}$$

in which the maximum likelihood estimator that maximizes the above log-likelihood is given as;

$$\hat{\theta} = \arg\max_\theta l(\theta) \tag{18}$$

The Akaike Information Criteria was used in selecting the best copula. Letting $M$ to be the number of parameters being estimated and $ln(\hat{L})$ the maximized log-likelihood value, the AIC values were obtained as;

$$AIC(M) = -2\,ln\,(\hat{L}) + 2M \tag{19}$$

for which smaller AIC values indicated better fit.

## *3.4. Goodness of Fit*

The Cramer-von Mises test was used to test for goodness of fit of the extreme value copulas models. This is a non-parametric test for testing a hypothesis $H_0$ which states that independent and identically-distributed random variables $Y_1, Y_2, \ldots, Y_n$ have a given continuous distribution function $F(y)$. The Cramer¨Cvon Mises test is based on a statistic of the type

$$\omega_n^2\left[\Psi(F(y))\right] = \int_{-\infty}^{+\infty} (\sqrt{n}F_n(y)F(y))^2\Psi(F(y))dF(y) \tag{20}$$

where $F_n(y)$ is the empirical distribution function constructed from the sample $Y_1, Y_2, \ldots, Y_n$ and $\Psi(t)$ is a certain non-negative function which is defined on the interval $[0,1]$ such that $\Psi(t), t\Psi(t)$ and $t^2\Psi(t)$ can be integrated on $[0,1]$.

This kind of tests, based on the "square metric" , were first considered by H. Cramer [15] and R. von Mises [16]. N. V. Smirnov [17] proposed putting $\Psi(t) \equiv 1$, and showed that in that case, if the hypothesis $H_0$ is valid and $n \to [\infty]$, the statistic $\omega^2 = \omega_n^2$ has in the limit an ”omega-squared” distribution which is independent of the hypothetical distribution function $F(y)$. A statistical test for testing $H_0$ based on the statistic $\omega_n^2$, is called an $\omega^2$( Cramer von Mises Smirnov) test, and the numerical value of $\omega_n^2$ is found using the following representation;

$$\omega_n^2 = \frac{1}{12n} + \sum_{j=1}^{n} \left[ F(Y_{(j)} - \frac{2j-1}{2n} \right]^2 \tag{21}$$

where $Y_{(1)} \leq ... \leq Y_{(n)}$ is the variational series based on the sample $Y_1...Y_n$. According to the $\omega^2$ test with significance level $\alpha$, the hypothesis $H_0$ is rejected whenever $\omega_n^2 \geq \omega_\alpha^2$, where $\omega_\alpha^2$ is the upper $\alpha-$ quantile of the distribution of $\omega_n^2$, i.e.$P[\omega^2 < \omega_\alpha^2] = 1 - \alpha$.

# 4. Results and Discussions

## 4.1. Descriptive Statistics

The data descriptive statistics were used to give a pre-analysis of the Ksh/Usd exchange rates and the NSE 20 price index. Table 1 gave the descriptive statistics of the data in which the mean exchange rates and the mean all share price index were estimated at Ksh. 97.08 and Ksh. 3,675 with a respective median of Ksh. 101.03 and Ksh. 3,711 respectively. The maximum and minimum NSE 20 price index were Ksh. 5,500 and Ksh. 1724 with a first and third quantile of Ksh. 3,043 and Ksh. 4,397 respectively . For the exchange rates, this were ksh. 116.07, Ksh. 79.44, Ksh. 86.99 and Ksh. 103.36 respectively.

