EXCHANGE MARKET PRESSURE IN SOUTH AFRICA AND KENYA: AN ANALYSIS USING EXTREME VALUE THEORY

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DEDICATION

This thesis is dedicated to my brother Rory Boer. Thank you for always being so loveable and such an enormous inspiration to me and my family. I love you very much.

Down syndrome was an unplanned journey but we love our tour guide!

But if anyone has the world's goods and sees his brother in need, yet closes his heart against him, how does God's love abide in him? Little children, let us not love in word or talk but in deed and truth

1 John 3:17-18

PREFACE

The work presented herein was made possible by many individuals.

First and foremost, thank you to our Almighty Lord Jesus Christ for making this journey possible and providing me this inspiring topic. My prayers with Ds S. van der Merwe were answered when I struggled to find a suitable topic, thank you Lord.

Thank you for my three supervisors, Prof Munapo, Mr Chanza, Mr Mhlanga for all the help and advice that you graciously offered. Thank you Mr Chanza for our entertaining session's with the statistical package R and for patiently showing me the way forward.

Thank you to my wife, Chandré, for inspiring me to continue my studies in the field that I so passionately love. I love you and Lienke-Mari so very much.

I am also very grateful to my parents and siblings who always inspire, motivate and energise not only in times of success, but also in times of stress or adversity.

Lastly, thank you to the NWU for providing me this opportunity to study at such a well-renowned and successful institution.

ABSTRACT

INTRODUCTION: Extreme value theory (EVT) is a branch of probability statistics applicable to financial data distributed with heavy tails where the distribution is stationary, independent and identically distributed. EVT is important for modelling situations that are rare in frequency but large in magnitude in terms of losses, depreciation or pressure. It is useful in conditions where a currency experiences extreme pressure or crises. Exchange market pressure (EMP) is the selling pressure of domestic currency or excess demand needed for foreign currency and composed of a weighted average of three components (rate-in-change in exchange rate, rate-in-change in interest rate and rate-in-change in reserves-to-narrow money). The objective of EMP is to determine periods of "extreme pressure" or currency crises (periods of successive stress). EMP using EVT has never been explored in African countries. Moreover, a comparison of two peak over threshold methods used in EVT (Generalised Pareto Distribution and Hill estimate) is studied and compared to empirical quantiles for measurement accuracy. In doing so, periods of extreme pressure or crises can be identified. Subsequently, the causes of these unwanted situations can be identified and monitored.

METHODOLOGY: The monthly data of the three components of the EMP index for two African countries (RSA and Kenya) were studied for a period of 19 years (1999-2017). Data was first studied to ensure stationarity and modelled with appropriate ARMA and/or ARCH/GARCH processes to ensure no heteroscedasticity. Once all assumptions were met for further analyses, the EMP index was calculated. Subsequently, the data was modelled using the Generalised Pareto Distribution (GPD) with the Peak over Threshold (POT) method using maximum likelihood estimation. Moreover, the data was also modelled using the non-parametric Hill estimate. Appropriate estimated and empirical quantiles are reported in order to determine periods of extreme pressure or crises. Data analysis was performed in Microsoft Excel (Microsoft, Redmont, United States) and R studio (CRAN, R Core Team, 2017) with associated packages.

RESULTS: The EMP index for both countries revealed stationarity but non-normality. The components of the EMP SA data-set were modelled with appropriate ARMA and/or ARCH/GARCH processes to ensure independent and identically distributed variables. Reliable and accurate estimates were obtained for the scale and shape parameter using the GPD POT method for both countries. Positive shape parameters confirmed generalised extreme value distributions with heavy tails of the Frechet type. Diagnostic plots revealed a good fit for the model. Similarly, accurate and reliable shape estimates were computed using the non-parametric Hill estimator for both countries. Estimated quantiles are provided using both methods. The GPD POT method more closely reflected estimates to the empirical qauntiles compared to the Hill method, especially at higher quantiles. Using, the 95th and 99th quantiles, periods of extreme pressure for each country is identified. In doing so, the respective components of the EMP index is evaluated against the backdrop of periods of extreme pressure or crises. Eight and ten periods of extreme pressure was identified for South Africa and Kenya respectively with no periods of currency crises (p=0.05). All three components of the EMP index played an individual role in the depreciative stress at different periods of pressure.

CONCLUSION: It is feasible to model the EMP data of two African countries with EVT using both peak over threshold estimation methods. However, the Generalised Pareto Distribution's method using maximum likelihood estimation was more accurate compared to the non-parametric, Hill estimate, especially at the 99th or higher percentiles.

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LIST OF ABBREVIATIONS

ADF:	AUGMENTED DICKEY-FULLER TEST
AIC:	AKAIKE INFORMATION CRITERION
ARCH:	AUTOREGRESSIVE CONDITIONAL HETEROSCEDASTICITY
ARMA:	AUTOREGRESSVIE MOVING AVERAGE
BIC	BAYESIAN INFORMATION CRITERION
CDF:	CUMULATIVE DISTRIBUTION FUNCTION
CLT:	CENTRAL LIMIT THEOREM
EMP:	EXCHANGE MARKET PRESSURE
e_t:	RATE-IN-CHANGE IN EXCHANGE RATE
EVT:	EXTREME VALUE THEORY
GARCH:	GENERALISED AUTOREGRESSIVE CONDITIONAL HETEROSCEDSTICITY
GDP:	GROSS DOMESTIC PROFIT
GEV:	GENERALISED EXTREME VALUE
GPD:	GENERALISED PARETO DISTRIBUTION
i_t:	RATE-IN-CHANGE IN INTEREST RATE
iid:	INDEPENDENT AND IDENTICALLY DISTRIBUTED
LIM:	LIMIT
LOG:	LOGARITHM
M1:	BASE OR NARROW MONEY SUPPLY
MLE:	MAXIMUM LIKELIHOOD ESTIMATION
P:	PROBABILITY
PP:	PHILLIPS-PHERON TEST
pp:	PAGES

POT:	PEAK OVER THRESHOLD
R_t:	RATE-IN-CHANGE IN RESERVES TO NARROW MONEY
RSA:	REPUBLIC OF SOUTH AFRICA
SA:	SOUTH AFRICA

LIST OF SYMBOLS

ξ:	XI (SHAPE PARAMETER)
$\sum$:	SUMMATION
μ:	MU (MEAN)
σ:	SIGMA (STANDARD DEVIATION) OR SCALE PARAMETER
%:	PERCENTAGE
$\in$:	ELEMENT
$\mathbb{R}$:	REALS (REAL NUMBERS)
ω:	OMEGA
K:	NUMBER OF OBSERVATIONS ABOVE THE THRESHOLD
N:	TOTAL NUMBER OF OBSERVATIONS IN ENTIRE DATA SET
n:	SUB- NUMBER OF OBSERVATIONS DEFINED FOR A PARTICULAR ANALYSIS
p:	PROBABILITY
Q:	LAGS

CHAPTER ONE: INTRODUCTION

1.1 EXTREME VALUE THEORY

Extreme value theory is a special branch of probability theory adapted to extremal analysis. It deals with the asymptotic behaviour of tail observations (Rocco, 2014). Using two- or three-sigma (σ) in a normal distribution will underestimate the probability of extreme events under heavy-tailed distributions (McFarlane, 2010; Kaminsky et al., 1998; Eichengreen et al., 1995). Pozo & Amuedo-Dorantes (2003) reported that the extreme value method not only indicated more evidence of speculative pressure but also accurate indications of crisis incidences. Even when the tails of distribution are thin, the extreme value method provides similar results to a normal distribution (Pozo & Amuedo-Dorantes, 2003). Recognising the limitations of crisis based threshold (two- or three- σ), recent literature has focussed on the extreme value approach (Pozo & Amuedo-Dorantes, 2003; Cumperayot & Kouwenberg, 2013). The extremal types theorem (Fisher-Tippett theorem) stipulates that if the extreme observation converges in distribution to a non-degenerate probability distribution, then it belongs to one of three families: Thin-tailed (Gumbel); Fat-tailed (Frechet) or no-tail (Weibull). The three families can be factored together and known as the Generalised Extreme Value. The sign of the parameter of the Generalised Extreme Value can either be positive (Frechet such as student's T or Pareto), zero (Gumbel such as normal or exponential) or negative (no tail such as Weibull and Beta distribution).

Another non-parametric technique for estimating the tail index of extreme values is known as the Hill-estimate (Hill, 1975). Most studies thus far have used this technique to estimate the tail index (McFarlane, 2010). The distribution of the data is required to be from a fat-tailed (Frechet) distribution (McFarlane, 2010; Huisman et al., 2001; Hill, 1975; Koedijk et al., 1992). An advantage of this technique is that it has been reported to be an unbiased estimator of small sample sizes.

However, recent papers have used another extreme value technique recognised as the peaks over threshold (POT) for estimating the tail index (Guru & Sarma, 2013). This method is preferred as it is applicable to fat-tailed, thin-tailed and no-tailed distributions. Moreover, the tail of the EMP index distribution can be estimated by fitting a Generalised Pareto Distribution (GPD) to values beyond a certain threshold. The POT method is formulated from the Pickland-Balkema-de Haan theorem which uses values in excess of a particular threshold to be approximated by the GPD. However, the underlying distribution must meet the Fisher-Tippett theorem. This approach enables the researcher to identify extreme observations without making assumptions regarding the value of the unknown distribution shape-parameter. This method is advantageous over the σ-based method (where the distribution is assumed to be normal) or the Hill-estimation which is based on non-parametric techniques and only relevant to a fat-tailed distribution.

The GPD has two parameters and is given by:

$$H(x) = 1 - \left(1 + \xi x / \sigma\right)^{-1/\xi} \qquad \xi \neq 0 \quad \text{.......... 1.1}$$

$$H(x) = 1 - \exp\left(-x/\sigma\right) \qquad \xi = 0 \quad \text{.......... 1.2}$$

The scale parameter sigma is always positive whereas the shape parameter (ξ) can assume positive, negative or zero values. As stated earlier, when the shape parameter is positive, the distribution belongs to the Frechet class (fat-tailed) distributions, when it is zero it belongs to the Gumbel (thin-tailed) distribution and when negative, the distribution belongs to the Weibull family (no tail).

When implementing the POT method, a threshold μ must be identified to define the beginning of the tail. Then a GPD is fitted to the peaks over the threshold μ by implementing maximum likelihood estimation. When the GPD parameters are estimated for the "surpassing" values, the p^{th} quantile on the tail of the distribution can be estimated. The formula is described in detail in Chapter two and three. Usually, when using the POT approach, one would implement the probability stress threshold fixed at 0.05 (95^{th} percentile) or at 0.01 (99^{th} percentile). Using the formula, the entire tail region can be calculated using different probability quantiles.

When choosing the value for the tail threshold, μ, there is a balance trade-off between variance and bias. If the value chosen is too high, there would be few observations resulting in high variability. If the value chosen is too low, the tail region of the distribution may be biased (McNeil & Frey; 2000; Gavin, 2000). Recent research has opted to use the top 20% of values, if observations are taken from 20 years of data (Guru & Sarma, 2013). If the sample is small, the non-parametric Hill estimator method may be more suitable.

The previous sections indicated that extreme value is applied when a distribution is heavy-tailed. A distribution of this type could be associated with "exchange market pressure". The next section highlights more information about this construct.

1.2 EXCHANGE MARKET PRESSURE

Exchange market pressure (EMP) was introduced and developed by the pioneering researchers, Girton & Roper in 1977. Changes in the exchange rate exert an influence on a given country's macroeconomic management which affect indices such as inflation, trade balance, unemployment and many others. The exchange rate could be pressurised due to the selling pressure of the domestic currency or excess demand for foreign currency. The monetary authority of the country can either intervene or allow the pressure to appreciate or depreciate the exchange rate. If intervention is implemented in periods of depreciative pressure, the policy makers usually raise the interest rate to attract investment opportunities or sell international reserves to meet the demand of foreign currency (Guru & Sarma, 2013). In order to encapsulate currency exchange pressure, an understanding and analysis of exchange rate depreciation, decreases in foreign exchange reserves and increases in interest rate are fundamental. To include these three essential forms of pressure into a single composite factor or index, is what is known as EMP. The objective of EMP is to determine periods of "extreme pressure" or currency crises (two or more continuous periods of stress) (Guru &Sarma, 2013).

The formula for the EMP index is explained in more detail in Chapter two and three. The EMP index is a weighted average of e_t, r_t and i_t. e_t reflects the exchange rate fluctuations whereas the second component (r_t) reflects variations in the reserves compared to the total supply of narrow money. Lastly, i_t reflects movements of interest rates in the South African economy. The weights in this particular index are provided by the relative size of their respective standard deviations against that of the exchange rate component (Guru & Sarma, 2013).

Positive changes in the EMP index reflect depreciative changes, thus reflecting stronger selling pressure of the domestic currency or excess demand for foreign currency. It is important to note that negative values of the EMP index reflects the appreciative nature of the exchange index and does not imply depreciative pressure. Examples are increases in reserves or decreases in the interest rate. Consequently, the values of the right (upper depreciative tail) will be studied extensively. For many years it has been reported that financial data rarely fit a normal distribution, in fact, most financial data are heavy tailed and leptokurtic (Fama, 1965). The next section postulates the problem statement where extreme value theory is applied on EMP.

1.3 PROBLEM STATEMENT

To the researcher's knowledge, research of this nature has never been conducted in Africa. A few studies have studied EMP in South Africa but never went as far as to model the data using extreme value theory (Fiador & Biekpe, 2015). An analysis of this kind is especially important in developing countries where negative net export positions arise, with a deteriorating foreign exchange position. Moreover, in developing countries variables such as the output growth (lower gross domestic profit (GDP) implies smaller demand for money), private capital flows (capital inflows end up in the consumption market), current account balance (inverse relationship with EMP), terms of trade (deteriorating terms of trade implies a need for more foreign currency) and public debt are usually different to those of developed countries.

Also, most studies in other regions did not employ extreme value theory. The EMP have not been compared using the Hill estimate and GPD in EVT. We do not know whether these methods will be feasible in an African context, and if so, would EMP be estimated accurately. Moreover, would the use of EMP allow policy makers or the monetary authorities of the African governments or reserve bank to manipulate interest rates or foreign reserves to prevent future crises periods? Lastly, during the past twenty years, periods of high and lower volatility regarding EMP pressure can be identified as well as the relative contribution of each factor involved with the EMP, that is, changes in the exchange rate or changes in foreign reserves or changes in the interest rate. An in-depth analysis could help identify possible cause of the relative contributions of each factor.

Therefore, the research questions that emulate from this study are: Is it possible to model the data using EVT? Which estimation method (Hill or GPD POT) is best to accurately estimate periods of extreme pressure? Is the use of EMP analysis using extreme value theory feasible and accurate for identifying periods of extreme pressure and the incidence of crises in South Africa? Finally, what are the individual contributions for the three factors involved with EMP estimation in periods of stress or crises? Consequently the objectives of the current study can be formulated.

1.4 OBJECTIVES OF THE STUDY

1: To determine whether the EMP index of two African countries is stationary and heavy-tailed or not and if so, to model the data using extreme value theory.

2: To compare the parametric (GPD POT) and non-parametric (Hill) estimation methods in describing periods of extreme pressure in South Africa and Kenya.

3: To identify periods of extreme pressure or crises in South Africa and Kenya using extremal analysis for the period 1999 to 2017.

4: To study the three components of EMP estimation at periods of extreme pressure or crisis.

1.5 HYPOTHESES OF THE STUDY

1: The financial EMP data presented for both South Africa and Kenya will be stationary and demonstrate heavy-tailed Frechet distributions. Consequently, it will be suitable to model with EVT techniques.

2: Both estimation methods will provide feasible and accurate estimations of extreme pressure.

3: Periods of extreme pressure or crisis will be identified for both countries for several time periods

4: All three components of the EMP index will demonstrate causes for periods of extreme pressure or crises at certain points of time.

1.6 STRUCTURE OF THE DISSERTATION

This thesis is divided into five main chapters.

Chapter one provides a brief introduction and problem statement of the study. The objectives, hypotheses and plan of study is also highlighted.

Chapter two details an overview of the literature with regards to the extreme value theorem and estimation of exchange market pressure.

The methods and procedures related to data collection and analyses are described in **Chapter three**.

Chapter four presents the data analysis, results and interpretation of the study.

Lastly, **Chapter five** provides the summary, conclusion, limitations and future studies.

1.7 AUTHORS CONTRIBUTIONS

1: The use of extreme value theory is feasible and accurate to determine the exchange market pressure in South Africa and Kenya.

2: The parametric Generalised Pareto Distribution method of Peak over Threshold is more accurate than the non-parametric Hill estimate method for modelling Exchange Market Pressure.

3: Several periods of stress were accurately identified for both the South African and Kenyan data sets at different probability levels.

4: The use of the statistical package R and associated packages were relevant, effective and efficient for the studied estimation and modelling methods frequently employed with extreme value theory.

1.8 LIMITATIONS OF THE STUDY

1: The feasibility of extreme value theory in other African country's still need to be determined. Especially so, in poorer regions with a lower gross domestic profit, areas with a rising interest rates or current account deficit and declining international reserves.

2: The accuracy of modelling Exchange Market Pressure when using other subclasses (such as Gumbel or Weibull) of the Generalised Pareto Distribution still needs to be determined.

3: Further research is needed to provide more "timely" early warning signals for policy makers and financial analysts to counter periods of pressure or crises.

4: The contagion effect of a neighbouring country or a country whom South Africa or Kenya has close financial ties with, needs to be addressed.

CHAPTER TWO: LITERATURE REVIEW

2.1 EXTREME VALUE THEORY

Extreme value theory (EVT) affords a strong theoretical foundation for constructing statistical models to describe extreme events (Gilli & Kellezi, 2006). EVT is used in the study of extreme events and their associated asymptotical distributions (Rocco, 2014). The events occur rarely in frequency, but are extreme in magnitude compared to the majority of events. A classical question asked with EVT is: “if things go wrong, how wrong will they go?” EVT is concerned with the construction of models so that the possibility of an extreme event could be addressed (McNeil, 1999). The foundation of the EVT theory was set by Fisher & Tippett (1928) who reported that the distribution of extreme values from an independent and identically distributed (iid) sample with a cumulative distribution function can converge to one of three applicable distributions. Many textbooks are available that provide a detailed account of EVT and applications thereof (Coles, 2013; Embrechts et al., 2013; Reiss & Thomas 2013; McNiel et al., 2005; Beirlant et al., 2004)

Extreme event risk is existent in all spheres of risk management (McNeil, 1999). In fields such as engineering, geography and climate, EVT is well established, whereas in financial data, the use is becoming increasingly popular due to stock market crashes, credit losses, and periods of crises (Longin, 2017). Examples of risk management are: market-risk, credit-risk, operational-risk, insurance-risk, flood-risk, drought-risk, stock market-risk and many more. Market risk may be related to the day-to-day risk for losses occurred due to an adverse event, or operational risk management may be related to the amount of capital needed to cushion against credit down gradings or other extreme events (McNeil, 1999). It is crucial to be able to model risks so that the possibility of extreme outcome is addressed and this is where the field of extreme value theory is very useful. As stipulated earlier, EVT is a methodology that is needed to model rare events with unprecedented consequences such as large financial losses, floods, heavy rainfall, droughts and others (Gilli & Kellezi, 2006). The theoretical framework and computational tools regarding the use of EVT in finance have improved vastly in the last three decades due to stock market crash in 1987, the Asian Financial Crisis in 1997, the hedge fund crisis in 1998 and the more recent credit crisis in 2007 (Rocco, 2014).

The theorem of EVT can be compared to the central limit theorem (CLT). The CLT states that when non-dependent random variables are summed, the sum when normalised tends to a normal distribution with a bell-shaped curve. Similarly the EVT, shows that the standardised maxima of a sequence of independent and identically distributed (iid) random variables converges to a given EVT distribution family (Rocco, 2014). Where the CLT is associated with the sums of random variables and a unique limit, EVT is concerned with the maxima and three families of asymptotic distributions.

