DESIGN AND VALUATION OF KENYA SHILLING CURRENCY OPTIONS

A project report

By

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I46/60025/07

Submitted to the School of Mathematics in partial fulfillment of the requirements for the degree of postgraduate diploma in Actuarial Science.

University of Nairobi

August 2009.

DECLARATION

This research project is my own original work and has never been presented for any degree in any other university.

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This project has been presented for examination with my approval as university supervisor.

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1 Aknowledgement

The author would like to thank Dr. Weke And Dr. Acholla Without whose valuable input and guidance this paper would not have complete.

Many thanks to my employer the Evangelical Lutheran Church of Kenya for their support and giving me time off to concentrate on my studies.

Finally to my family for their unwaivering support and encouragement throughout this period.
To all i thank you sincerely.

2 Abstract

Foreign exchange rates have become a source of concern for most manufacturers and the business community as a whole. Since Kenya maintains a flexible exchange rate, the value of the kenya shilling is determined by the market forces of supply and demand.
Thus any events that could potentially harm the country's stability or are percieved by the international markets as having an effect on the local economy,have a direct impact on the value of the shilling and may cause its value to fluctuate.
Since events affecting the value of any currency can not always be predicted accurately, movements in the foreign currency markets often leave substantial amounts of loss in their wake.

If a manufacturer has to import raw materials then a depreciation in the local currency would result in higher production costs as more units of the local currency would be required to purchase a unit of the foreign currency. It would therefore cost more to impport goods.
On the other hand if the local currency appreciates against major world currencies then exporters would have to accept a cut in their profit margins since their products would not be competitively priced owing to high production costs locally as a result of strong local currency.
This paper aims to design a financial instrument that would be used by firms to hedge against foreign exchnage exposure.
The currency values and trade volume data that will be used in this paper are for the year ending 2007 as compiled by the central bank of kenya.
Given that Kenya's balance of trade up to the year ending 2007 was negative; this imp;ies that the country imported more than it exported.
The major currencies used in terms of trading volume were the US Dollar, the Euro and the British Pond Sterling.
This paper will structure and price currency derivatives with the shilling against these three major currencies.

3 Introduction

3.1 Derivatives

This is a financial instrument that derives its value from an underlying usually tradable asset. Derivatives can be Forwards, futures or options.

3.2 Types of Derivatives

Forwards
This kind of derivative is straight forward the investor enters into a contract to purchase or sell an asset at a future date for a predetermined price.
Futures are traded over the counter that is (OTC).

Futures
Futures are similar to forwards with the distinction that futures are exchange traded as well as traded over the counter.

Options
There are two types of options;
Call Option
A european call option gives the holder the right but not the obligation,to buy the underlying asset at a certain price and date.
Put option
A european put otion gives the holder the right but not the obligation to sell the underlying asset at a certain price and date.
Option Positions
The buyer of the option has a long option position.
The seller of the option has a short option position.

We shall restrict this study to the valuation and pricing of european options such that the option is exercised only on the date of maturity and not before.

3.3 Uses of Derivatives

Hedging

Derivatives are almost always used to shield bisinesses or individuals against exposure to certain risks that may arise in the course of doing business such as an increase in the price of raw materials at a future date.

In order to reamin profitable firms use derivatives to hedge aginst these exposures.

Speculation

Afew people trade in derivatives purely for speculative reasons and try to take advantage of price inconsistencies between the market prices and option prices.

3.4 Hedging

Hedging is used as a strategy to cover exposure to an expected risk assosiated with doing business.

A perfect hedge is thus considered as being one that can completely eliminate any particular risk.

3.5 Hedging Strategies

3.5.1 Short Hedge

A short hedge is suitable for a firm that owns an asset or will own an asset in the future and intends to sell it.

The strategy involves entering a short position on a futures contract.

If a firm expects payment in dollars six months from now then the value of the payment will depend on the value of the dollar in six months time.

By entering a short position in the currency markets the firm enters a contract to sell the Dollars they will recieve at a predetermined price and date in the future.

While this is an effective strategy to hegde against the depreciation of the dollar the firm would loose out on any gains it would make if

the dollar value were to increase.
A better strategy would therfore be to go long on a put option. This gives the firm the right but not the obligation to sell the dollars in six months time.
An initial premium is however paid upon purchase of the put option. This is the only loss incurred if the option is not exercised.

3.5.2 Long Hedge

A long hedge is suitable for a firm that expects to purchase an asset in the future.
If a local firm is to make a payment in dollars six months from now then their primary concern will be to ensure that this paymant does not become higher than expected due to an increase in the value of the dollar.
The firm should therefore enter into a long futures position.