***Table 1.*** *NSE 20 Index and Exchange Rates Descriptive Statistics.*

| | Min | First Q | Median | Mean | Third Q | Max |
|---|---|---|---|---|---|---|
| KSH/USD Exchange Rate | 79.44 | 86.99 | 101.03 | 97.08 | 103.36 | 116.07 |
| NSE 20 Price Index | 1724 | 3043 | 3711 | 3675 | 4397 | 5500 |

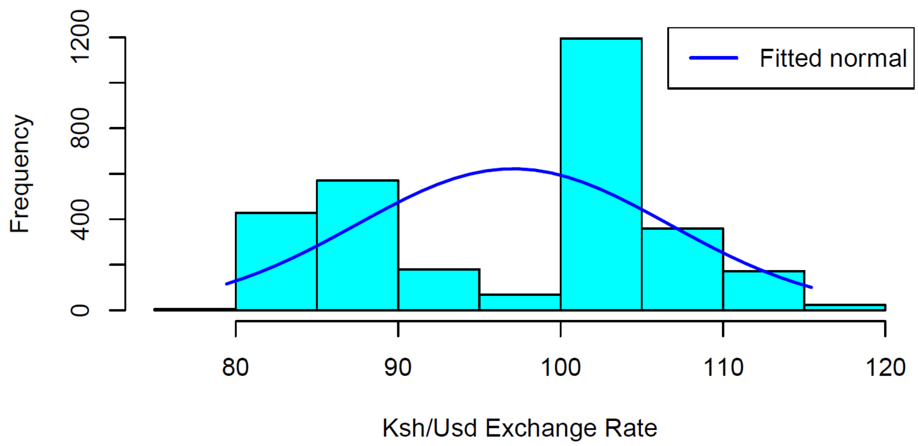


***Figure 1.*** *Histogram of Exchange Rate Data.*

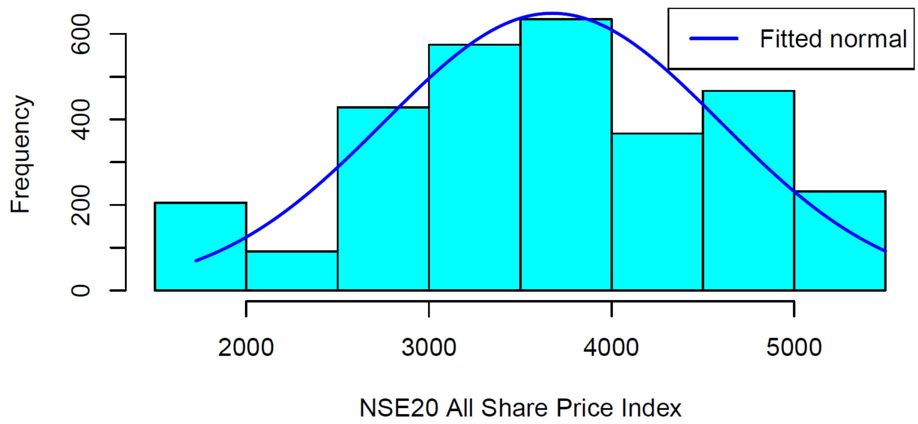


***Figure 2.*** *Histogram of NSE 20 Price Index.*

Figures 1 and 2 above gave a respective graphical representation of the Ksh/Usd exchange rates and NSE 20 price index data. The mean NSE 20 price index and Ksh/Usd exchange rates were smaller than the median NSE 20 price index and Ksh/Usd exchange rates which gave an indication of majority of the datapoints being to the right of the mean value. This was attributed to the demeanishing value of the Kenyan Shilling to the American dollar thus high inflation rates over time as confirmed by a higher Third Quartiles compared to First Quartiles of the study data.

*NSE 20 Price Index and Exchange Rates Time Series* This study used a time series plot as a data visualization tool to illustrate the NSE 20 price index and the Ksh/Usd exchange rates data points at successive time periods in years. Each point in Figures 3 and 4 corresponds to a point in time with the respective value of the Ksh/Usd exchange rate and NSE 20 price index respectively.