Specifically, if n iid random variables (X1, X2, ..., Xn), Mn symbolises the maximum.

That is Mn = max {X1, X2, ..., Xn}.

If F is the cumulative distribution function (CDF) of Xj (j =1, 2, ..., n), the distribution function of Mn is provided by F^n (Rocco, 2014). Taking the limit will produce:

$$\lim_{n\to\infty} (F)^n\,(x) = \begin{cases} 1, & \text{if } F(x) = 1 \\ 0, & \text{if } F(x) < 1 \end{cases}$$

which is a degenerate function.

Fisher & Tippett (1928) standardised the variable Mn using an affine transformation with a positive scale parameter (Cn > 0) and a positive location parameter dn, reducing to study the asymptotic distribution of:

$$\frac{M_n - d_n}{C_n}$$

to obtain a non-degenerate limit distribution for the maxima.

2.2 MODELLING EXTREME RISK

A branch in Mathematics called probability theory is used to model risks. Risks are random variables and can follow many different distribution types. A particular probability distribution could provide partial information about that distribution. Extreme risks occur when values from the tail of the distribution is taken. Again, a particular probability distribution is to be selected, usually through the statistical analysis of previously observed data. As a consequence EVT provides the researcher or risk manager with the best possible estimate of the tail area of that distribution.

The two most widely used methods for identifying extremes in financials variables are the Block Maxima or Peak over Threshold method (POT). The Block Maxima considers the largest values in successive periods (Figure 2.1a) whereas the POT method (Figure 2.1b) considers values exceeding a specific threshold. The Block Maxima method is the more out-dated method whereas the POT method uses data more efficiently, and therefore is more popular in recent studies (Gilli & Kellezi, 2006; Bali, 2003; McNeil, 1999).

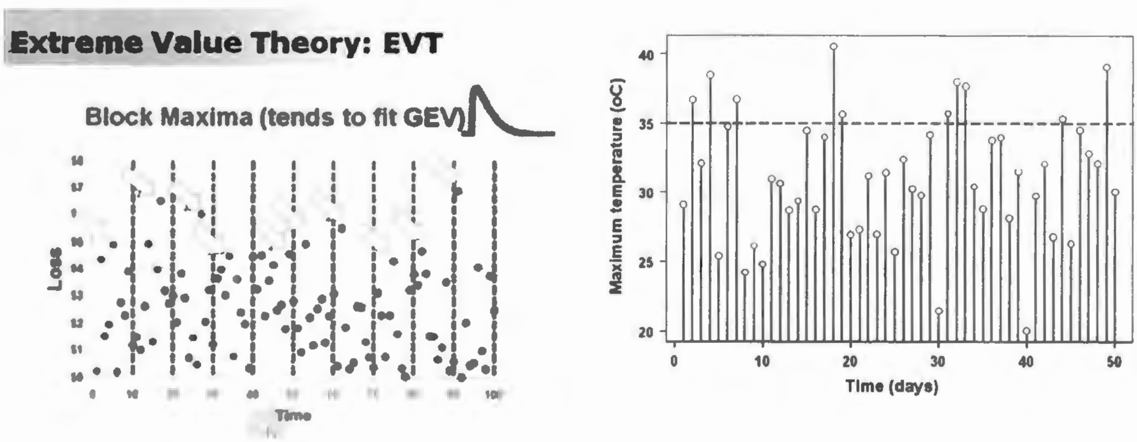

Figure 2.1a & 2.1b: Extreme value theory – The Block Maxima and the Peak over Threshold method

The block maxima approach divides the N observations into m subsamples with n observations each. The maximum of each block is selected (hence the name block maximum). See the arrows and dotted line in Figure 2.1a above. The extreme values in each block are identified and the distribution of the sequence is studied. When m and n grow sufficiently large, the EVT states that the limit distribution of block maxima fits to one of three groups. The fit depends on the behaviour of the studied tail (upper tail in the figure above). If it is power-law decaying, it is associated with the fat or heavy tailed distribution (Rocco, 2014). If exponentially decaying, the normal distribution is applicable and the third type is when upper bounded support exists. Most financial data consists of heavy tailed distributions and not bounded. These three asymptotic distributions can be grouped as the generalised extreme value distribution (GEV). It is dependent on shape parameter known as Xi or expressed as ξ. When $\xi > 0$ the Frechet case is applicable, when $\xi = 0$, the Gumbel case is applicable, and finally when $\xi < 0$, the Weibull case is applicable.

Within the POT class, two further models may be distinguished. The first of these is the non-parametric model built around the Hill estimator (Beirland et al., 1996). The second of these is the fully parametric model based on the Generalised Pareto Distribution (Embrechts et al., 1998).

Shortly, the POT method defined extreme values that exceed a particular threshold. The purpose is to model the distribution of the exceedances over the threshold with the random variables $Yj = Xj - \mu$ in which those observations Xj that exceed μ ($Xj > \mu$). As the threshold, μ, grows to infinity (right end point becomes finite), the positive sequence, when scaled, fits with the parametric family known as the Generalised Pareto Distribution. When financial returns fits a GEV distribution with Xi, the shape parameter, being larger than zero and an adequately large μ, the exceedances over μ fits a GPD. The Block Maxima and POT approaches are parametric and they fit a parametric model using the technique of maximum likelihood to the upper tail (Rocco, 2014). The Block Maxima and POT method is discussed in more detail in the next few sections.

The parametric approaches (Block maxima and POT approaches) and the non-parametric approach (Hill estimator) are very useful and theoretically sound and practically applicable when used correctly. McNeil (1999) favours the POT approach due to reasons of simplicity. A parametric formula for extreme risk is obtained and used to give estimates of statistical error using techniques of maximum likelihood estimation.

2.3 GENERAL MATHEMATICAL THEORY

2.3.1 GENERALISED PARETO DISTRIBUTION

The GPD has two parameters. See formula 1.1 and 1.2 in the previous chapter.

The scale parameter (σ) is always positive whereas the shape parameter (**ξ**) can assume positive, negative or zero values. When the shape parameter is positive, the distribution belongs to the Frechet class (fat-tailed) distributions, when it is zero it belongs to the Gumbel (thin-tailed) distribution and when negative, the distribution fits the Weibull family (no tail). See Figure 2.2 below for schematic presentation.

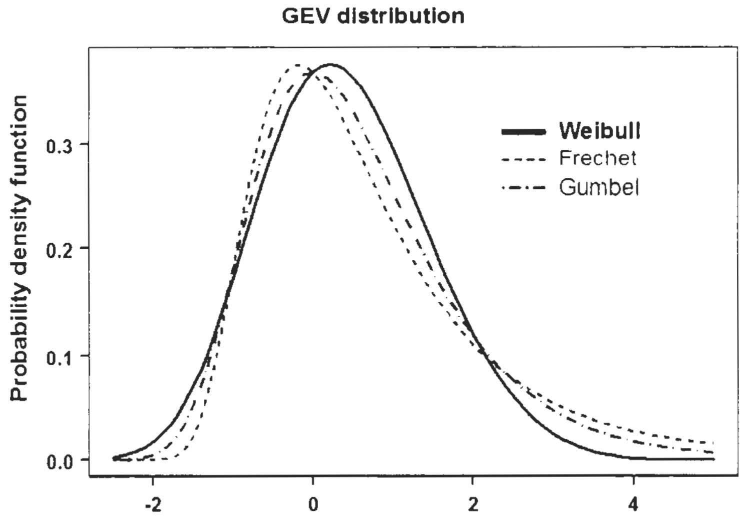

Figure 2.2: Generalised Pareto distribution with a Frechet, Gumbel and Weilbull sub-class.

Frechet: $F(x, \mu, \sigma, \xi) =$	$[e^{-x\wedge-\alpha}]$	$[0, x \leq 0]$
Weibull: $F(x, \mu, \sigma, \xi) =$	$[e^{-(-x)\wedge\alpha}]$	$[1, x > 0]$
Gumbel: $F(x, \mu, \sigma, 0) =$	$[e^{-e\wedge-x}]$	$[x \in \mathbb{R}]$

The first case is the most relevant for risk management since the GPD is heavy tailed when $\xi > 0$. When $\xi > 0$ we find that E $[X^k]$ is infinite for $k \geq 1/\xi$. When $\xi = ½$, the GPD is an infinite variance (second moment distribution). When $\xi = ¼$, the GPD has an infinite fourth moment. The normal distribution cannot model these phenomena but the GPD is used to precisely capture this behaviour.

2.3.1.1 PEAK OVER THRESHOLD

When implementing the POT method, a threshold μ must be identified to define the beginning of the tail. Then a GPD is fitted to the peaks over the threshold μ by implementing maximum likelihood estimation. When the GPD parameters are estimated for the "surpassing" values, the p^{th} quantile on the tail of the distribution can be estimated using the following formula:

$$X_p = \mu + \frac{\sigma}{\xi}\left[\left(\frac{np}{k}\right)^{-\xi} - 1\right] \qquad 2.1$$

n: total number of observations,

k:number of observations above the threshold μ,

σ̂, ξ̂: maximum likelihood estimates of the GPD parameters,

p: probability level

Usually, when using the POT approach, one would implement the probability stress threshold fixed at 0.05 (95th percentile) or at 0.01 (99th percentile). Using the formula listed in the previous paragraph, the entire tail region can be calculated using different p quantiles.

An important issue to the POT approach is that there is a trade-off between variance and bias when choosing the threshold, μ (Rocco, 2014). When the threshold chosen is too high, few observations remain, and not enough for reliable estimation. If the threshold chosen is too low, conventional data is used (not extremal), yielding estimated which are biased. Incorrect conclusions will be drawn if the threshold chosen is too high or too low as the scale and shape estimators will be unreliable. Rocco (2014) provided four possible methods to deal with this delicate and important decision. Firstly, choosing μ so that 5-15% of the data is selected. Guru & Sarma (2013) proposed the use of a 20% threshold. Secondly, if using the Hill estimator method, the use of Hill plots. This method estimates values for Xi as a function of μ, until stable estimates are yielded. The hill plot should demonstrate a horizontal line in the Hill plot as demonstrated in the figure below (Figure 2.3).

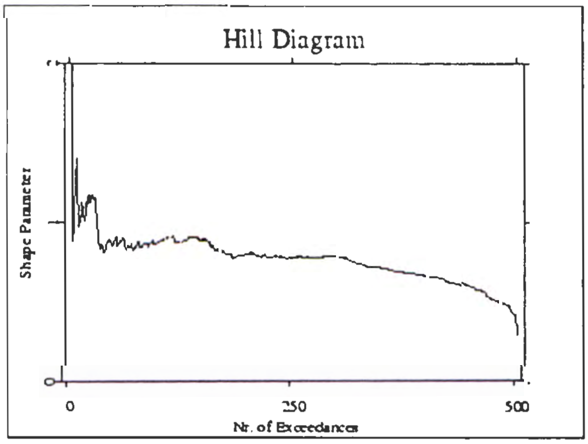

Figure 2.3: Example of a Hill diagram

Thirdly, Monte Carlo simulations can be applied by selecting a threshold value which minimises the mean squared error whilst regarding the balance between variance and bias. Lastly, algorithms can be incorporated by using the bootstrap method to select the most suited threshold value.

Another important consideration when applying EVT, including the POT method, is that the data must be iid. Most financial time series are not iid (Rocco, 2014). Consequently, the dependence structure of the data must be accounted for. The financial time series must be stationary, and if it is stationary, the fitting of some ARCH/GARCH (generalised autoregressive conditional heteroscedasticity) model could eliminate the influence of autocorrelation. The ARCH/GARCH model structure will be discussed in the next section.

2.3.2 HILL ESTIMATOR

The Hill estimator has been well developed in recent years and applied widely, with good results and sometimes superior to the Block Maxima and POT methods (although less favourable).

Non-parametric statistics considers the order and ranks of the data (X1, n > ... Xn, n). The formula was first proposed by Hill (1975) and given by (inverse of the log-exceedance above threshold):

$$Hk,n = k^{-1}\sum_{j=1}^{k}\log(n-j+1) - \log X_{n-k}$$

....2.2

K represents the cut-off between the tail and central observations so that Xj,n can be considered extreme observations.

Alternatively, the formula can also be structured in a different way that is more user-friendly (Kang & Song, 2017).

$$\xi_n = \frac{1}{n}\sum_{i=1}^{n}\log X_i - \log X_{n+1} \qquad \text{2.3}$$

Where n represents the largest observations (cut-off between tail and central observations).

The asymptotic properties (weak consistency, strong consistency and asymptotic normality) is provided by Embrechts et al. (2013).

The 100pth quantile using the Hill estimator is computed by the following formula (Kang & Song, 2017).

$$X_p = X_{n+1}\left[{n+1}\big/_{N+1} \right]^{\xi_n} \qquad 2.4$$

Where n is the tail observations, N is the entire sample and Xi is the Hill estimator.

The second part of the literature overview provides insight into EMP.

2.4 EXCHANGE MARKET PRESSURE

Exchange market pressure (EMP) was presented and established by the ground-breaking researcher Girton & Roper (1977). The concept was further formalised by Weymark (1995). A country's exchange rate may come under attack due to excess demand for foreign currency or selling pressure of the country's own currency. The country's monetary authorities can either defend the exchange rate pressure by implementing policies to counter it or allow depreciation of the currency. Usually, intervention strategies are implemented whereby policy makers raise the interest rate to entice investors or the monetary authorities could decide to sell international reserves to meet the demand of foreign currency (Guru & Sarma, 2013). Consequently, the monetary authorities of a given country must comprehensively understand the status and changes of a country's exchange rate, foreign exchange reserves interest rate. The inclusion of these three essential and dynamic variables into a single composite factor or index, is what is known as EMP

The objective of EMP is to determine periods of "extreme pressure" or ultimately a currency crises. A currency crisis results with two or more continuous periods of stress (Guru & Sarma, 2013). Economists must know when such pressure occurs, the intensity thereof, and then provide advice to policy makers with the best methods of countering the pressure.

The EMP index is given by:

$$EMP_t = e_t - \left[\sigma_e / \sigma_r\right] r_t + \left[\sigma_e / \sigma_i\right] i_t \quad \text{..............} 2.5$$

where e_t is the relative change in nominal exchange rate of ZAR against US dollar on month t

r_t is the relative change in ratio of gross forex reserves to narrow money (reserves-to-M1) in month t

i_t is the relative change in interest rate in month t

σ_e, σ_r, σ_i are the standard deviations of e_t, r_t and i_t.

The EMP index is a weighted average of e_t, r_t and i_t. e_t mirrors the exchange rate fluctuations whereas r_t reflects changes in the reserves compared to the overall supply of base money. Lastly, i_t reflects movements of interest rates in the South African economy. The weights in this particular index are provided by the relative size of their respective standard deviations against that of the exchange rate component (Guru & Sarma, 2013). When the EMP index reflects positive values, depreciative changes result, which indicates an increased selling pressure of the domestic currency or excess demand for foreign currency. Importantly, negative values mirror the appreciative nature of the exchange index. For the purposes of this study, the positive values of the EMP index (upper depreciative tail) will be studied in more detail. The next section, focuses on what happens when a currency suffers from extreme pressure or when a currency crisis is elicited.

When extreme pressure is experienced in the economy of a given country, the term currency market stress is used (Guru & Sarma, 2013). However, if the pressure is more severe and longer in time with a sustained period of two or more periods of stress, the term currency crisis is used (Guru & Sarma, 2013). A simplistic definition to define currency crisis would be large movements in the nominal exchange rates (Pozo & Amuedo-Dorantes, 2003). Practically, this phenomenon can be viewed as speculative attacks on the local currency. In some instances they are successful and in others the government is able to intercept by increasing the domestic interest rate or the use of international reserves (Pozo & Amuedo-Dorantes, 2003). The large positive values of EMP index is used by economists to identify the possibility of a currency crisis. Large negative extreme values are ignored and not indicative of currency stress although they yield other unwanted ramifications (Pozo & Amuedo-Dorantes, 2003). Eichengreen et al. (1996) defined currency crisis as periods in time when unusually large values of the EMP index resulted. Subsequently, "threshold" definitions were used to define a currency crisis. In a study by Eichengreen et al. (1995) a currency crisis was identified when the EMP value exceeded two standard deviations above the mean. Others, preferred to use three standard deviations above the mean (Kaminsky et al., 1998). The use of standard deviation based threshold requires that the data is normally distributed, which in the case of financial data is rarely so (Ezzamel et al., 1987; Blattberg & Gonedes, 1974). The following figure (Figure 2.4) demonstrates the differences between a normal bell-shaped distribution and a heavy tailed distribution.

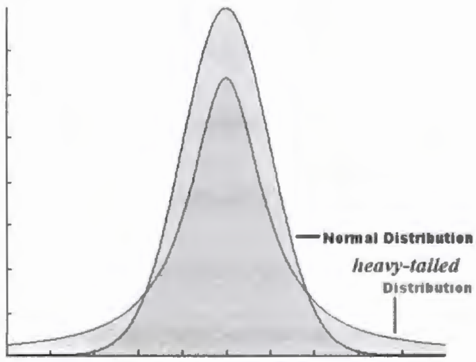

Figure 2.4: Normal vs heavy-tailed distribution

Studies that have focussed more specifically on the EMP index have also reported non-Gaussian distributions (Heinz & Rusinova, 2015; Guru & Sarma, 2013; Pozo & Amuedo-Dorantes, 2003). Crisis episodes in most countries are rare events, and therefore difficult to predict. Prediction results will most likely be biased and inaccurate if the EMP index follows a non-normal distribution (Heinz & Rusinova, 2015). As stipulated in the previous section, most financial data, including the EMP index are heavy-tailed as a large amount of data are concentrated in the tails of the distribution. Consequently, the likelihood of extreme pressure (as defined in the first line of this paragraph) is increased when compared to the Gaussian distribution (Heinz & Rusinova, 2015; Guru & Sarma, 2013; Koedijk et al., 1990). This is illustrated clearly in Figure 2.5 in the study by Guru & Sarma (2013). The next paragraph discusses possible explanations by using examples of an extreme pressure or currency crisis.

It has been reported that not only a range of macroeconomic variables but also contamination from cross-countries are pertinent predictors of extreme pressure or currency crisis. Specific examples include and are not limited to: disproportionate credit growth, over-appraisal of exchange rate, a decline in international reserves, rising interest rates, an increase in the current account deficit, outflow of portfolio management and flight of capital (Heinz &

Rusinova, 2015; Guru & Sarma, 2013; McFarlane, 2003; Pozo & Amuedo-Dorantes, 2003). In a study by Aizenman & Hutchison (2012) it is demonstrated how the financial in the United States affected emerging markets. From their study, it is clear that markets with more foreign liabilities (short and long term debt) were more prone to cross-country contagion. Countries where the liabilities exceeded the foreign reserves and other emerging markets countered the shock by exchange rate depreciation and less so by reserve loss (Aizenman & Hutchison, 2012). It is also noteworthy to realise that countries that have suffered a currency crisis may be more susceptible to another crisis in the near future as they will remain exposed even if the correct policies was applied (Heinz & Rusinova, 2015).

Guru & Sarma (2013) reported 11 periods of currency market stress using a probability of 5% and three episodes when using a probability of 1%. This study was performed in India from 1992 to 2012. The authors showed that if the study employed a normal distribution to define probabilities of stress with the EMP data, 53 periods of market stress would be found using a 95% level. No currency crisis of two or more continuous periods of persistent stress was found in India during this period.