That is a contract to buy a certain amount of dollars at a certain price and date in the future.
With this hedge the firm runs the risk of making a loss if the dollar depreciates, in which case they would be buying the dollar at a higher rate than the market rates.
A better strategy would be go long on a call option which would give the firm the right but not the obligation to buy the required amount of dollars.
If the dollar depreciates then the firm does not exercise the option and the firm only looses the premium it paid in order to purchase the option.

Problems Encountered

1. *To find the optimum hedge ratio.*

That is the ratio between the size of the positions taken in the futures contracts and the size of the exposure,that will minimise the variance of the hedge. This is can easily be calculated,first defination of the symbols used.

δS; Change in spot price S,During a period of time equal to the life of the hedge.

δF; Change in futures prices F,during a period of time equal to the life of the hedge.

σ_S; Standard deviation of δS

σ_F; standard deviation of δF

ρ; coefficient of correlation between δs and δF

h^*; Hedge ratio that minimises the variance of the hedgers position.

The minimum hedge ratio is thus given by;

$$h^* = \rho \frac{\sigma_S}{\sigma_F}$$

2. *To find the optimal number of futures contract*

Defination of variables used;

N_A; Size of positions being hedged

Q_F; Size of one futures contract

N^*; Optimal number of futures contracts for hedging

$$N^* = h^* \frac{N_A}{Q_F}$$

3.6 Statement of Problem

The economic environment in kenya changes constantly, factors affecting the economy are varied and can range from climatic to political.
These have an impact on the kenya shilling making its value fluctuate.
Most manufacturers have to import some or all of their raw materials.Of primary concern is to minimise the cost of production by keeping the cost of raw materials at a minimum.
The cost of production is therefore dependent on prevailing exchange rates. When the kenya shilling depreciates the cost of raw materials inevitably rises.
According to export data, kenya's exports are pedominantly agricultural and the income earned is also dependent on the prevailng exchange rates.
Presently, firms have to absorb any losses incurred when exchange rates vary.
This study is therefore a bid to explore the need to minimise and hedge against loses resulting from exchange rate fluctuations.

3.7 Objectives of study

Given that there is a need to hedge against movements in exchange rates the broad objectives of this study are;

1.To design financial derivatives that can be easily used by firms to hedge against exchange rate exposure.

2.To competitively price the derivatives designed.

3.To set convienient specifications of the derivatives contracts such that their date of delivery matches that of most business cycles.

3.8 Significcance of Study

The study may prove to be of importance to Firms,Individuals and Abitraguers.

Firms
These will benefit directly from the derivatives. Firms will be able to use currency derivatives to shield themselves against fluctuating exchange rates and reduce assosiated costs.

Individuals
Individuals will benefit by taking advantage of the derivatives in the purchase of the undelying asset at competitive prices.

Abitraguers
These will benefit by taking advantage of price discrepancies, such as when the price of a futures contract of an asset is not in line with the cash price.

4 Literature Review

The 1946 Bretton Woods agreement established fixed exchange rates between most currencies.
Under this understanding various countries agreed to keep their currencies within a narrow band of a parity value.
In 1973 however, floating exchange rates were adobted. Today only a few countries maintain a fixed exchange rate normaly determined by the central bank.
The central bank of kenya maintains a floating exchange rate system, thus the value of the Kenya shilling is determined by the market forces of supply and demand. These tend to vary unpredictably and can range from mild to adverse market movements.
This has led to market players such as importers and exporters and others in business, being exposed to a volatile currency.

Given that the central bank can not directly intervene in the direct control of the value of the Shilling,There are measures that can be put in place in an effort to stabilise it. Thus the central bank has introduced monetary policies that help to cushion the shilling against major market movements.
These policies do not shield the shilling entirely and in the end it is the business community that has to absorb the loses incurred when markets move south.

The vast majority of foreign exchange instruments exist outside the country, these are used to hedge against market movements that could be potentially harmful to businesses.

However it is important to use these forex products appropriately so as to maximise their effectiveness and realise profits. Most importantly, to time the maturity of these products and match them to the financial obligations of the company.

Thus the maturity dates of this instruments are such that they match market demand.

The valuation of currency derivatives is nomally by modifying the Black Scholes Model and incorporating the interest rates of the for-

eign currency being evaluated.
We will use the riskless interest rates. This are the rates at which a government borrows using securities denominated in its own currency.
The BSM model uses a constant volatility but for the valuation of the option prices in this paper, we will use a varying volatility i.e volatility that changes with the passage of time.
Volatility to be used in the BSM Fomulas will be derived from historic data and estimated using the GARCH(1,1) Model.
This is because the variance, which is taken to be the volatility, is mean reverting and the GARCH(1,1) Model incorporates this.
The currency derivatives designed in this paper will have their variables of interest derived from data clollected from the market over time.
The exchange rate data is from the central bank of Kenya. The foreign riskfree rates of interest are from the respective central banks.The European Central Bank, the Bank of England and the Federal Reserve.