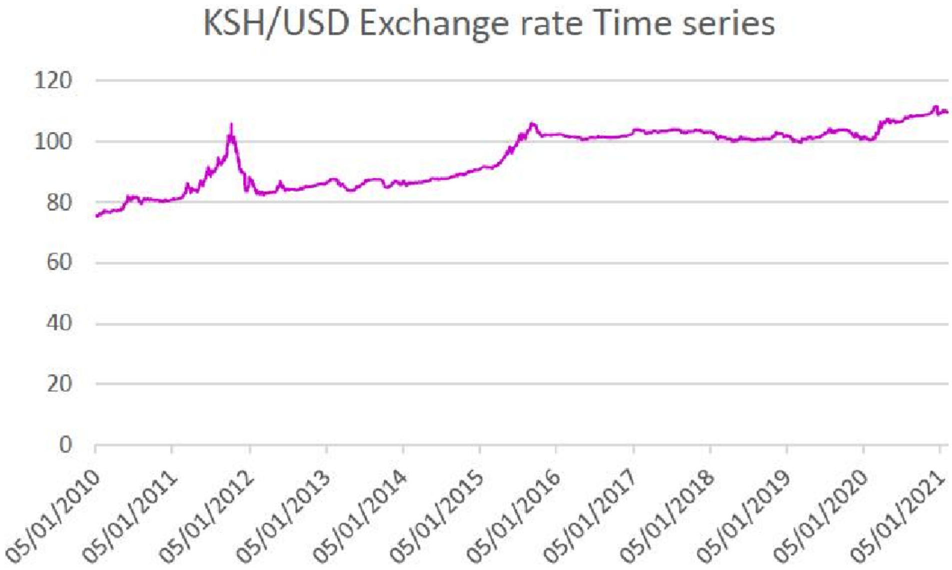


***Figure 3.*** *KSH/USD Exchange Rates Time Series.*


***Figure 4.*** *NSE 20 Price Time Series.*

### *4.2. Extreme Value Analysis of Ksh/Usd Exchange Rates*

In the analysis of extreme value copula analysis of dependencies between exchange rates and NSE 20 price index, the study aimed to first determine the threshold using the mean residual plot and parameter stability plots. An estimate of model parameters was obtained and model fit plots with respective trace plots, for this case the daily returns were modelled to determine extreme values.

#### *4.2.1. Mean Residual Life Plot*

To select a threshold for the extreme value distribution for this study, the mean residual life plot was first used as given in Figure 5 for the Ksh/Usd exchange rates. The choice of an appropriate threshold for this study required a compromise between the model precision and bias as a low threshold would tend to make the results more certain than when it is high and our extreme value method would only become approximately valid once the threshold is sufficiently high. The mean residual life plot was assumed to be linear above the threshold at which the study extreme value model becomes valid.

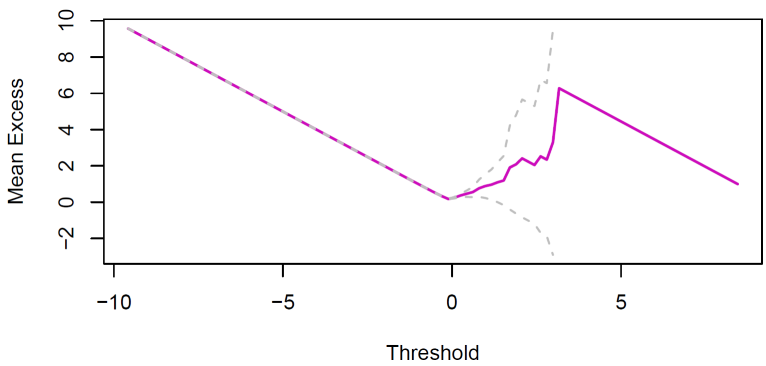


***Figure 5.*** *KSH/USD Exchange Rates Mean Residual Life Plot.*

The parameter stability plot was also in threshold determination for which the study extreme value parameters were plotted against a range of values of $u$ as in Figure 6 The parameter estimates were assumed to be stable above the threshold at which the study extreme value model becomes valid. Confidence intervals were included so as to evaluate the linearity of the plots after accounting for the effects of estimation uncertainty. From this the daily return threshold was established to be at 0.5.