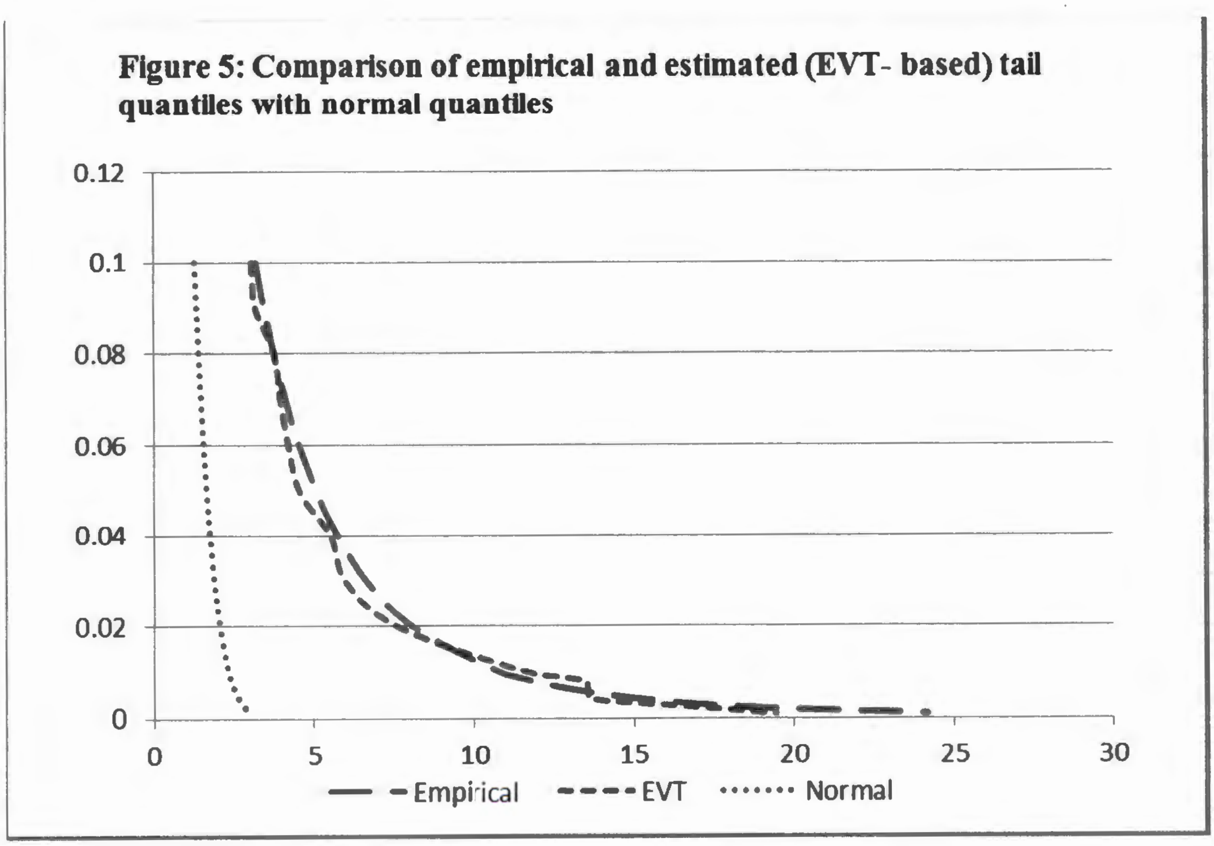

Figure 2.5: Comparison of empirical and estimated tail quantiles with normal quantiles in India (Reprinted with permission from Guru & Sarma, 2013)

Similarly, Pozo & Amuedo-Dorantes, (2003) reported between three and five periods of currency market stress in six different Asian countries, between four and nine periods of stress in four European countries and between two and six periods of stress in six Latin American countries.

The next section briefly describes how most countries counter extreme pressure or a currency crisis.

As stated in the introductory paragraph, usually the monetary authorities react decisively to exchange market pressure by raising the interest rate to attract investment opportunities or the country may decide to sell some of its international reserves (Guru & Sarma, 2013; Pozo & Amuedo-Dorantes, 2003). This action is deemed necessary to find the means to the draw foreign currency. Researchers in the Philippines (Gochoco-Bautista & Bautista, 2005) attempted to study various research studies (Tanner, 2002; 1999) using the EMP index to counter currency pressure. They reported that raising interest rates and contracting domestic credit growth both were used successfully to reduce the EMP. However, in crisis periods, the contraction of domestic credit growth was the most viable option. Interestingly, the researchers go the extent to state that there is a perverse and debilitating effect when the interest rates are raised which could be counterproductive (Gochoco-Bautista & Bautista, 2005). The researchers report high interest rates could cause bankruptcies, debt default, burden on the public sector and weakening of the banking system.

The EMP is not only used to predict extreme pressures or currency crisis but has also been used for other reasons. For example, a study by van Poeck et al. (2007) determined whether certain European countries should be eligible to enter the European Union States using exchange market pressure.

2.5 CONCLUSION

This chapter provided a literature overview regarding extreme value theory and associated aspects related to modelling and mathematical & statistical theory. The peak over threshold methods of GPD and Hill estimate are discussed together with the computation of their respective quantiles. Finally, the construct EMP, and the three components thereof was discussed together with similar studies that have been explored in India, Asia, Latin America and the Philippines.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 RESEARCH DESIGN

This study was quantitative and exploratory in nature where financial data for two different African countries (RSA, Kenya) for the past 20 years was analysed to construct a monthly EMP index. Quantitative and exploratory research was used to employ statistical and mathematical models pertaining to EMP.

Financial data from 1999 to 2017 was obtained from the Global Markets Research team (Rand Merchant Bank). Rand Merchant Bank is a division of First Rand Bank Limited and one of the largest corporate and investment Banks in Africa. The Rand Merchant Bank Global Markets Research Team provides comprehensive financial Market Research analyses.

3.2 DATA ANALYSIS

3.2.1 EXCHANGE RATE, INTEREST RATE AND RESERVES-TO-M1 MONEY SUPPLY

The data obtained included monthly data pertaining to the average monthly exchange rate of the ZAR and the Kenyan Shilling against the US dollar. Also, the ratio of monthly reserves to base values (indicative of the adequacy of reserves and how much the foreign exchange reserves cover the most liquid money supply) was also obtained for each country. Lastly, data for the movement of monthly nominal interest rates was obtained. The movements of these three components and their relative changes is schematically demonstrated in the next chapter. All three variables were computed to reflect rate relative changes. All three financial variables (rate-of-change in exchange rate, rate-of-change in interest rate and rate-of-change in reserves-to-M1) must demonstrate stationarity if used for subsequent analysis with extreme value theory. Other than the general descriptive statistics (mean, median, variance, standard deviation, skewness and kurtosis), the stationarity according to the Jarque-Bera Test statistic was determined as a first step. Another important component when applying extreme value theory is the assumption of no-autocorrelation in the time series. The next section explains how the data analysis was applied in such instances.

3.2.2 ARCH/GARCH PROCESSES

The second step towards achieving an EMP index, was to specify the time series dynamics of each of the components. When no time varying volatilities were observed, the appropriate standard deviations were used for components that display features of conditional heteroscedasticity using ARCH and GARCH models. The standard Box-Jenkins methodology was applied to arrive at the best fitting time series model. In doing so, the EMP series was standardised for each individual component if serial-correlation was reported to achieve independence and identically distributed distribution. The results of the Box-Jenkins methodology and Ljung Box Q-statistics for the first and second moment are demonstrated in tables for the three components. The basic statistics of exchange rate, nominal interest rate and ratio of reserves to base money is presented in a table (maximum, minimum, mean, standard deviation, variance, skewness, kurtosis). Possible periods of more and less volatility are identified within the total period of 19 years (RSA) and 18 years (Kenya).

3.2.3 CALCULATION OF THE EMP INDEX

The EMP index was calculated as reported in Chapter 2. The calculations for each country were performed in Microsoft Excel 2016 (Microsoft, Redmont, United States)

$$EMP_t = e_t - \left[\sigma_e / \sigma_r \right] r_t + \left[\sigma_e / \sigma_i \right] i_t \quad \ldots\ldots 3.1$$

Descriptive statistics are provided for the EMP index (Chapter 4). The movement of the EMP index is demonstrated in a figure. The descriptive statistics, tests for normality, skewness, kurtosis and autocorrelation was analysed with statistical package R and R studio (CRAN, R Core Team, 2016). The website for the R project is http://www.r-project.org and the source code is http://www.gnu.org/licences/gpl.html. The R language is a dialect code of the S language, established by John Chambers at the Bell labs in the 1970's.

3.2.4 DEFINING MARKET STRESS USING EXTREME VALUE THEORY

In this study, extreme positive values of the EMP index as indicative of intense currency market pressure were examined. Extreme values are rare in nature and occur with a small probability. The probability of a crises event that is an EMP index that exceeds the [(1-p) x 100] percentile will indicate a stress event. Consequently, a threshold value for the identification of a stress event is provided. Where the observed valued of the EMP index is more than this threshold, the index at that particular point can be considered under stress.

The quantiles of these points (usually 95th or 99th percentile) are located in the tail regions of a probability density function. Financial data often display non-normal behaviour with asymmetry and kurtosis.

3.2.4.1 GENERALISED PARETO DISTRIBUTION: PEAK OVER THRESHOLD

The largest 20% of the EMP index values was considered extreme observations. As such, the tail threshold μ was the probability of the EMP index being higher than this is 0.2. A GPD was fitted to the "excesses" over μ and apply the estimated GPD parameters to compute crisis-thresholds given for the 95th and 99th percentile. An observation of the EMP index larger than these thresholds will be indicative of a stress situation. Several tail quantiles for different probability levels p was computed to compare the results of the GPD to that of a normal distribution and the empirical (actually observed) quantiles.

The GPD parameters are estimated for the "exceeding" values and the pth quantile on the tail of the distribution was estimated using the following formula:

$$X_p = \mu + \sigma/\xi \left[\left(np/k \right)^{-\xi} - 1 \right] \qquad 3.2$$

The formula was explained in more detail in Chapter 2.

3.2.4.2 HILL ESTIMATOR

Similarly the Hill estimator was also fitted to the "threshold" values as in 3.2.4.1 The Hill estimator was fitted to the tail of the distribution and the estimated Hill parameter (Xi) was used to compute crisis-thresholds at the 95th and 99th percentile. Again several tail quantiles (for different probability levels p) was computed to compare the results of the Hill estimator not only to that of the empirical quantiles but also to that of the GPD POT and normal distribution.

The data is sorted from largest to smallest (X1,n > … Xn,n). The formula as proposed by Hill (1975) is given by:

$$Hk,n = k^{-1}\sum_{j=1}^{k}\log(n-j+1) - \log X_{n-k}$$

……………………………………………………………3.3

K represents the cut-off between the tail and central observations so that Xj,n can be considered extreme observations.

Alternatively, the formula can also be structured in a different way that is more user-friendly (Kang & Song, 2017).

$$\xi_n = \frac{1}{n}\sum_{i=1}^{n}\log X_i - \log X_{n+1} \quad \text{……………………………………………………………3.4}$$

Where n represents the largest observations (cut-off between tail and central observations).

The 100pth quantile using the Hill estimator is computed by the following formula (Kang & Song, 2017).

$$X_p = X_{n+1}\left[{n+1}\big/{N+1}\right]^{\xi_n} \quad \text{……………………………………………………………3.5}$$

Where n is the tail observations, N is the entire sample and Xi is the Hill estimator.

The EMP index was analysed using extreme value theory by using the statistical package R and R studio (CRAN, R Core Team, 2017).

3.2.5 ANALYSING THE STRESS EPISODES

Once the stress events are identified, an analysis of the stress events can be performed in the context of prevailing conditions in these countries around the stress periods. Furthermore, the contribution of each of the three components of the EMP index can be assessed during the stress periods. However, as this thesis is based on statistical theory and application, the influence of the respective countries' economies is not studied in detail.

3.3 STATISTICAL ANALYSIS

All data was analysed in the statistical package R (CRAN, R Core Team, 2016) and Microsoft Excel (Microsoft, Redmont, United States). Firstly, the three components of the EMP index was analysed as rate-of-changes in Microsoft Excel (Microsoft, Redmont, United States). Subsequently, the descriptive statistics and skewness, kurtosis, normality and stationarity was reported in R with the packages 'tseries' (Trapletti et al., 2017), 'forecast' (Hyndman et al., 2017) and 'fBasics' (Wuertz et al., 2014). The next step was to calculate the time varying volatilities with appropriate ARMA and/or ARCH/GARCH processes (for each one of the three components of the EMP index). These analyses were also conducted in R with the packages 'portes' (Mahdi & McLeod, 2017) and 'rugarch' (Ghalanos, 2015). Ljung-Box statistics for the mean and squared series were used to identify whether ARMA and/or time varying volatilities were present. Finally, the EMP index was calculated with formula 3.1. Again, descriptive statistics in association with skewness, kurtosis, normality, stationarity and Ljung-Box statistics are provided. Subsequently, the EMP index was modelled with the GPD POT and Hill estimate methods. This analysis was performed in R with the packages 'fextremes' (Wuertz et al., 2013), 'extRemes' (Gilleland, 2016) and 'ReIns' (Reinkens et al., 2017). Estimates for the shape and scale parameters are provided. The estimates were also manually calculated in Microsoft Excel (Microsoft, Redmont, United States) using formula 3.4 for certainty. Lastly, the quantile for each method was calculated for p=0.001 to p=0.2 using R and manual calculations (Formula's 3.2 & 3.5). The empirical quantiles were calculated manually in excel using the quantiles p=0.001 to p=0.2. As a final step, periods of crises were identified and the main contributor of the EMP index identified. These analyses were run for two African countries namely ZAR and Kenya. Probability values less than 0.05 were considered statistically significant.

3.4 LIST OF STATISTICAL TESTS

1: Descriptive statistics (mean, median, variance, standard deviation, skewness, kurtosis)

2: Normality (Jarque-Bera test statistic confirmed by Skewness, Kurtosis, Kolmogorov-Smirnov test)

3: Stationarity (Augmented Dickey Fuller test confirmed by Phillips-Peron test)

4: ARCH Lagrange Multiplier test (at different lags)

5: Ljung-Box test statistic for series and squared series (for mean and variance)

6: Time series ARMA analyses

7: Extreme value theory: Peak over threshold using maximum likelihood estimation with 'extRemes' confirmed by 'fextremes'

8: Extreme value theory: Peak over threshold using non-parametric Hill estimate with 'ReIns' confirmed by 'fextremes'.

9: Calculation of empirical and estimated quantiles using 'fextremes'; 'extRemes' & 'ReIns'.

3.5 ETHICAL CONSIDERATIONS

Ethical approval was granted from the North West University Ethical Committee (Mafikeng campus). The ethical approval number is NWU-00511-17-A9. The ethical approval certificate is attached as an Addendum (Appendix B). Any information that was attained in connection with this study will remain confidential and will not be unveiled. A permission letter was acquired from the Director of the Global Markets Research Team of Rand Merchant Bank. All questions and data sheets were arithmetically coded and no identifying names were included in the data pool. All raw and analysed data was and will be safely and securely deposited at the primary researcher's office. No-one except the researcher and project supervisors will have access to the processed data sheets. The participation in this study was entirely voluntary and the Directors from the Global Markets Research Team were free to withdraw and terminate participation at any time for any reason.

CHAPTER FOUR: DATA ANALYSIS, RESULTS AND INTERPRETATION

The results of the current study are provided for ZAR and Kenya countries. The results for South Africa are provided in section 4.1 and Kenya section 4.2.

4.1 SOUTH AFRICAN DATA

The table depicted below provides descriptive statistics, normality-test, stationarity-tests, auto-correlational tests for each of the three components of the EMP index for the period March 1999 to February 2017 (Table 4.1).

Table 4.1: SA- Descriptive statistics and time series tests of components of Exchange Market Pressure

	Rate of change of exchange rate	**Rate of change of interest rate**	**Rate of change in reserves-to-M1**
Descriptive statistics			
Mean	0.4282	-0.3232	0.0452
Median	0.1586	0.4551	0.0066
Standard Deviation	3.8585	3.0291	3.5446
Minimum	-9.9433	-12.0210	9.7919
Maximum	21.0129	7.7668	-20.3660
Skewness	1.2478	-1.0416	-0.9787
Excess Kurtosis	5.4773	2.0066	4.8117
Jarque-Bera	334.69 (0.00)*	77.572 (0.00)*	249.84 (0.00)*
Stationarity test			
ADF test statistic	-5.8462 (0.01)*	-4.4596(0.01)*	-5.5505(0.01)*
PP test statistic	-152.43 (0.01)*	-79.699 (0.01)*	-215.41(0.01)*
ARCH LM test			
Lag 1	0.2988 (0.585)	49.189 (0.000)*	1.2725(0.259)
Lag 5	0.7264 (0.982)	59.131 (0.000)*	6.900(0.228)
Lag 10	4.2588 (0.935)	60.088 (0.000)*	15.172(0.126)
Autocorrelation test			
Ljung-Box Q statistic for series			
Q(20)	31.809 (0.045)*	201.02 (0.00)*	20.715(0.414)
Q(30)	51.283 (0.009)*	219.21 (0.00)*	37.914(0.152)
Q(40)	60.188 (0.021)*	346.57 (0.00)*	51.059(0.113)
Heteroscedasticity test			
Ljung-Box Q statistics for squared series			
Q(20)	6.756 (0.997)	108.535 (0.000)*	35.580 (0.017)*

Q(30)	10.165 (0.999)	116.612 (0.000)*	37.064 (0.175)
Q(40)	12.260 (1.000)	120.463 (0.000)*	43.748 (0.315)

* denotes significantly less than 0.05.

All three financial variables demonstrate non-normality but are stationary as demonstrated by Guru & Sarma (2013). They are skewed and show excess kurtosis (except interest rates). Significant Ljung-Box statistics for the series are shown for the rate of change- exchange rate and –interest rate. The series was modelled with appropriate ARMA models. Significant Ljung-Box statistics for the squared series are shown for the rate of change–interest rate and –reserves-to-M1. These will be dealt with appropriate ARCH/GARCH processes. The results for these are depicted in the next section (4.1.1).

The three figures depicted below (Figure 4.1, Figure 4.2, Figure 4.3) provide the movements of monthly exchange rate, interest rates and reserves-to-M1 for the period 1999 to 2017. The exchange rate is compared to the US dollar. The exchange rates were stable over this period although increased volatility can be seen in the year 2002 and 2009. Regarding interest rates, the fluctuations are more volatile, especially in 2002/2003 and 2008. Similar results are depicted for the reserves-to-M1 ratio. More information regarding the economic situation in South Africa is described in the next chapter.