5 Research Methodology

5.1 Introduction

In this section, procedures and strategies used in the study are described.
Parameters of interest are explained and derived from the data.
The Black Scholes option pricing formulas are modified and used to price foreign currency options.
Foreign currencies used are the British pound sterling, The American dollar and the Euro against the Kenya shilling.

5.2 Foreign Currency Options

The global foreign currency market is the largest and most liquid. As such it is affected by several factors irrespective of where trading occurs, these include;

Government Monetary Policy
This affects the country's inflationary pressures and interest rates which directly affect the value of domesstic currencies. *Political Conditions*

The stability of a country greatly determines how much it's currency is worth in the global markets any uncertainty in the country's politacal stability leads to a decline in the value of a currency.
Due to this reasons calculation of currency options is by modifying the Black Scholes Model so as to incorporate prevailing domestic and foreign risk free rates of interest which tend to vary over time.

5.3 The Black Scholes Model

In order to be able to value currency options using this model, we have to make the following assumptions;

1. We assume that the foreign excchange spot rate denoted by S follows a geometric brownian motion process.

2. The call and Put Option prices are a function of only one stochastic Variable, S.

3. The interest rates r and r_f are constant.

4. We assume a risk neutral world. Such that the equation used to value the option does not involve any variable affected by the risk preferences of the investor hence we can conclude that the returns are at the prevailing risk free interest rates.
In a risk neutral world the process followed by the spot price is thus;

$$dS = (r - r_f)Sdt + \sigma Sdz$$

Where;
r is the domestic risk free interst rate.
r_f is the foreign risk free rate of interest.

Define

S_o is the current spot price of the currency.
F_o is the forward rate of the option.
T is time to maturity of the option.

Currency options have the advantage that the holder can earn the risk free rate of interest if he invests in the foreign bond market. Therefore we can treat foreign exchange forwards like a stock providing a known dividend yield.

Thus the forward rate of an option can be written as;

$$F_o = S_o e^{(r-r_f)T}$$

This can now be used to modify the Black Scholes option pricing formula.

The formula for a european call option can now written as;

C=S$_o N$(d$_1$)−Ke^{-rt}N(d_2)

and for a put option;

P=Ke^{-rt}N($-d_2$)−S$_o N$(-d$_1$)

Where $N(d_1)$ is the cummulative normal distribution function.
d_1 and d_2 are found as follows;

$$d_1 = \frac{\ln\left(\frac{S_o}{K}\right) + \left(r + \frac{\sigma_{n+k}^2}{2}\right)T}{\sigma_{n+k}\sqrt{T}}$$

$$d_2 = \frac{\ln\left(\frac{S_o}{K}\right) + \left(r - \frac{\sigma_{n+k}^2}{2}\right)T}{\sigma_{n+k}\sqrt{T}}$$

5.4 Estimating The Variables of Interest

The Black Scholes Model Requires the following parameters to be used;
F_o; the foward rate which is calculated using the formula;

$$F_o = S_o e^{(r-r_f)T}$$

K; The strike price.
This will be modified and we will use the expected value of the currency at time T, i.e
K=E(S_T)
and

$$E(S_T) = S_o e^{-\mu T}$$

Given that;
μ is the expected return over short Period of time.

T; This is the time to maturity and is normally specified in the option contract.

σ; This is the measure of volatility of the currency,i.e. the uncertainty of the returns earned.

Volatility will be evaluated from historic data and estimated using the Garch (1,1)Model.

5.5 The Generalised Autoregressive Conditional Heteroskedasticity Model

GARCH(1,1) Model

The(1,1)indicates that σ_n, the volatitlity at time $T = n$, is based on the most recent observations of U^2 and the most recent estimates of the varaince rates.

In practice, over a period of time, variance and thus volatility tends to revert to the mean variance rate.
The GARCH(1,1)Model therefore incorporates this and σ_n^2 is calculated from a long run average rate of variance V_L, as well as from σ_{n-1} and U_{n-1}

The equation for GARCH (1,1) model is given by;

$$\sigma_n^2 = \gamma V_L + \alpha U_{n-1}^2 + \beta\, \sigma_{n-1}^2$$

Where γ,α and β are the weights assigned to the parameters and they must sum up to one. That is,

$$\gamma + \alpha + \beta = 1$$

V_L is the long term variance rate.
σ_n^2 is the variance rate on day n.
σ_n is the volatility of a market variable on day n as estimated at the end of day n-1.