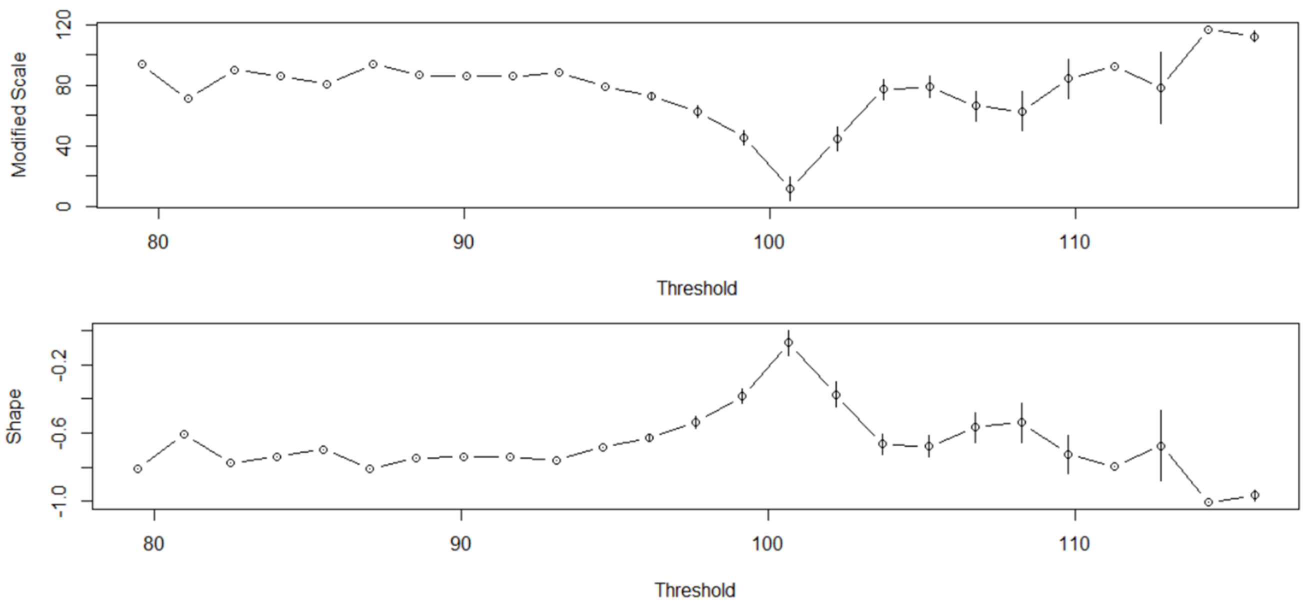


***Figure 6.*** *Ksh/Usd Exchange Rate Parameter stability plot.*

#### *4.2.2. Fitted POT Model Parameters*

The Peak Over Threshold was used to analyze the values that deviated from the mean of the full data for the Ksh/Usd exchange rates as given in Table 2.

***Table 2.*** *Ksh/Usd Exchange rates EVT Model Parameters.*

| | Location | Scale | Shape |
|---|---|---|---|
| Parameter Estimate | 94.4238 | 10.1685 | -0.4421 |
| Std Error | 0.2028 | 0.1548 | 0.0120 |

### *4.3. Dependence Structure Modeling*

For the dependence structure analysis between Ksh/Usd Exchange rates and the NSE 20 price index, the Gumbel, Frank and Clayton copulas were used. For this case all the extreme exchange rates with daily return greater than 0.5 were pulled and classified as the extreme values, then this was modelled against the NSE-20 for those periods using copula analysis.

***Table 3.*** *Copula Models for NSE 20 Index and Extreme Exchange Rates Data.*

| | Alpha | Std Error | Log-Likelihood | Tau |
|---|---|---|---|---|
| Gumbel | 1.0000 | 0.222 | -0.00002321 | 0.2857 |
| Frank | -2.138 | 0.1160 | 169.8000 | 0.1526 |
| Clayton | -0.1092 | 0.009 | 36.8600 | 0.4118 |

The Gumbel copula had the lowest log-lokelihood of -0.00002321 compared to that of the Frank and Clayton copulas which was 169.8 and 36.86 respectively. The tau coefficients were 0.2857, 0.1526 and 0.4118 for the Gumbel, Frank and Clayton copulas respectively. The copula parameter value was 1.00 for the Gumbel copula, -2.138 for the Frank copula and -0.1092 for the Clayton Copula. The Clayton copula had the lowest standard error which made it a copula of choice in modeling dependence structure for this study given in table 3.