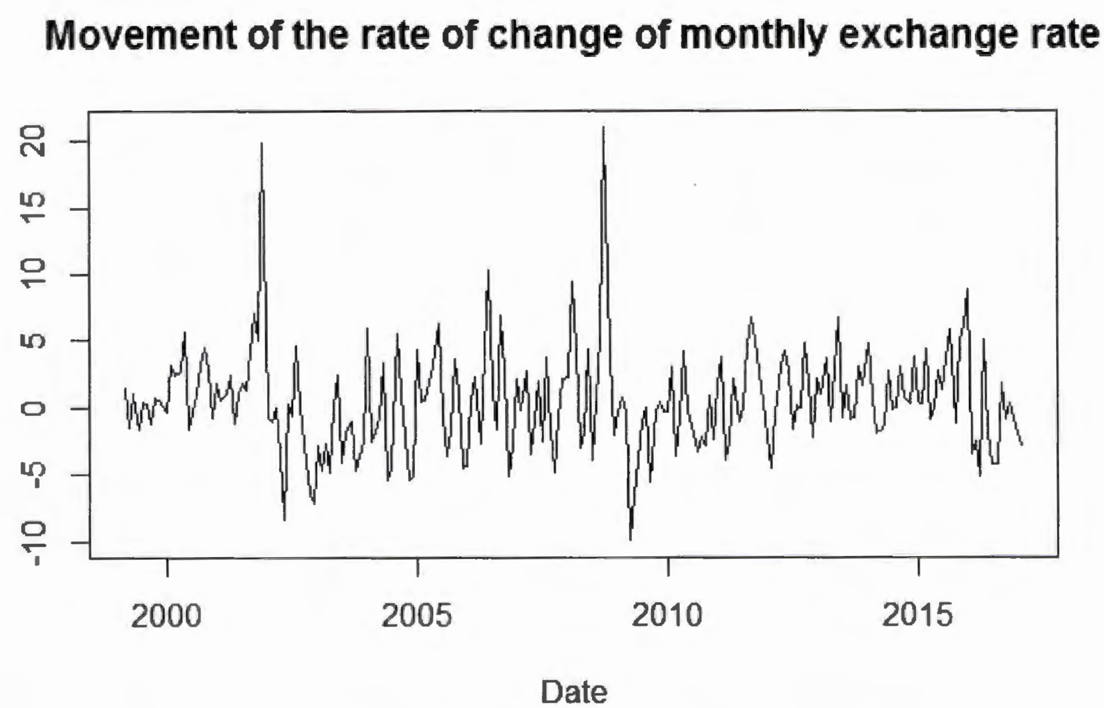

Figure 4.1: SA- Movement of the rate of change of monthly exchange rate

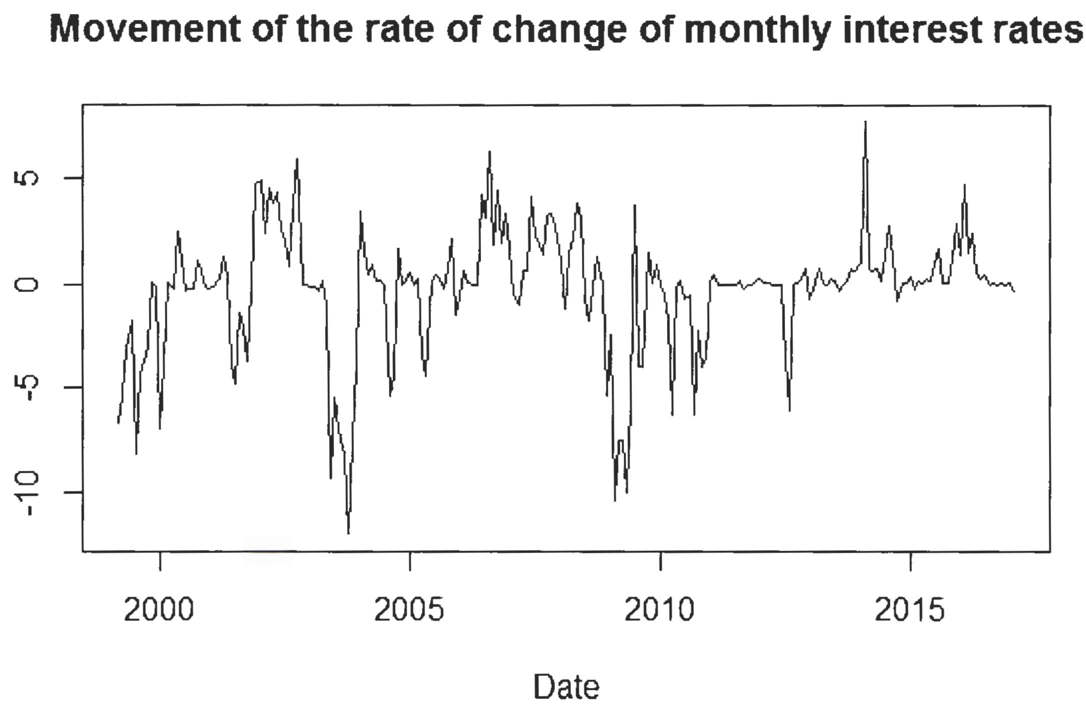

Figure 4.2: SA- Movement of the rate of change of monthly interest rates

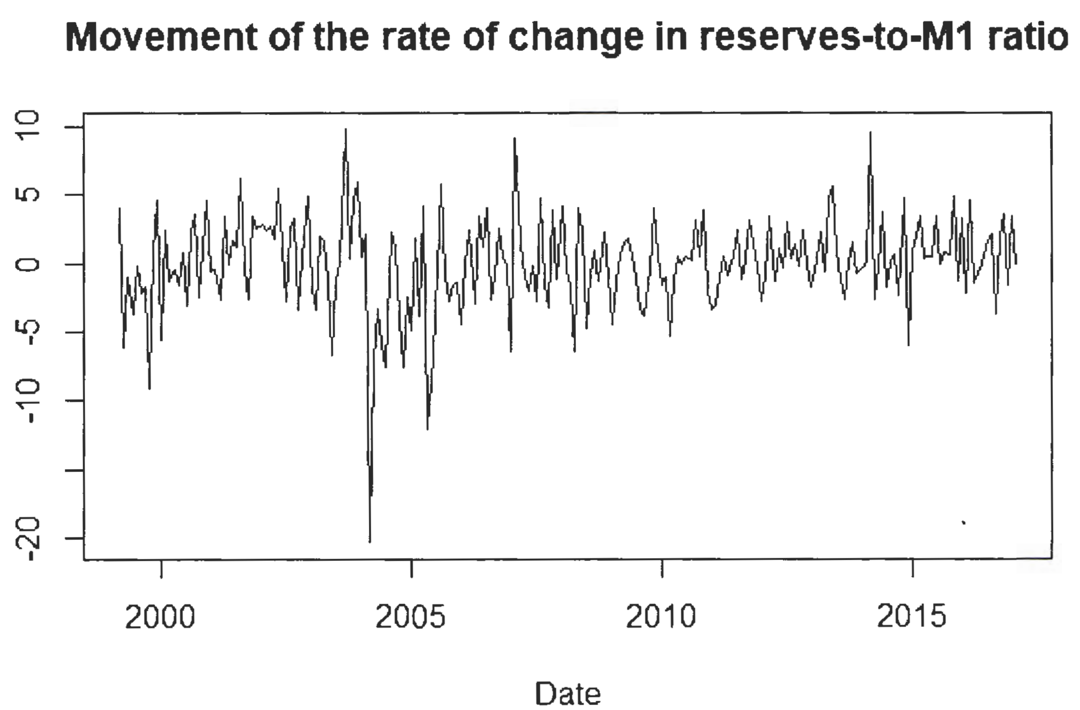

Figure 4.3: SA- Movement of the rate of change in reserves-to-M1 ratio

4.1.1 EMP INDEX CALCULATION

Using the exchange rate, interest rate and reserves-to-M1 data from South Africa, the EMP index can be calculated. This formula was also presented in Chapter 2.

$$EMP_t = e_t - \left[\sigma_e / \sigma_r \right] r_t + \left[\sigma_e / \sigma_i \right] i_t \text{ .... } 4.1$$

e_t: relative change in nominal exchange rate of ZAR against US dollar on month t

r_t: relative change in ratio of gross forex reserves to narrow money (reserves-to-M1) in month t

i_t :relative change in interest rate in month t

σ_e, σ_r, σ_i are the standard deviations of e_t, r_t and i_t.

However, before the respective standard deviations can be applied in the formula, we need to use the standardised standard deviations (for the variables in the EMP index that displayed conditional heteroscedasticity) to ensure that the assumption of iid holds. As such the EMP index requires the standardisation of the time varying volatilities. Consequently, the time series dynamics are displayed of each constituent of the series (Table 4.2, Table 4.3, and Table 4.4). These analyses were performed successfully in the study carried out by Guru & Sarma, (2013).

The e_t series demonstrated autocorrelation with significant Ljung-Box statistics for the mean series revealing an MA[1] process (Table 4.1).

Table 4.2: SA- Specification for the rate of change of exchange rate: A [MA(1)] model

Parameter	**Estimate**	**Standard error**
MA(1)		
Intercept	0.282	0.1053
MA(1)	0.5008	0.0578
AIC = 4.0915		
BIC = 4.1852		
Weighted Ljung-Box Test for residuals:	Weighted Ljung-Box Test on squared residuals:	
Q(1)= 0.005 (0.946)	Q(10) = 5.663 (0.773)	
Q(6)= 3.820 (0.701)	Q(15) = 6.999 (0.935)	
Q(25)= 20.523 (0.719)	Q(25) = 9.411 (0.997)	

The i_t series displayed autocorrelation with significant Ljung-Box statistics signifying an ARMA process. Moreover, the squared series also demonstrated serial-correlation suggesting a generalised autoregressive conditional heteroscedasticity (GARCH) effect (Table 4.1). The time series method of Box and Jenkins was applied and an appropriate model for the rate of changes in interest rate was found to be a AR(1)-GARCH(1,1) process. The information for this model and the diagnostic examination is presented in Table 4.3.

Table 4.3: SA- Specification for the rate of change of interest rate: A [AR(1)-GARCH(1,1)] model

Parameter	Estimate	Standard error	p-value
AR(1)- GARCH(1,1)			
μ	0.1228	0.1053	0.2433
AR(1)	0.5008	0.0578	0.0000
Omega	0.1911	0.2095	0.3617
Alpha 1	0.4216	0.1140	0.0002
Beta 1	0.5774	0.0753	0.0000
AIC = 4.0915			
BIC = 4.1852			
Weighted Ljung-Box Test for residuals:	Weighted Ljung-Box Test on squared residuals:	Weighted ARCH LM test	
Q(1)= 2.576 (0.109)	Q(1) = 0.388 (0.533)	Q(3) = 0.673 (0.412)	
Q(6)= 2.672 (0.066)	Q(15) = 1.132 (0.829)	Q(5) = 1.171 (0.683)	
Q(25)= 4.492 (0.157)	Q(25) = 1.679 (0.940)	Q(7) = 1.411 (0.839)	

Lastly, the r_t series showed significant Ljung-Box statistics for the squared series (heteroscedasticity) demonstrating a GARCH [1,1] process. The process is depicted in the table below (Table 4.4).

Table 4.4: SA- Specification for the rate of change of forex reserves to M1 ratio: A GARCH[1,1] model

Parameter	Estimate	Standard error	p-value
GARCH(1,1)			
μ	0.2068	0.2028	0.3079
Omega	0.3195	0.3004	0.2875
Alpha 1	0.0466	0.0254	0.0667
Beta 1	0.9219	0.0396	0.0000
AIC = 5.2325			
BIC = 5.3107			
Weighted Ljung-Box Test for residuals:	Weighted Ljung-Box Test on squared residuals:	Weighted ARCH LM test	
Q(1)= 0.000 (0.995)	Q(1) = 0.072 (0.788)	Q(3) = 0.793 (0.373)	
Q(2)= 0.015 (0.985)	Q(5) = 1.557 (0.726)	Q(5) = 1.725 (0.535)	
Q(5)= 0.670 (0.929)	Q(9) = 5.701 (0.334)	Q(7) = 5.418 (0.186)	

The standardised standard deviations of the respective ARMA and/or GARCH processes for each factor of the EMP index is used for the calculation of the EMP index.

An example of the R-code used is provided below.

R code example: Rate of change of Exchange rate (Descriptive statistics and ARMA/GARCH specifications)

Packages

```
library(tseries)

library(forecast)

library(FinTS)

library(fBasics)
```

#EXCHANGE RATE

```
ab<-ts(RSA$FX, frequency = 12, start=c(1999,3))

ab

plot(ab, xlab="Date", ylab="", main="Movement of the rate of change of monthly exchange rate")

basicStats(RSA$FX)

FinTS.stats(ab)

jarque.bera.test(ab) # Test for normality

adf.test(ab) # Test for stationarity

pp.test(ab) # Test for stationarity

ArchTest(ab, lag=1) # Test for ARCH effect

acf(ab, lag.max = 20) # ACF plot

pacf(ab, lag.max = 20) # PACF plot

auto.arima(ab) # To determine ARMA process

Box.test(RSA$FX, lag=20, type=c(("Ljung-Box"))) # Ljung-Box test for series

var=(RSA$RAT-mean(RSA$RAT))^2

Box.test(var, lag=20, type=c(("Ljung-Box"))) # Ljung-Box test for squared series


library(portes)

LjungBox(RSA$RAT, lag=20, squared.residuals=TRUE) # Ljung-Box test for squared series

library(rugarch)

model.garch = ugarchspec(mean.model=list(armaOrder=c(0,1)), variance.model=list(garchOrder=c(0,0)),distribution.model = "std") # ARMA / GARCH Model specification

model.garch.fit = ugarchfit(data=ab, spec=model.garch)

coef(model.garch.fit)

sigma(model.garch.fit)
```

```
model.garch.fit
fit<-arima (ab,order=c(0,0,1)) # if only MA specification
fit
coef(fit)
tsdiag(fit)
Box.test(residuals(fit),lag=25, type="Ljung-Box")
```


The calculation of the EMP index was performed in Microsoft Excel (2013) using the standardised standard deviations with no heteroscedasticity. Using these estimated volatilities and the EMP formula listed above the EMP index series from 1999 to 2017 was calculated. The descriptive statistics for the series is depicted in the table below (Table 4.5) and the movement of the EMP index series is schematically demonstrated in the accompanying figure (Figure 4.4). The series is shown to be non-normally distributed with a positive skew. Other studies performed on the analysis of EMP similarly demonstrated non-Gaussian distributions (Heinz & Rusinova, 2015; Guru & Sarma, 2013; Pozo & Amuedo-Dorantes, 2003). The time series analysis reported in Table 4.4 demonstrate that the EMP series is stationary with no autocorrelation for the series or squared series.

Table 4.5: SA- Descriptive and Standard time series tests for EMP index: 1999 to 2017

Descriptive statistics for the EMP series	
Mean	0.3081
Median	0.4923
Standard deviation	8.2586
Variance	68.2044
Minimum	-26.3520
Maximum	37.1180
Skewness	0.3167
Kurtosis	2.6897
Normality	
Jarque-Bera	71.363 (0.00)
Stationarity	
ADF test statistic	-5.2316 (0.01)
PP test statistic	-180.71 (0.01)
ARCH LM test	
Lag 1	0.3960 (0.529)
Autocorrelation test	
Ljung-Box Q statistic for series	
Q20	24.248 (0.232)
Q30	43.481 (0.053)
Heteroscedasticity test	
Ljung-Box statistic for squared series	
Q20	16.317 (0.697)
Q30	26.270 (0.661)

As schematically demonstrated in the figure below the EMP index reveals more or less constant volatility during the entire period. Several spikes of depreciation (positive value of the EMP index) can be seen in December 2001, March 2004, June 2006, October 2008, February 2014 and December 2015. The biggest of those is in February 2014.

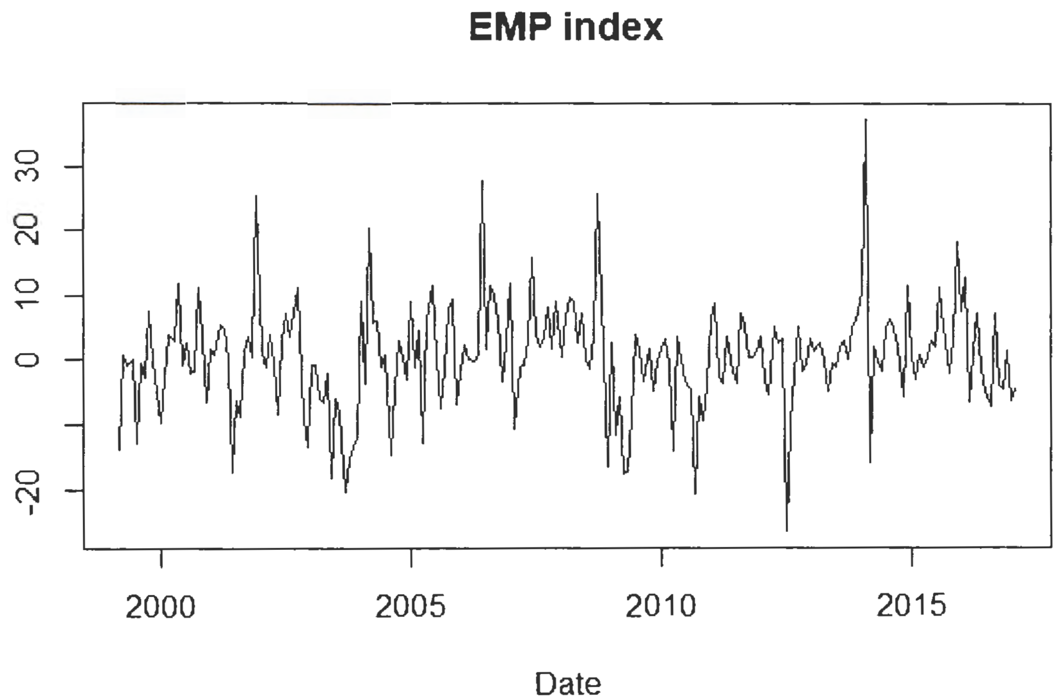

Figure 4.4: SA- Movement of the EMP index (1999 – 2017).

Since we have studied the EMP index in South Africa from 1999 to 2017, we now need to demonstrate the identification of a stress period. These are periods of extreme positive values in the EMP index. Periods of sustained stress over two or more periods are indicative of a currency crisis. The application of extreme value theory will be used to demonstrate these periods of extreme pressure and/or currency crisis.

4.1.2 EXTREME VALUE THEORY: PEAK OVER THRESHOLD ANALYSIS OF THE EMP INDEX

The study by Guru & Sarma (2013) chose a threshold value of the largest 20% of values. In our study we decided to use a threshold value of 15% of the data to be extreme observations as our South African data set is less volatile to that presented by Guru & Sarma (2013). The tail threshold (largest 15% of values) chosen is 7.00. This equates to the largest 35 values. In the accompanying figure (Figure 4.5), it is evident that the POT estimates levels off and becomes stable after thirty-five observations.

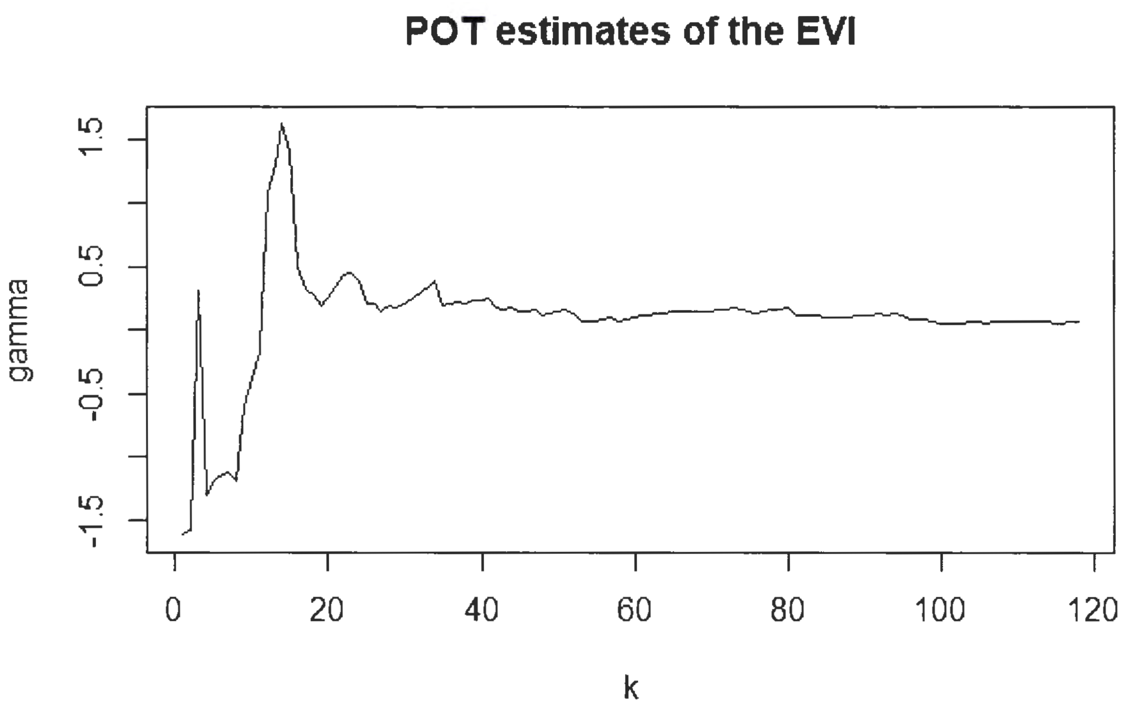

Figure 4.5: SA- Peak over threshold estimates to determine the threshold value

Using this threshold value, we proceeded to fit a generalized Pareto distribution (GPD) to the values exceeding 7.00. The maximum likelihood estimation method is utilized. The analysis was conducted in the statistical program R. The code is provided in the next section. The package fExtremes (Wuertz et al., 2013) is used for the analysis. Consequently, the estimated parameters are used to calculate crisis thresholds at the 95th percentile and 99th percentile. The formula used for the peak over threshold method is:

$$X_p = \mu + \sigma/\xi\left[\left(np/k\right)^{-\xi} - 1\right]$$

....4.2

n = 216,

k= 35 (number of observations above the threshold μ),

$\hat{\sigma}$, $\hat{\xi}$: maximum likelihood estimates of the GPD parameters (see Table 4.6)

Usually, when using the POT approach, one would implement the probability stress threshold fixed at 0.05 (95th percentile) or at 0.01 (99th percentile). Using the formula listed in the previous paragraph, the entire tail region can be calculated using different p-quantiles. The table below (Table 4.6) depicts the parameters estimated by the GPD.

Table 4.6: SA- Generalised Pareto Distribution: Peak over threshold estimation results for the EMP series

% of observations above the threshold	Amount of observations above the threshold	Threshold (u)	Shape parameter (ξ)	Scale parameter (σ)	P=0.05 95th percentile	P=0.01 99th percentile
15%	35	7.00	0.400	3.415	12.13	24.48

The shape parameter was shown to be 0.400, which is a positive number and indicative of the heavy-tailed and Frechet distribution. The results in Table 4.5 also revealed non-normality (Jarque-Bera statistic) and excess kurtosis. The Histogram of the EMP index confirms the positive skew and kurtosis (Figure 4.6).

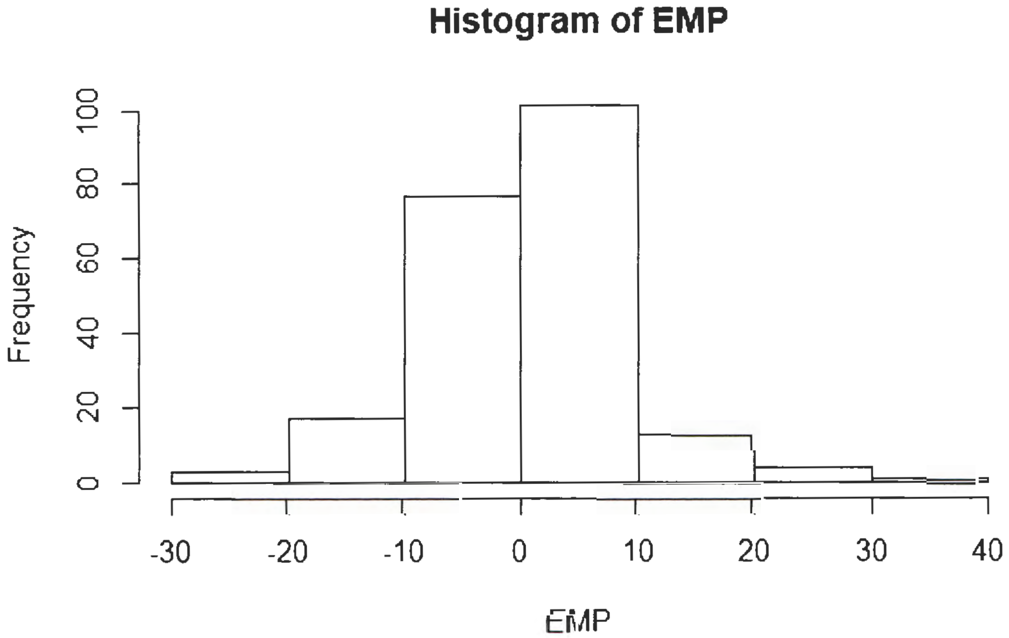

Figure 4.6: SA- Histogram of the EMP index for the period 1999 to 2017

The following four figures demonstrate the diagnostic plots for the fitted distribution (Figure 4.7, Figure 4.8, Figure 4.9, Figure 4.10). The observations are fitted well for the tail and excess of the underlying distribution (Figure 4.7 & Figure 4.8). The figures demonstrate a good fit with the peak over threshold method (using maximum likelihood estimation), with the use of the top 15% values. In figure 4.9, the scatterplot of the residuals is random and spread with the red line nearly parallel to the X-axis indicating a good fit. The residuals in the QQ-plot are also fitted close to the 45 degree line in the next figure (Figure 4.10).

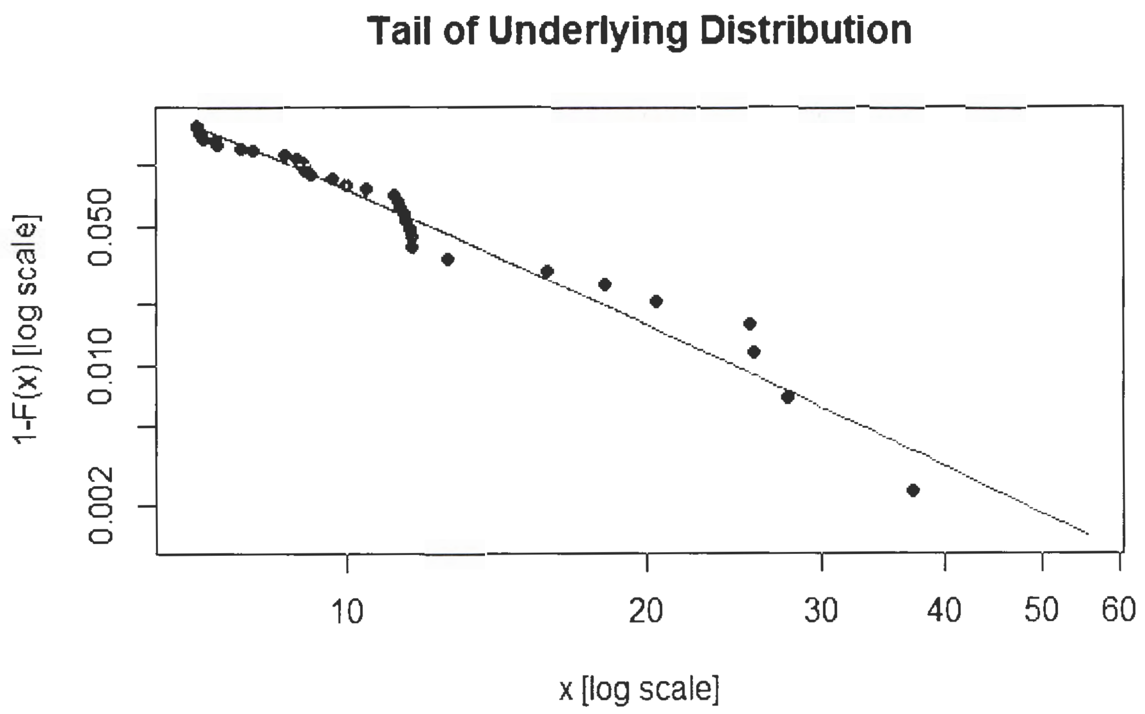

Figure 4.7: SA- Diagnostic plot for Peak over threshold analysis: Tail of the underlying distribution

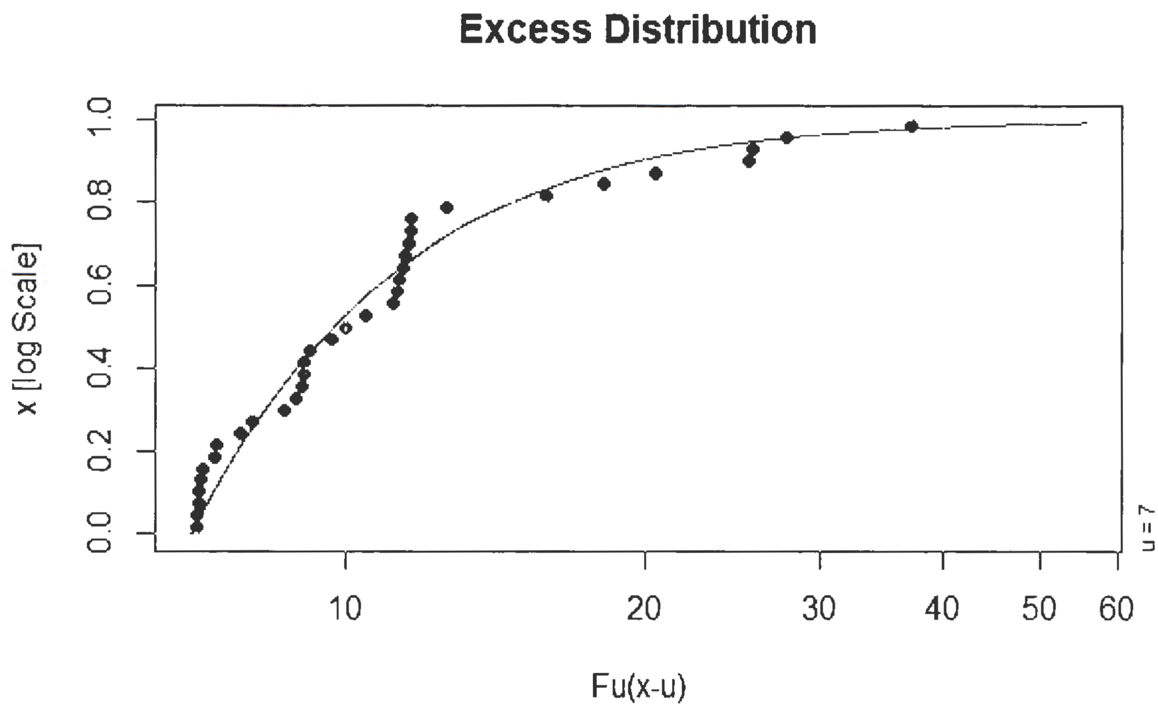

Figure 4.8: SA- Diagnostic plot for Peak over threshold analysis: Excess distribution

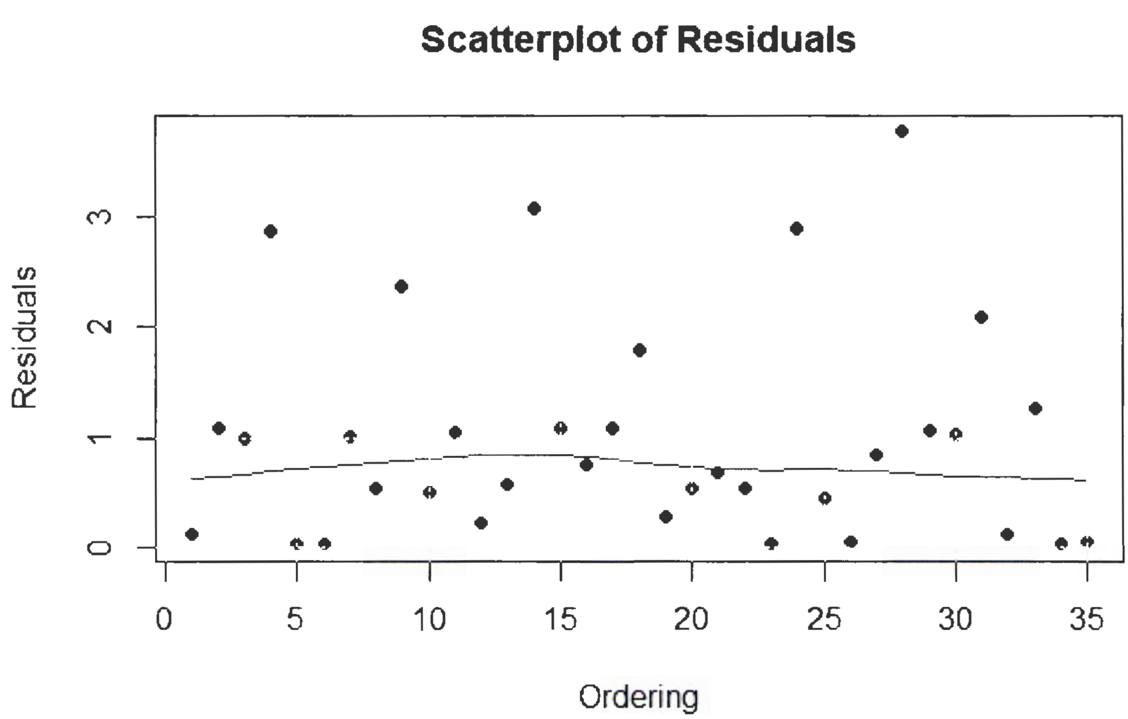

Figure 4.9: SA- Diagnostic plot for Peak over threshold analysis: Scatterplot of the residuals

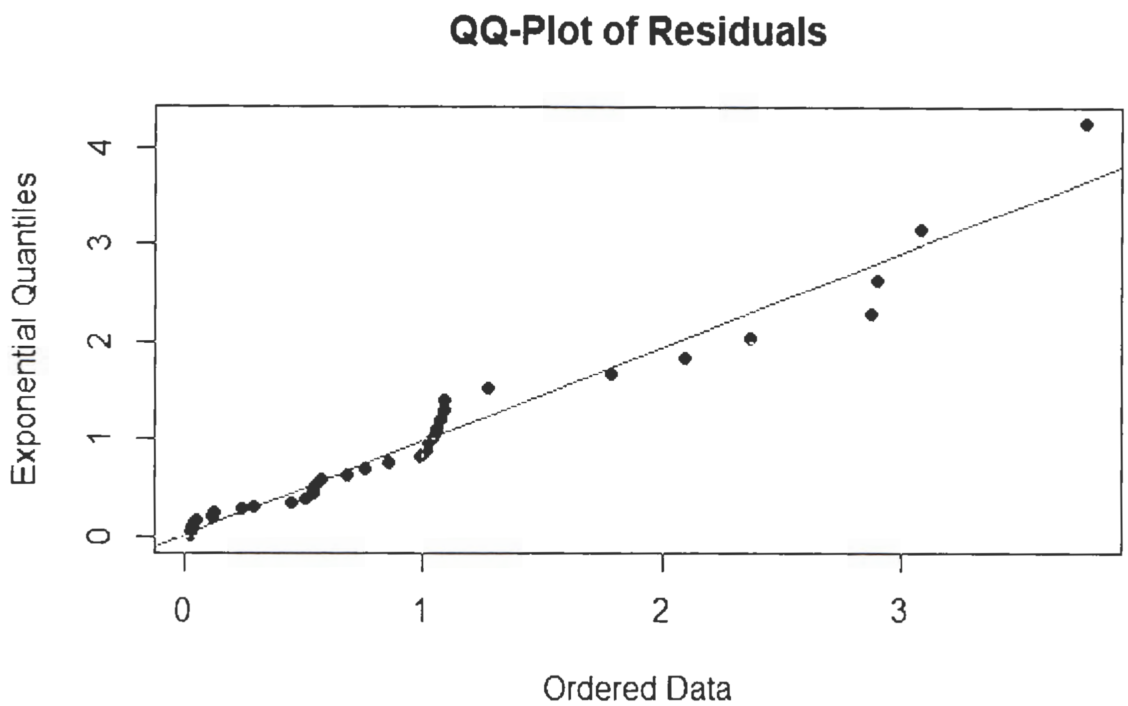

Figure 4.10: SA- Diagnostic plot for Peak over threshold analysis: QQ-plot of the residuals

The estimated 95th percentile for the EMP index is 12.13 and 24.48 for the 95th and 99th percentile. These are indicative of the crisis threshold or stress periods at 0.01 and 0.05 probabilities respectively. EMP values larger than these thresholds would indicate period of stress/crisis at the corresponding probability levels. Table 4.7 demonstrates that the EVT quantiles fit the empirical quantiles better than the normal distribution quantiles as reported in Guru & Sarma (2013). The normal distribution crisis based thresholds are very low and therefore, many false alarms would be raised. As studied in the table (Table 4.7), it is clear that the model is accurate for values up to the 95th percentile, and that the accuracy of the estimated quantiles for the 96th to 99,99th percentile decreases. However, the model still provides a better fit when compared to the normal distribution.

Table 4.7: SA- Estimated tail quantiles of the EMP index: 1999-2017

Probability level	Estimated quantiles (EVT)	Empirical quantiles	Normal distribution quantiles	Estimated quantile (Hill)
0.80	6.31	5.45	0.842	5.83
0.81	6.47	5.98	0.878	5.99
0.82	6.65	6.12	0.915	6.17
0.83	6.84	6.30	0.954	6.37
0.84	7.04	6.45	0.995	6.58
0.85	7.27	7.12	1.036	6.81
0.86	7.51	7.15	1.080	7.07
0.87	7.79	7.41	1.126	7.36
0.88	8.09	7.86	1.175	7.69
0.89	8.43	8.68	1.227	8.06
0.90	8.82	9.05	1.282	8.49
0.91	9.26	9.19	1.341	8.98
0.92	9.78	10.03	1.405	9.58
0.93	10.41	11.17	1.476	10.29
0.94	11.17	11.32	1.555	11.19
0.95	12.13	11.50	1.645	12.35
0.96	13.40	11.65	1.751	13.94
0.97	15.23	15.89	1.881	16.29
0.98	18.18	20.50	2.054	20.29
0.99	24.48	25.73	2.326	29.54
0.9950	32.80	27.80	2.576	43.00
0.9990	63.84	37.12	3.090	102.83

Hill estimate is discussed in the latter part of the SA data

In the current study, an EMP index larger than 12.13 would be indicative of currency stress at p=0.05 (GPD POT). As such, eight periods of stress are highlighted. At p=0.01 (values larger than 24.48), four periods of extreme stress or crisis are highlighted between 1999 and 2017 (GPD POT). The months affected are: December 2001; March 2004; June 2006; June 2007; October 2008; February 2014; December 2015; February 2016. If currency crisis is defined as periods of two consecutive months of stress, none such periods are found. The four periods of extreme pressure with p=0.01 are: December 2001; June 2006; October 2008; February 2014. If the current study used normally distributed thresholds at p=0.05, 92 exceedances would have been raised causing many false positive warnings. If the Hill estimate is used (right hand column), the same periods of time would be selected at p=0.05, but at p=0.01 only one period of extreme pressure is flagged.

In the next section, the stress period (p=0.05) is reflected in Table 4.8 with the individual factors of the EMP index. The highlighted cells show the individual components mostly responsible for the high EMP values during the respective periods. In December 2001, June 2006, October 2008 and December 2015, the rate of change in exchange rates were the most influential values on the EMP index. In June 2007, February 2014 and February 2016, the rate of change in interest rates were the most powerful values for driving the EMP index into an extreme positive index. Lastly, in March 2004, the rate-in-change in reserves-to-M1 was the most prominent component to influence the EMP index. Although a near currency crisis was elicited in January 2014 and February 2014, values of the EMP index returned to normal in March 2014. Also, fortunately the value for the EMP index for January 2014 was not indicative of severe currency pressure (p=0.01).

Similar results for periods of stress or crises are also reported in Asian studies (Guru & Sarma, 2013; Pozo & Amuedo-Dorantes, 2003). The study by Guru & Sarma (2013) also reported the influence of the individual components in periods of extreme pressure.