For the extreme exchange rate dependence with the NSE20 price index, the correlation coefficient was estimated at -0.1092 with a kendalls tau of 0.4118 as is shown in 3 This showed that a unit increase in the daily returns of extreme Ksh/Usd exchange rates for which maximums were obtained, would result into a 0.1092 unit decrease of the NSE20 price index in Kenya.

Dependence for the Ksh/Usd exchange rate data and the NSE20 price index for normal data was also evaluated. The graphical representation is given as in Figure 7 for the pair plot respectively for the Ksh/Usd exchange rate data and the NSE20 price index. The correlation coefficient was estimated at -0.3281 with a p-value of 0.0001. From the correlation coefficient, a unit increase in the Ksh/Usd exchange rate would result into a 0.33 unit decrease of the NSE20 price index in Kenya. This showed that a deterioration of the Kenyan shilling in value would negatively affect the price of the NSE20 index at the Nairobi Securities Exchange market.

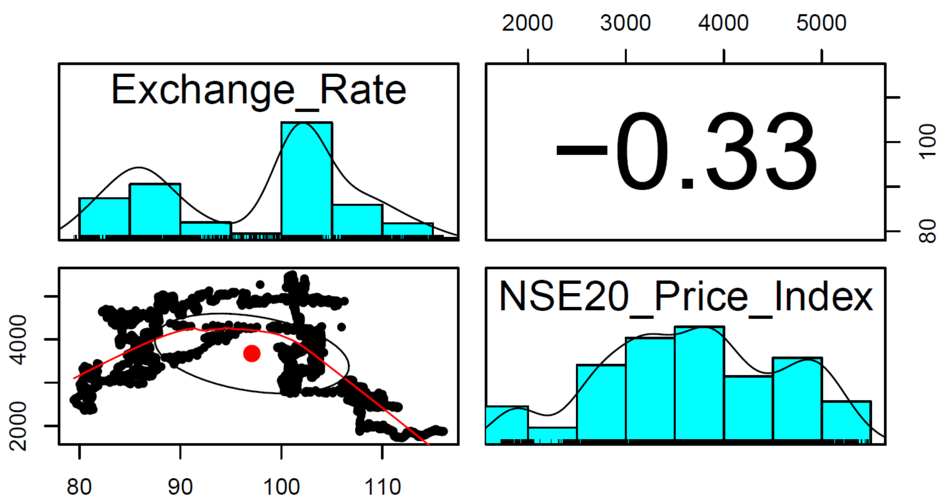


***Figure 7.*** *NSE 20 Index and Exchange Rates PairPlot.*

### *4.4. Goodness of Fit Measures*

#### *4.4.1. Peak over Threshold Modeling*

In order to analyze the goodness of fit of the peak over threshold method in modeling extreme exchange rates in Kenya, the model diagnostic plots were used. In assessing whether the model fit sample and the empirical model sample came from the same distribution, the probability plot was used in which the data points lied in a straight line giving an indication of goodness of fit of the Peak Over Threshold method in modeling extreme exchange rates in Kenya Figure 8.