Table 4.8: SA- Extreme pressure or crisis of the EMP index with individual components for each month

Month of extreme EMP	EMP	Component of the EMP index		
		Rate-in-change Exchange rate	Rate-in-change Interest rate	Rate-in-change -Reserves-to-M1
December 2001	25.43	19.86	4.73	2.53
March 2004	20.50	-2.02	0.43	-20.37
June 2006	27.80	10.32	4.29	1.22
June 2007	15.89	1.97	4.18	-0.23
October 2008	25.73	21.01	1.29	-1.41
February 2014	37.12	0.69	7.77	0.03
December 2015	18.21	6.08	2.98	-1.36
February 2016	12.66	-3.41	4.78	-2.30

The **R code** used for extreme value theory (GPD and Peak over threshold) is provided below:

```
library(fExtremes)

library(ExtRemes)

library(relns)

bfit<-gpdFit(RSAGARCH$EMP, u=7.00)

bfit

plot(bfit)

summary(bfit)

gpdQuantPlot(RSAGARCH$EMP, threshold=7.00, type="GP")

gpdRiskMeasures(bfit)

gpdRiskMeasures(bfit, prob = c(0.80, 0.81, 0.82, 0.83, 0.84, 0.85, 0.86, 0.87, 0.88, 0.89, 0.90,
0.91, 0.92, 0.93, 0.94, 0.95, 0.96, 0.97, 0.98, 0.99, 0.995, 0.999, 0.9995, 0.9999))

print(bfit, ci=0.95); summary(bfit, ci=0.95)
```

4.1.3 EXTREME VALUE THEORY: HILL ESTIMATE

Quantiles calculated according to the Hill estimate are also provided in Table 4.7. Figure 4.11 below confers with the earlier decision to use a threshold value of 7.00 (that is K=35). A parallel line to the X-axis can be drawn up to k=35. The largest 35 values were sorted from largest to smallest (rank ordered), and formula 4.3 (Kang & Song, 2017; Hill, 1975) was applied to determine the Hill estimate (Xi [Hill]).

$$\xi_n = \frac{1}{n}\sum_{i=1}^{n} \log X_i - \log X_{n+1} \quad \text{.......} 4.3$$

The Hill estimate calculated is 0.54172

The 100p[th] quantile using the Hill estimator was also computed according to formula 4.4 (Kang & Song, 2017). The analysis was also run in R (package ReIns). The code for the R package is provided below.

$$X_p = X_{n+1}\left[n + \frac{1}{N+1}\right]^{\xi_n} \quad \text{.......} 4.4$$

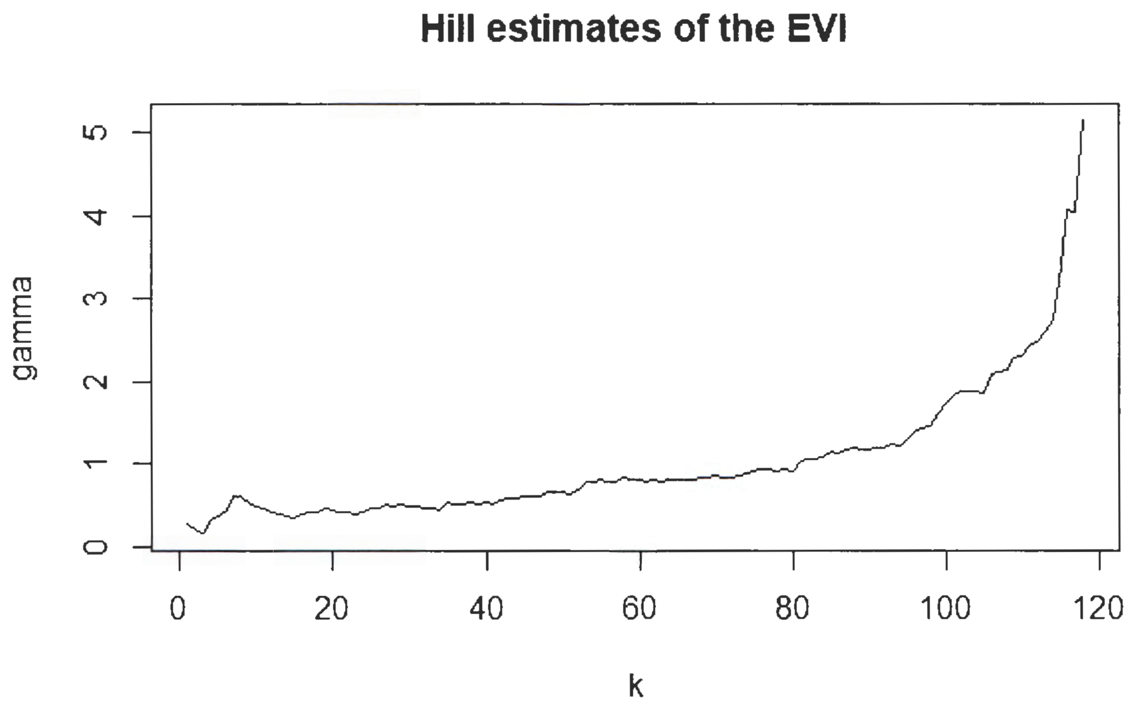

Figure 4.11: SA- Hill estimate to obtain cut-off between tail and central observations

When studying Table 4.7, it is clear that the GPD POT method outperforms the Hill estimate (compared to the empirical quantiles) at higher quantiles (p=0.001 to p=0.10) where the risk of extreme crises becomes more formidable. However, there are instances where the Hill estimate provides a better index compared to the GPD POT method and especially so at percentiles of 0.80 to 0.89.

The **R code** used for extreme value theory (Hill estimate) is provided below

```
Library (ReIns)

Hill(RSAGARCH$EMP[RSAGARCH4EMP>0])gamma[35]

Hill(RSAGARCH$EMP[RSAGARCH4EMP>0], plot=TRUE)
```

The next section focuses on the EMP of another African country.

4.2 KENYAN DATA

Table 4.9 provides information about descriptive statistics, normality, stationarity and serial-correlation for the three components of the EMP index for the period August 2008 to February 2017. All three financial variables demonstrate non-normality but are stationary. They are skewed and show excess kurtosis (except rate of change in reserves-to-M1). No significant Ljung-Box statistics for the series or squared series for any lags are shown for any of the three components of the EMP index. As a consequence all variables demonstrate no time varying volatilities and do not need to be modelled with ARMA and/or ARCH/GARCH processes.

Table 4.9: Kenya- Descriptive statistics and time series tests of components of Exchange Market Pressure

	Rate of change of exchange rate	Rate of change of interest rate	Rate of change in reserves-to-M1
Descriptive statistics			
Mean	1.2113	1.7749	0.1961
Median	0.3675	0.0000	0.2454
Standard Deviation	4.1471	22.7226	4.7410
Minimum	-7.9584	-54.9211	-22.9134
Maximum	31.4292	230.0882	14.4729
Skewness	2.5134	5.2549	-0.6876
Excess Kurtosis	14.1578	50.1740	2.5784
Jarque-Bera	1915.7 (0.00)*	22254 (0.00)*	73.487 (0.00)*
Stationarity test			
ADF test statistic	-5.2867 (0.01)*	-4.8719 (0.01)*	-5.8741 (0.01)*
PP test statistic	-229.2 (0.01)*	-167.92 (0.01)*	-167.92 (0.01)*
ARCH LM test			
Lag 1	0.0147 (0.904)	0.0008 (0.977)	1.1990 (0.2735)
Lag 5	0.3515 (0.997)	0.1289 (0.999)	1.7745 (0.879)
Lag 10	1.3861 (0.999)	0.2248 (1.000)	3.9088 (0.9514)
Autocorrelation test			
Ljung-Box Q statistic for series			
Q(20)	18.143 (0.578)	21.077 (0.393)	24.972 (0.203)
Q(30)	31.899 (0.372)	31.745 (0.380)	30.295 (0.451)
Q(40)	50.044 (0.133)	35.020 (0.694)	42.084 (0.381)
Heteroscedasticity test			
Ljung-Box Q statistics for squared series			
Q(20)	2.045 (0.999)	0.593 (1.000)	7.707 (0.994)
Q(30)	17.158 (0.971)	1.286 (1.000)	26.071 (0.672)
Q(40)	18.018 (0.999)	1.878 (1.000)	31.009 (0.845)

* denotes significantly less than 0.05.

The three figures depicted below (Figure 4.12, Figure 4.13, Figure 4.14) provide the movements of monthly exchange rate, interest rates and reserves-to-M1 for the period 2000 to 2017. The exchange rate is compared to the US dollar. The exchange rates were stable over this period although increased volatility can be seen in the mid-year of 2014. For the second component namely, interest rates, the fluctuations are less volatile, but large increases are observed throughout 2005. Although Figure 4.14 demonstrates the most volatility for reserves-to-M1 ratio, the fluctuations are relatively stable over time with only one large negative spike in mid-2014.

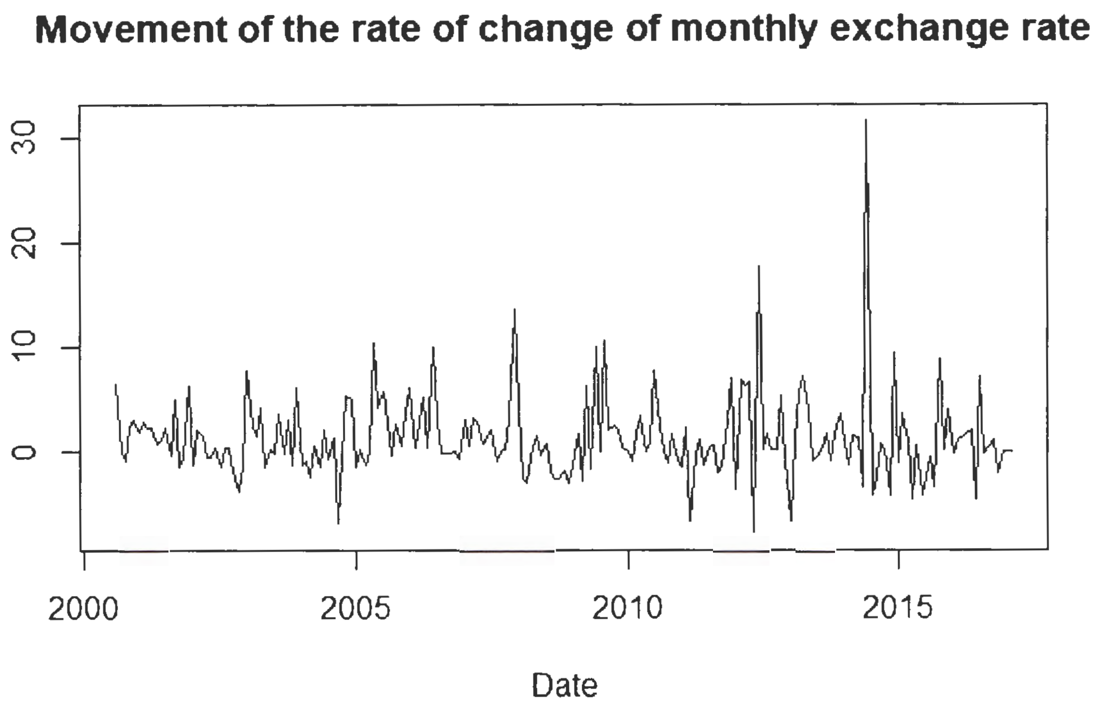

Figure 4.12: Kenya- Movement of the rate of change of monthly exchange rate

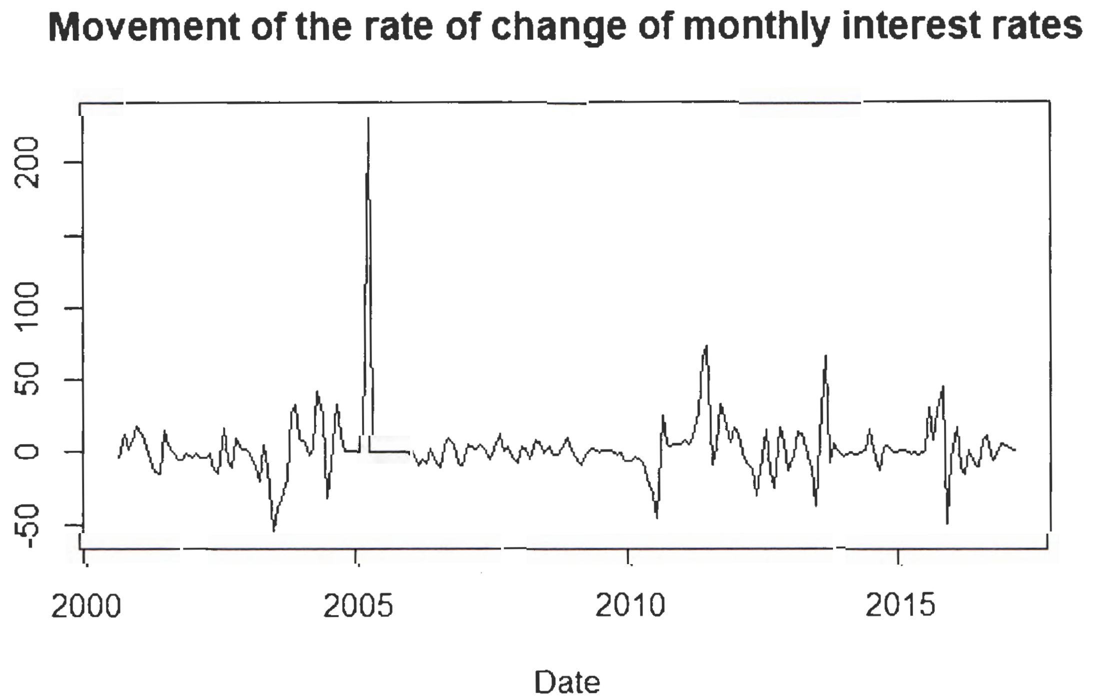

Figure 4.13: Kenya- Movement of the rate of change of monthly interest rates

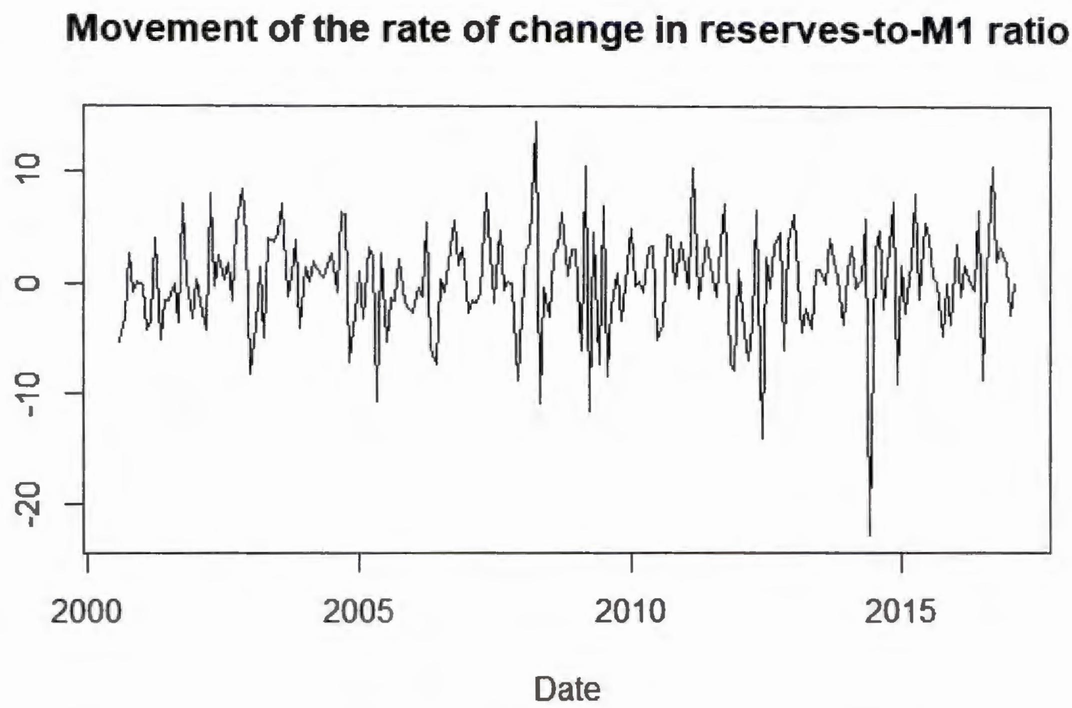

Figure 4.14: Kenya- Movement of the rate of change in reserves-to-M1 ratio

4.2.1 CALCULATION OF THE EMP INDEX

Using the three components of the EMP index for Kenya, the exchange market pressure for monthly data can be calculated (formula 4.1).

As stated earlier, the respective standard deviations can only be applied when each variable is independent and identically distributed. Consequently, EMP index requires the standardisation of the time varying volatilities (Guru & Sarma, 2013). None of the three variables for the Kenyan data displayed time varying volatility for the mean and series (no heteroscedasitcity).

The calculation of the EMP index was performed in Microsoft Excel (2013). The EMP index series was calculated from August 2000 to February 2017. The descriptive statistics for the series (Table 4.10) and a schematic presentation of the EMP index (Figure 4.15) is provided. The results of the series show that it is not normally distributed with a positive skew. A large value for Kurtosis is reported. The time series analysis depicted in Table 4.10 reveals that the series is stationary with no serial-correlation for the mean or squared series.

Table 4.10: Kenya- Descriptive and Standard time series tests for EMP index: August 2000 to February 2017

Descriptive statistics for the EMP series	
Mean	1.3637
Median	0.6002
Standard deviation	8.7584
Variance	76.7098
Minimum	-19.4800
Maximum	54.0353
Skewness	1.6646
Kurtosis	7.0402
Normality	
Jarque-Bera	516.23 (0.00)*
Stationarity	
ADF test statistic	-5.66 (0.01)*
PP test statistic	-224.56 (0.01)*
ARCH LM test	
Lag 1	0.004 (0.95)
Autocorrelation test	
Ljung-Box Q statistic for series	
Q20	18.281 (0.569)
Q30	27.066 (0.620)
Heteroscedasticity test	
Ljung-Box statistic for squared series	
Q20	4.850 (0.999)
Q30	17.153 (0.971)

* denotes significantly less than 0.05

The figure of the EMP index illustrates relatively constant volatility during the studied period. Several spikes of depreciation (positive value of the EMP index) are shown in early 2003 and mid-2014. These are discussed in greater detail in the next section. Extreme value theory was applied to demonstrate possible periods of extreme pressure and/or currency crisis.

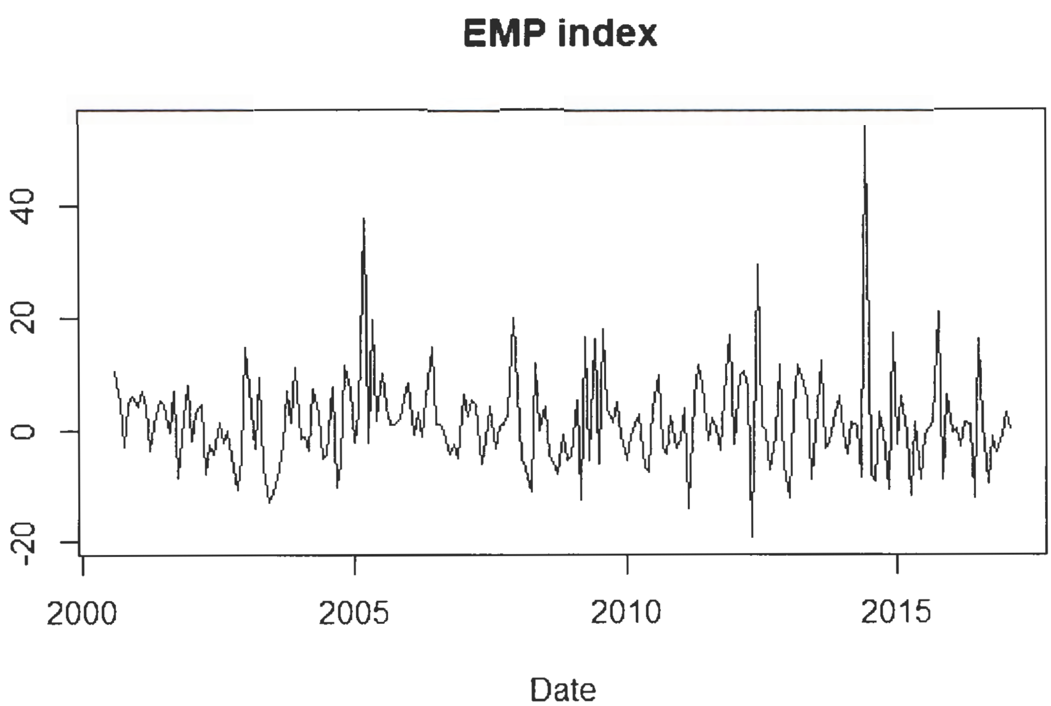

Figure 4.15: Kenya- Movement of the EMP index (August 2000 – February 2017).