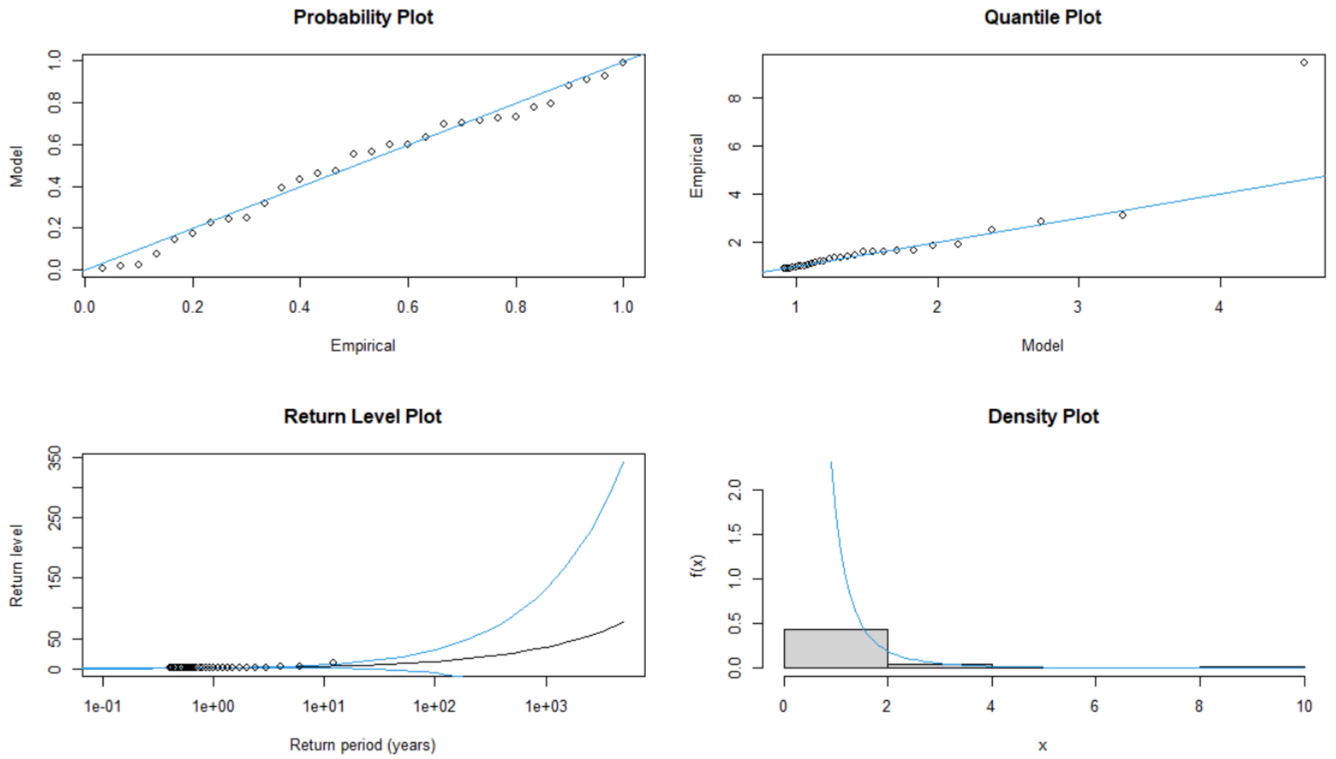


***Figure 8.*** *Ksh/Usd Exchange Rates POT Diagnostic Plot.*

#### ***4.4.2. Dependence Structure Modeling***

For diagnostic analysis of the fitted models in analyzing the dependence structure, the Cramer Von Mises test was used. The test results were given as in Table 4 for which ties were assumed to be true. The Clayton copulas had a respective X-statistic of 5.6041 with associated parameter values of -0.34273. The P-value for the copula was estimated at 0.001661. This shows that Clayton copula fits as a model to use.

***Table 4.*** *Cramer-von Mises Test Results.*

| | X-Statistic | Parameter | P-Value |
|---|---|---|---|
| Clayton | 5.6041 | -0.34273 | 0.001661 |

## 5. Conclusion

The Peak Over Threshold was evaluated as a model of good fit in the analysis of extreme Ksh/Usd exchange rates. The Clayton Copula model was selected as a copula of good fit in modeling the dependence structure as it had the lowest standard error value of 0.009 with a parameter value close to zero. This study thus concludes that copula models and extreme value methods can be used to analyze the dependence structure between the extreme Ksh/Usd exchange rate and the NSE 20 price index, this has also been shown by other studies done [18, 19]

From the study we note that extreme exchange rate daily returns have a negative effect on NSE20 price index by 0.1092 which is lower than for normal data with a correlation coefficient of -0.33. From this we can deduce that a consistent decrease of the KSH/USD exchange rate has more impact on NSE20 price index than the sudden extreme daily changes. Government should work towards coming up with policies that ensure overall good performance of KSH/USD exchange rate overtime to maintain good performance of the country and input more confidence to the investors. Additionally when sudden big change in KSH/USD exchange rate is realised government/policy makers should act fast to counter this effect.

Investors can use information deduced from this study for better planning on how to invest as it reduces fear of investing during the sudden extreme exchange rate periods and thus focus should be on observing the overall trend.

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