4.2.2 EXTREME VALUE THEORY: PEAK OVER THRESHOLD ANALYSIS OF THE EMP INDEX

For the Kenyan data, the researcher used a threshold value of 20% similar to the study by Guru & Sarma (2013). The data set contains 199 observations. 20% of 199 equates to 40 values. Consequently, the threshold value for the Kenyan data set is 6.50. In the supplementary figure (Figure 4.16), it is clear that the POT estimate levels off and becomes stable after 40 observations. Subsequently, a generalised Pareto distribution (GPD) to the values exceeding 6.50 can be fitted (formula 4.2). The maximum likelihood estimation method is utilized.

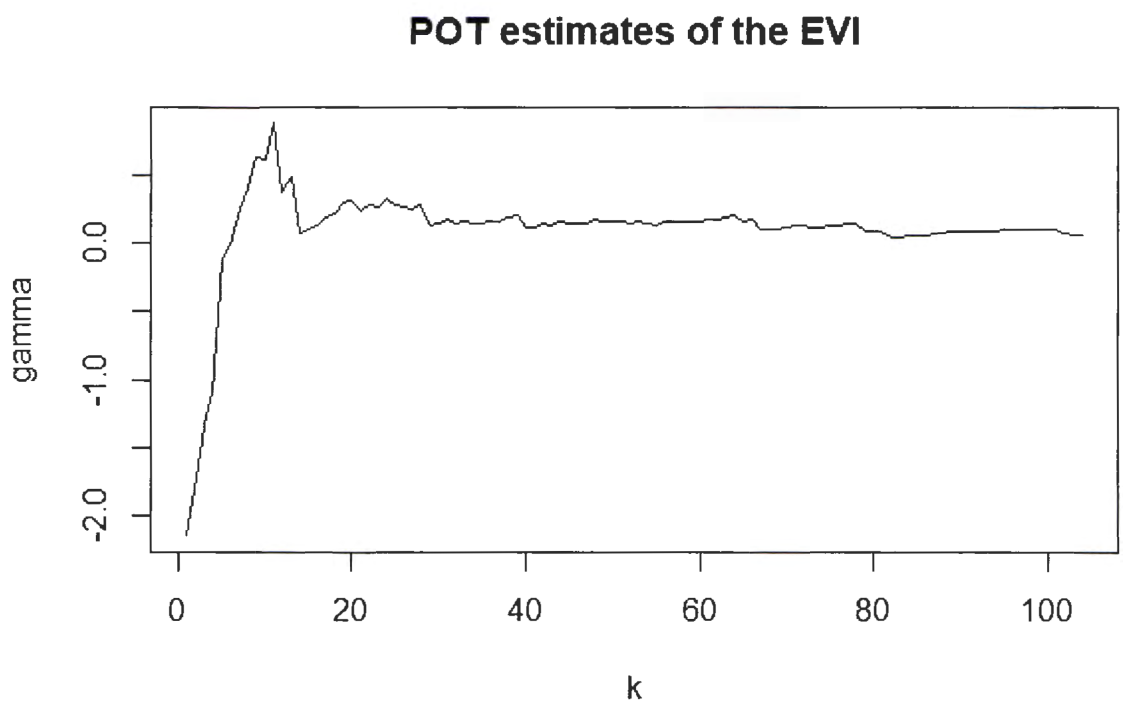

Figure 4.16: Kenya- Peak over threshold estimates to determine the threshold value

The table below (Table 4.11) depicts the parameters estimated by the GPD.

Table 4.11: Kenya- Generalised Pareto Distribution: Peak over threshold estimation results for the EMP series of the Kenyan data

% of observations above the threshold	Number of observations above the threshold	Threshold (u)	Shape parameter (ξ)	Scale parameter (σ)	P=0.05 95th percentile	P=0.01 99th percentile
20%	40	6.50	0.1662	6.1756	16.17	30.53

The shape parameter is 0.166 which is a positive number and indicative of a Frechet (heavy-tailed distribution). The results in Table 4.10 also revealed non-normality and excess kurtosis. The Histogram reiterates a positive skew and is leptokurtic (Figure 4.17).

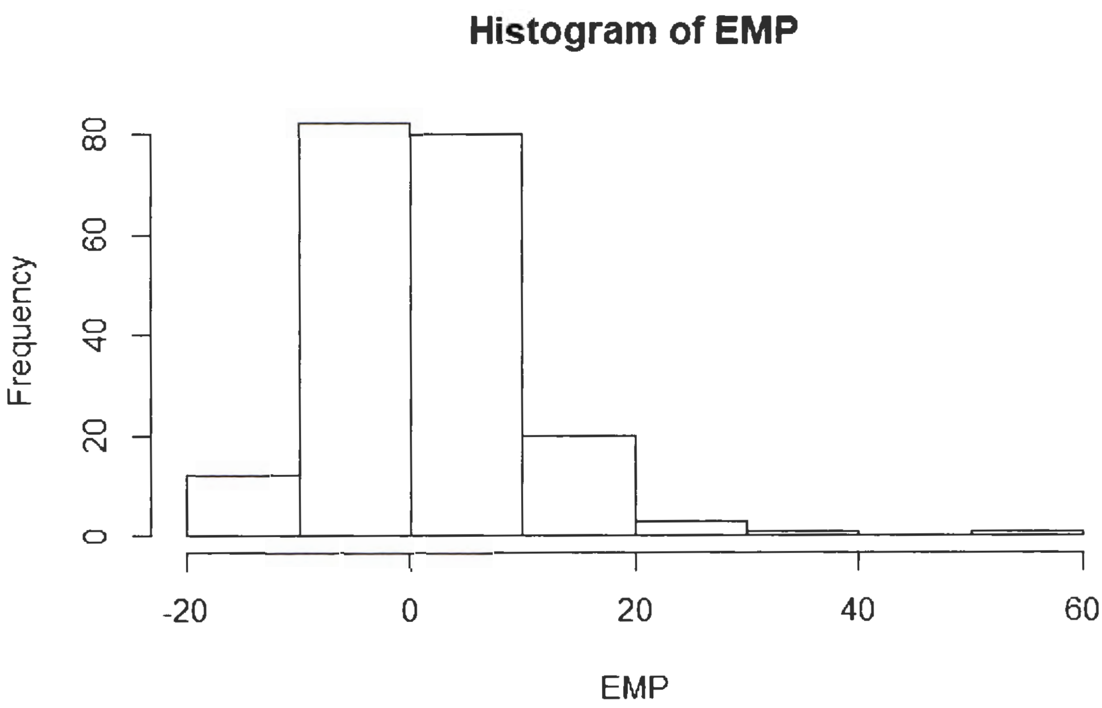

Figure 4.17: Kenya- Histogram of the Kenyan EMP index for the period 2000 to 2017

Figure 4.18 - Figure 4.21 demonstrate the diagnostic plots for the GPD (peak over threshold) fitted distribution for Kenya. The observations exceeding the threshold value of 6.50 are fitted well for the tail and excess of the underlying distribution (Figure 4.18 & Figure 4.19). The scatterplot of the residuals (Figure 20) is random and spread with the red line nearly parallel to the X-axis indicating a good fit. The residuals in the QQ-plot are also fitted close to the 45 degree line in the next figure (Figure 21).

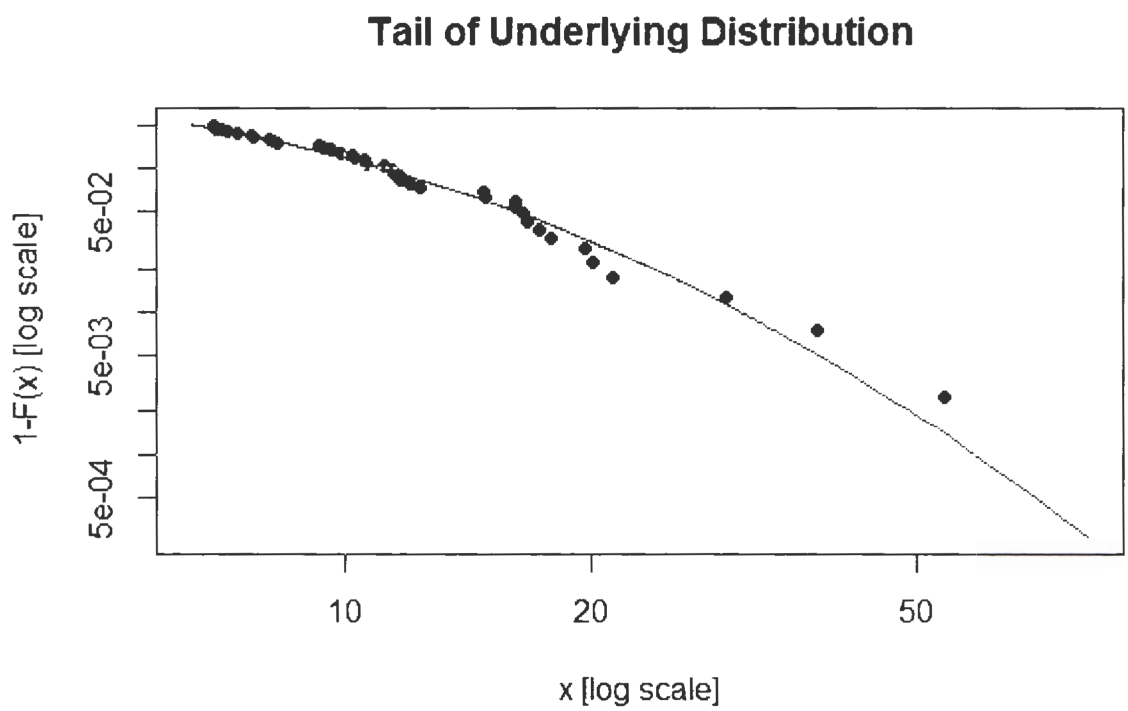

Figure 4.18: Diagnostic plot for Peak over threshold analysis: Tail of the underlying distribution

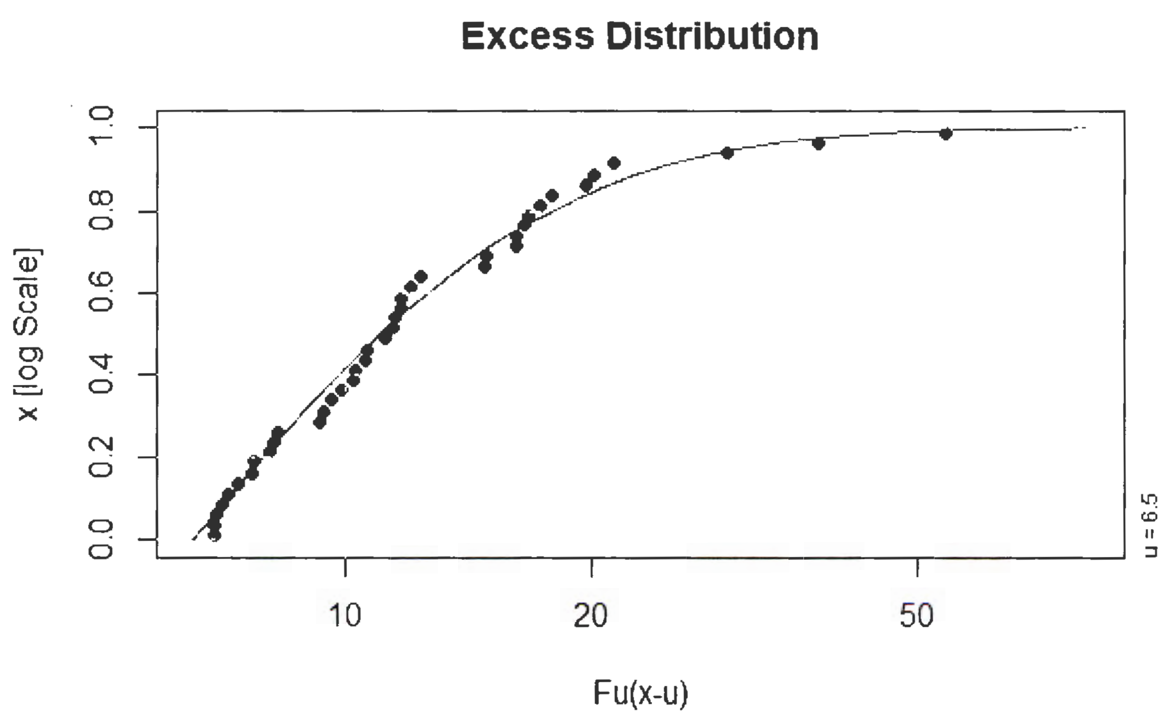

Figure 4.19: Kenya- Diagnostic plot for Peak over threshold analysis: Excess distribution

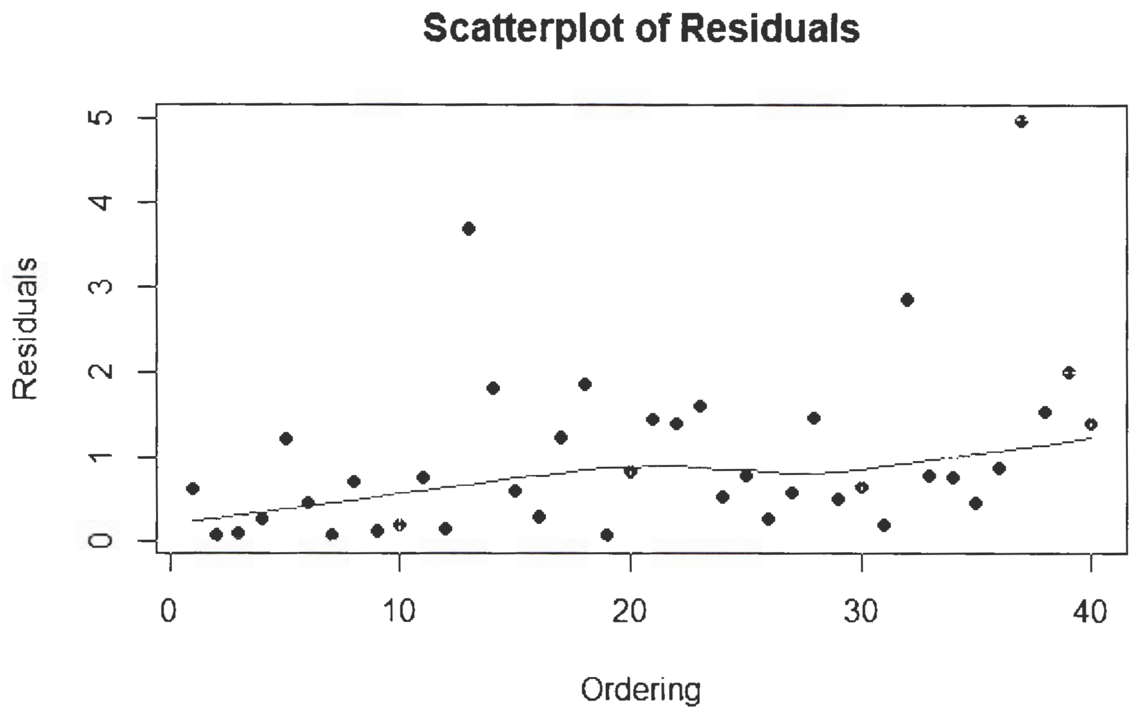

Figure 4.20: Kenya- Diagnostic plot for Peak over threshold analysis: Scatterplot of the residuals

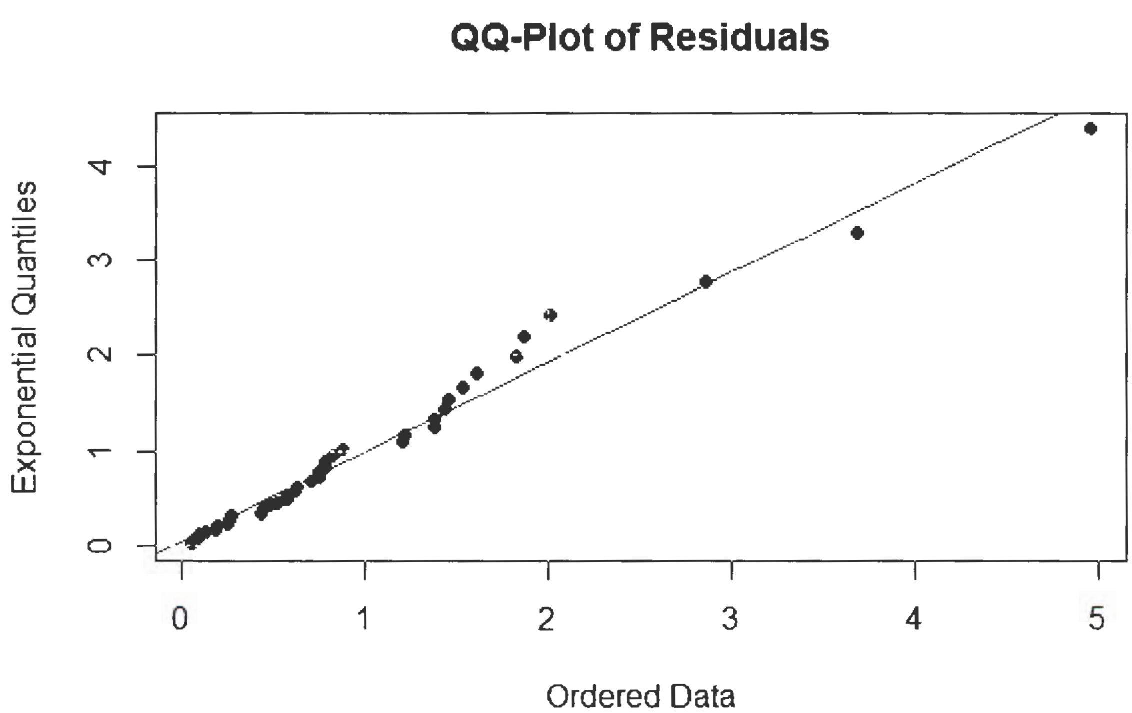

Figure 4.21: Kenya- Diagnostic plot for Peak over threshold analysis: QQ-plot of the residuals

The estimated 95th percentile for the EMP index is 16.17 and 30.53 for the 99th percentile. EMP values greater than these percentile-based-thresholds would indicate period of stress/crisis at the corresponding probability levels. Table 4.12 demonstrates that the EVT quantiles fit the empirical quantiles better than the normal distribution quantiles. The Hill estimated quantiles are discussed in the next section (4.2.3)

Table 4.12: Kenya- Estimated tail quantiles of the EMP index

Probability level	Estimated quantiles (EVT)	Empirical quantiles	Normal distribution quantiles	Estimated quantile (Hill)
0.80	6.53	6.18	0.842	6.28
0.81	6.85	6.91	0.878	6.51
0.82	7.12	7.08	0.915	6.75
0.83	7.55	7.36	0.954	7.02
0.84	7.94	7.73	0.995	7.31
0.85	8.35	8.16	1.036	7.64
0.86	8.80	9.31	1.080	8.01
0.87	9.29	9.62	1.126	8.42
0.88	9.83	10.23	1.175	8.90
0.89	10.42	10.55	1.227	9.44
0.90	11.07	11.18	1.282	10.07
0.91	11.81	11.46	1.341	10.82
0.92	12.65	11.70	1.405	11.72
0.93	13.62	12.37	1.476	12.83
0.94	14.77	14.85	1.555	14.25
0.95	16.17	16.13	1.645	16.14
0.96	17.94	16.71	1.751	18.78
0.97	20.32	17.92	1.881	22.84
0.98	23.87	20.06	2.054	30.09
0.99	30.53	29.17	2.326	48.21
0.9950	37.99	37.88	2.576	77.25
0.9990	59.05	54.04	3.090	230.85

Hill estimate data discussed in latter part of chapter

In this study, an EMP index greater than 16.17 would be indicative of currency stress at p=0.05 (GPD POT). As such, ten periods of stress are identified. At p=0.01 (values greater than 30.53), two periods of extreme stress are identified between 2000 and 2017 (GPD POT). The months affected are: March and May 2005, December 2007, April 2009, August 2009, November 2011, June 2012, June and December 2014 and October 2015. No period of currency crisis was defined which is periods of two consecutive months of stress. The two periods of extreme pressure (p=0.01) are: March 2005 and June 2014. If the current study employed normally distributed thresholds (p=0.05), 82 exceedances would have been raised causing many unnecessarily flagged periods. The same periods are flagged when the Hill estimate is used for the 95th percentile. However, at the 99th percentile no time-periods demonstrate pressure situations from 2000-2017.

Because the EMP index and extreme periods of stress have been identified, it is possible to explore in more detail what economic activities transpired at this time. Table 4.13 is representative of the individual factors of the EMP index. The highlighted cells display the individual components mostly responsible for the high EMP values during these ten periods. During March 2005, the rate of change in interest rates were the most influential value on the EMP index. However, during June 2014, both the rate-in-change in exchange and interest rate were responsible for driving the EMP index into an extreme positive index. Fortunately, during July 2014, all components returned to stable values free of extreme pressure. Regarding values exceeding p=0.05, seven of the remaining eight pressure situations, the rate-in-change in exchange rate was mostly responsible. Moreover, during November 2011 and October 2015, the rate-in-change in interest rate was also responsible. Similar results are reported in the study by Guru & Sarma (2013) where individual components are identified as the most likely contributors of extreme pressure. In their study, the rate-in-change in exchange rate and interest rate were individually and at different periods, responsible for all incidents of pressure.

Table 4.13: Kenya- Extreme pressure or crisis of the EMP index with individual components for each month

Month of extreme EMP	EMP	Component of the EMP index		
		Rate-in-change Exchange rate	Rate-in-change Interest rate	Rate-in-change -Reserves-to-M1
March 2005	25.43	-1.41	15.26	3.09
May 2005	19.68	10.30	0	-10.73
Dec 2007	20.06	13.60	-6.99	-8.84
April 2009	16.57	6.21	0.55	-11.73
August 2009	17.92	10.64	0	-8.32
Nov 2011	10.23	2.86	6.63	-7.05
June 2012	29.17	17.61	-3.33	-13.91
June 2014	20.50	31.43	14.04	-22.91
Dec 2014	17.28	9.50	-0.83	-9.07
Oct 2015	21.23	8.79	15.19	-4.79

4.2.3 EXTREME VALUE THEORY: HILL ESTIMATE

Quantiles computed according to the Hil estimate are depicted in Table 4.12. Figure 4.22 below confirms the earlier decision to use a threshold value of 6.50 (that is K=40). A parallel line to the X-axis can be drawn up to k=40. The largest 40 values were sorted from largest to smallest (rank ordered) and formula 4.3 was applied to determine the Hill estimate (Xi [Hill]).

The Hill estimate calculated is 0.68015

The 100pth quantile using the Hill estimator was also calculated according to formula 4.4.

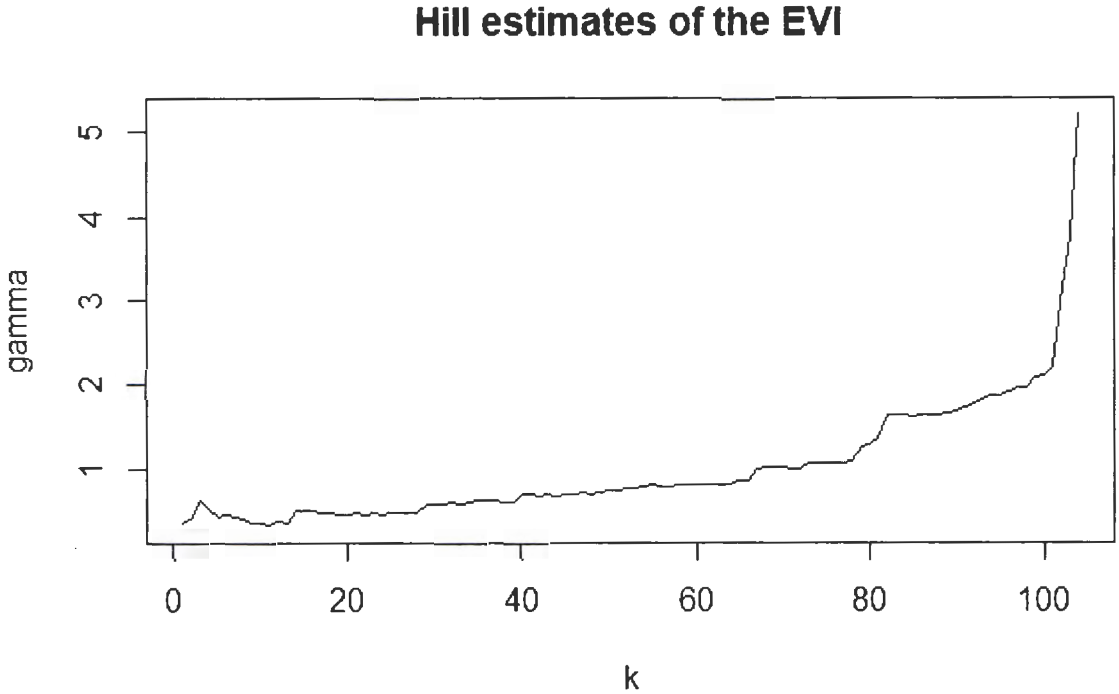

Figure 4.22: KENYA- Hill estimate to obtain cut-off between tail and central observations

When revisiting Table 4.12, it is certain that the GPD POT method provides a better estimate of the empirical quantiles compared to the Hill estimate. This is shown across all quantiles (0.80 to 0.999). There are only 5 quantiles where the Hill estimate provides a better index compared to the GPD POT method.

CHAPTER FIVE: SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

Extreme value theory is a useful method to model data in instances where the distribution shows heavy-tails. Often, financial data displays serial-correlation with heavy-tails. The data cannot be modelled as a normal distribution where the distribution is symmetric and bell-shaped. In a normal distribution; 2- or 3-sigma is used to calculate the probability of events falling within 2-sigma (99.45%) or 3-sigma (99.73%) ranges. Simply, in extreme value theory, the heavy tails of the data is used to model events that are rare but extreme in nature.

Under heavy-tailed financial data, a different distribution is needed for improved modelling accuracy. The generalised Pareto distribution is very applicable in such cases. The GPD has three subclasses namely: Frechet, Gumbel or Weibull. In most cases, financial data will demonstrate the Frechet sub-class where the shape parameter (Xi) is positive. The block maxima or peak over threshold method is then used to estimate the model parameters using maximum likelihood estimation. In some cases the non-parametric Hill estimate method is used to model the data especially if the sample size is small. A threshold value is chosen for the non-parametric and peak over threshold methods. Using the scale and shape estimates, quantiles can be computed to determine the probabilities of extreme pressure, risk or crises.

The use of modelling for the GPD requires stationarity, independent and identically distributed variables. If serial-correlation is depicted, often studied with financial data, appropriate ARMA and/or ARCH and GARCH processes are needed to ensure no time varying volatilities. Once all assumptions are met, the data can be modelled using extreme value theory.

Consequently, policy makers, financial analysts and economists can be fore-warned to intervene with ensuing extreme events. Particularly extreme value theory is very applicable in the exchange market pressure as a countries exchange rate may become pressurised due to surplus demand for foreign currency or the selling burden of its own currency.

This chapter provides a summary of the study, conclusions based on the objectives and hypotheses, limitations and recommendations for future research.

5.2 SUMMARY

The **first chapter** of this thesis provides the reader with an introduction of extreme value theory and exchange market pressure. Subsequently, the problem is explained and stated with the objectives to highlight the necessity and importance of the current study. The EMP index of African countries have never been modelled with EVT such as Latin American countries, East Block countries, European countries and India. The research questions that arose were: If the EMP from two African countries can be modelled with EVT? Which estimation method (GPD or Hill) would be more feasible? Is it possible to identify periods of extreme pressure or crises in these countries and to identify the source of the pressure?

In order to address these questions a thorough literature overview **(chapter two)** was conducted. The first part of the chapter addresses essential information regarding extreme value theory whilst the latter part elucidates a literature study of exchange market pressure. For EVT, the Generalised Pareto Distribution and its subclasses and Block Maxima and Peak over Threshold methods are discussed. Information surrounding the non-parametric Hill estimator is also expatiated.

The **third chapter** provides information pertaining to the methods used, the calculation of the three components of the EMP index, the calculation of the EMP index (including the handling of serial-correlation), application of extreme value theory, computation of quantiles, calculation of stress episodes, statistical analyses and ethical considerations.

Finally the **fourth chapter** details all information regarding data analyses, results and interpretation. Results for two African countries namely, South Africa and Kenya are presented. Before the EMP index was calculated, the data for the three components of the EMP index was scrutinised for stationarity and to ascertain whether the data was independent and identically distributed. Some of the components for the SA data demonstrated ARMA and/or ARCH/GARCH processes whereas the Kenyan data demonstrated no time varying volatilities and as such, no ARMA and/or ARCH/GARCH processes were needed for the Kenyan data. Subsequently, the EMP index was calculated and again examined for stationarity and heteroscedasticity. Appropriate processes were applied for the SA data-set. As such, the assumptions were not violated and consequently the EMP index was modelled with the GPD POT method using maximum likelihood estimation for SA and Kenya. Estimated shape and scale parameters were analysed with the statistical software R. Similarly, the EMP index was modelled using the non-parametric Hill estimate. Quantiles were computed from 0.80 to 0.999 using the normal distribution, empirical distribution, estimated distribution using GPD POT and estimated distribution using the Hill estimate. This enabled the researchers to identify periods of extreme pressure and/or crises using the 95th or 99th percentile. As a result, periods of extreme pressure or crises could be identified. Finally, the relative contributions of exchange rate, interest rate and/or reserves-to-M1 were studied.

The conclusion of the study is elicited in section 5.3.

5.3 CONCLUSION

The conclusion of the current study can be derived from the stated objectives and hypotheses of the study.

Objective one

To determine whether the EMP index of two African countries is stationary and heavy-tailed or not and if so, to model the data using extreme value theory.

Hypothesis one

The financial EMP data presented for both South Africa and Kenya will be stationary and demonstrate heavy-tailed Frechet distributions.

Both the SA and Kenyan EMP index's demonstrated stationarity (significant ADF & PP test statistics), high Kurtosis (2.69 & 7.04), heavy tails with positive Xi estimates (0.40 & 0.17) indicating Generalised Pareto Distribution from a Frechet sub-class. As a result, the EMP index of both countries were modelled using extreme value theory. Similar results were also reflected in a study performed in India (Guru & Sarma, 2013). Other EMP studies have also demonstrated non-Gaussian distributions with heavy tails (Heinz & Rusinova, 2015; Pozo & Amuedo-Dorantes, 2003).

As a result, the hypothesis is *accepted.*

Objective two

To compare the parametric (GPD POT) and non-parametric (Hill) estimation methods in describing periods of extreme pressure in South Africa and Kenya.

Hypothesis two

Both estimation methods will provide feasible and accurate estimations of extreme pressure.

Both estimation methods provided accurate estimations of extreme market pressure when studied as quantiles and compared to actually observed quantiles. However, quantiles estimated using the GPD POT method using maximum likelihood estimation (MLE) were more closely reflected to the empirical quantiles and the diagnostic plots demonstrated a good fit. Poor results were reported when the Hill estimate was used, for higher percentiles (0.990; 0.995 and 0.999) when compared to empirical quantiles. Consequently, periods of extreme pressure at p=0.99 were not flagged.

Consequently, the hypothesis is *partially accepted*.

<u>**Objective three**</u>

To identify periods of extreme pressure or crises in South Africa and Kenya using extremal analysis for the period 1999 to 2017

<u>**Hypothesis three**</u>

Periods of extreme pressure or crisis will be identified for both countries for several time periods

Using p=0.05, eight periods of stress was reported for the South African data (GPD POT). At p=0.01, four periods of extreme stress or crisis was depicted (GPD POT). The year and month flagged were: December 2001; March 2004; June 2006; June 2007; October 2008; February 2014; December 2015; February 2016. Although a near currency crisis was elicited in January 2014 and February 2014, no periods of currency crisis were identified. The four periods of extreme pressure with p=0.01 were: December 2001; June 2006; October 2008; February 2014. Using the Hill estimate, the same periods of time would be selected at p=0.05, but at p=0.01 only one period of extreme pressure is flagged.

At p=0.05, ten periods of stress are identified for the Kenyan data (GPD POT). At p=0.01, two periods of extreme stress are identified between 2000 and 2017 (GPD POT). The months affected are: March and May 2005, December 2007, April 2009, August 2009, November 2011, June 2012, June and December 2014 and October 2015. No periods of currency crisis was defined. The two periods of extreme pressure (p=0.01) are: March 2005 and June 2014. Identical episodes are flagged when the Hill estimate is used at the 95th percentile. However, at the 99th percentile no time-periods exhibit pressure situations.

Asian studies also reflected the use of EMP to identify periods of pressure or crises (Guru & Sarma, 2013; Pozo & Amuedo-Dorantes, 2003).

As such, the third hypothesis is *accepted.*

<u>**Objective four**</u>

To study the three components of EMP estimation at periods of extreme pressure or crisis.

<u>**Hypothesis four**</u>

All three components of the EMP index will demonstrate causes for periods of extreme pressure or crises at certain points of time.

For the South African data four periods were reported to be adversely affected by the rate-of-change in exchange rate (December 2001, June 2006, October 2008 and December 2015). In three other periods (June 2007, February 2014 and February 2016), the rate-of-change in interest rates were the most responsible for driving the EMP index into an extreme positive index. In one instance only (March 2004), the rate-in-change in reserves-to-M1 was the most likely factor for extreme pressure.

During March 2005, November 2011 & October 2015 the rate-of-change in interest rates were the most influential value on the EMP index for the Kenyan data. However, during June 2014 and October 2015, both the rate-in-change in exchange and interest rate were responsible for driving the EMP index into an extreme positive index. The rate-in-change in exchange rate was mostly responsible during May 2005, December 2007, April 2009, August 2009, June 2012 and December 2014.

As a result, the fourth hypothesis is *accepted* as contributions from each component were identified.

The main finding that emanated from this study is that EVT, specifically the generalised Pareto Distribution's method of Peak over Threshold using maximum likelihood estimation is both feasible and accurate to estimate and model the exchange market pressure of two African countries. Comparable results were also mirrored in a study performed in India (Guru & Sarma, 2013).

Moreover, the non-parametric method known as the Hill estimate is also a feasible and useful alternative, although less accurate at higher percentiles, for both studied data-sets. Reliable threshold values were selected for both countries in order to obtain accurate estimates of the shape and scale parameters. These estimates were applied in probability calculations to estimate the right tail quantiles of the EMP index series. The 95th and 99th percentiles were used to identify periods of extreme pressure and crises successfully. The three variables of the EMP index were studied at the time of extreme pressure or crises to identify the variable(s) most likely to have triggered flagged events. All calculations and computations were effectively applied not only in the statistical package R but also using mathematical and statistical formulas performed in Microsoft Excel. The results of the current study may help researchers, financial analysts and economists to better understand the causal factors, development or progression of EMP and contagion effect of currency pressure or crises.

5.4 LIMITATIONS, RECOMMENDATIONS AND FUTURE STUDIES

This study only applied EVT on the EMP of two African countries. Although, data was obtained for a further four African countries, EMP and EVT was not studied. Further research will be applied in subsequent countries where the gross domestic profit may be less than that of South Africa or Kenya. Also, this study should be repeated in countries where financial variables demonstrate more volatility and uncertainty for investment opportunities.

Also, in both studied papers (SA and Kenya), distributions were GPD of the Frechet sub-class. Perhaps other African countries will demonstrate the Gumbel (no tail) or Weibul (thin tail) sub-class distributions. It is not known, whether the EMP index can be modelled successfully and accurately with these sub-classes. It is recommended that future studies model the EMP index in such cases.

Although we used the more recent formula for calculating the EMP index, other formula's do exist (still using the identical three components of the EMP index), and these might demonstrate different results to the one's we have found. In some cases, the rate of change value is not used for one or two of the components and in others different weights are used. We used sigma ratio weights as recent studies did, where our sigma's were reported to be independent and identically distributed. It is recommended that future studies compare the different EMP formulas and the effect this has on the probability of risk or crises.

As the case with most studies modelling the probability of financial events, the approaches may not be applicable to verify the actual occurrence of crises events. There is no formal definition of extreme pressure or currency crises derived from theory. Also, banking and economic organisations do not systematically identify crisis countries. In short, there is no way to grade the precision of EMP approaches.

Clearly, substantial additional future studies are needed to develop early warning systems. This should be done to determine the trend of the EMP time series and to model it in such a manner that the probability of future crises events could be detected and predicted. In this way, researchers can be forewarned of future crises events. Or, mathematical and statistical formulas can be applied to ascertain if changes of certain magnitude for instance on the rate of change in interest rate would have an effect on the exchange market pressure.

Future studies should also attempt to build on research of this nature to disseminate the fundamental causal factors, development or evolution and possible contamination effect of currency pressure or crises. If a country demonstrates strong depreciative pressure, a neighbouring country, or a country with whom it has strong trade relations, contagion effect is highly likely to occur.

The work presented herein provides economists and financial analysts some of the necessary tools needed to predict foreign exchange crises.

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APPENDIX A: PROOF OF LANGUAGE EDITING

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30th October 2017

To whom it may concern

Editorial Assistance for M.Sc in Statistics Dissertation

Editorial intervention was restricted to: Language and illustrations as well as Completeness and consistency as defined by the current South African standards for Editing Practice. Where the editor provided advice on structure, they gave examples only and did not undertake a structural re-write themselves. Material for editing or proofreading was submitted in hard copy, where an electronic copy was submitted to the editor, their mark up was done using tracking Changes and the file returned in Word format only. The decision to accept and implement changes suggested rests solely on the candidate.

The name of the editor and brief description of the service rendered has been provided below.

Acknowledged by:

Candidate's Name: **PH BOER 24033944**

Dissertation title: **EXCHANGE MARKET PRESSURE IN SOUTH AFRICA AND KENYA: AN ANALYSIS USING EXTREME VALUE THEORY**

I declare that I have complied with the above conditions:

Signed: ____________________ Date: _______________

Editor's Name: PROF LIQHWA P.SIZIBA

I declare that I have edited /proofread the thesis in compliance with the above conditions, as instructed when engaged by the candidate.

Signed: LPSiziba ____________ Date: 30/10/2017

APPENDIX B: ETHICS APPROVAL CERTIFICATE

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Institutional Research Ethics Regulatory Committee

Email : Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF PROJECT

Based on approval by the **Human Resource Research Ethics Committee (HRREC) on 05/06/2017**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby **approves** your project as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: Exchange market pressure in South frica: an analysis using value theory

Project Leader/Supervisor: Prof E Munapo & Mr M Chanza

Student: PH Boer

Ethics number:

N	W	U	-	0	0	5	1	1	-	1	7	-	A	9
Institution				Project Number						Year			Status	

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Master's

Commencement date: 2017-05-17 **Expiry date**: 2020-05-17 **Risk:** NA

Special conditions of the approval (if applicable):

- Translation of the informed consent document to the languages applicable to the study participants should be submitted to the HRREC (if applicable).
- Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the HRREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- *The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC via HRREC:*
  - *annually (or as otherwise requested) on the progress of the project, and upon completion of the project*
  - *without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.*
  - *Annually a number of projects may be randomly selected for an external audit.*
- *The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the HRREC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.*
- *The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC via HRREC and new approval received before or on the expiry date.*
- *In the interest of ethical responsibility the NWU-IRERC and HRREC retains the right to:*
  - *request access to any information or data at any time during the course or after completion of the project;*
  - *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.*
  - *withdraw or postpone approval if:*
    - *any unethical principles or practices of the project are revealed or suspected,*
    - *it becomes apparent that any relevant information was withheld from the HRREC or that information has been false or misrepresented,*
    - *the required annual report and reporting of adverse events was not done timely and accurately,*
    - *new institutional rules, national legislation or international conventions deem it necessary.*
- *HRREC can be contacted for further information via Estie.Emtoch@nwu.ac.za or 018 289 2873.*

'ours sincerely

Prof LA Du Plessis

Digitally signed by Prof LA Du Plessis
Date: 2017.06.08 15:19:22 +02'00'

Prof Linda du Plessis
Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)