Given that S_i where i=1,2,3...n is the exchange rate on a given day then U_i is calculated as follows;

$$U_i = \frac{S_i - S_{1-i}}{S_i}$$

5.5.1 Estimating GARCH(1,1) Parameters

Let $V_i = \sigma_i^2$ i.e the variance estimated for day i.

Assume that the probability distribution of U_i conditional on the variance is Normal.
The best parameters are therefore those that maximise the following function.

$$\prod_{i=1}^{m}\Big[\frac{1}{\sqrt{2\pi v_i}}exp\Big(\frac{-\mu_i^2}{2v_i}\Big)\Big]$$

Taking logarithms this is equivalent to maximising the following function;

$$\sum_{i=1}^{m}\Big[-Ln(v_i)-\frac{\mu_i^2}{v_i}\Big]$$

Parameters in the model that maximise the expression are obtained by searching iteratively.

In the the tables attached the values of$\gamma\alpha$and β are obtained and substituted into the GARCH(1,1) model equation to obtain the value of σ_n^2 for the three exchange rates.

The σ_n so obtained is then used in the Black Scholes option pricing formulas in order to calculate the price of call and put options.

5.6 Forecasting Using The GARCH(1,1)Model

γ,α and β are the weights assigned to the parameters in the GARCH (1,1) equation and they sum up to one.
Such that;

γ+α+β =1

Let

γ = 1-α - β

Therefore;

$\sigma_n^2 = (1\text{-}\alpha\text{-}\beta)V_L + \alpha\mu_{n-1}^2 + \beta\sigma_{n-1}^2$

and

σ_n^2 - $V_L = \alpha(\mu_{n-1}^2$ - $V_L) + \beta(\sigma_{n-1}^2$ - $V_L)$

Thus the volatility on day n+k in the future;

σ_{n+k}^2 - $V_L = \alpha\ (\mu_{n+k-1}^2$ - $V_L) + \beta\ (\sigma_{n+k-1}^2$ - $V_L)$

Let E denote the expected value therefore;

E(σ_{n+k}^2 - V_L) = $(\alpha + \beta)^k(\sigma_n^2$ - $V_L)$

and
E(σ_{n+k}^2) = $V_L + (\alpha + \beta)^k(\sigma_n^2$ - $V_L)$

This equation forecasts the volatility on day n+k using the information at the end of day n-1.

Using the Black Scholes option pricing formulas the price of a call option on day n+k in the future is given by;

$$C=S_o e^{-r_f T} N(d_1) - K e^{-rt} N(d_2)$$

and that for a put option is given by;

$$P=K e^{-rt} N(-d_2) - S_o e^{-r_f T} N(-d_1)$$

and

$$d_1 = \frac{\ln\left(\frac{S_o}{K}\right) + \left(r - r_f + \frac{\sigma_{n+k}^2}{2}\right)T}{\sigma_{n+k}\sqrt{T}}$$

$$d_2 = \frac{\ln\left(\frac{S_o}{K}\right) + \left(r - r_f - \frac{\sigma_{n+k}^2}{2}\right)T}{\sigma_{n+k}\sqrt{T}}$$

r is the risk-free rate of interest.
r_f is the foreign risk-free rate of interest.
T is the time to maturity of the option.
σ_{n+k}^2 is the forecast volatility on day (n+k).

5.7 Interest Rates

Interest rates both domestic and foreign are determined by their respective central banks and these tend to cahnge from time to time depending on the prevailing economic environment and the monetary policies adopted as a result of this conditions.

The foreign interest rate r_f used in calculating option prices is the treasury rate. This is the interest earned when one invests in government treasury bills/bonds.
Which is the rate at which a government borrows in its own currency.
It is considered risk-free because no government will default on an obligation denominated in its own currency.

6 Results

The exchange rates used are the central bank of Kenya monthly average rates from the July 2005 up to Decmber 2007.

6.1 Variables of Interest

Let $v_i = \sigma_i^2$ the variance estimated for day i.
V_L the long run variance rate is calculated for all exchange rates as follows;

$$V_L = \frac{\gamma}{(1 - \alpha - \beta)}$$

Let exchange rate at the end of day i be S_i. And at the end of day i-1 is S_{i-1}.
U_i is the propotional change in the exchange rate between end of day i and end of day i-1. It is calculated as follows.

$$U_i = \frac{S_i - S_{1-i}}{S_i}$$

We then iteratively search for the values of α, β and γ that will maximise the following function;

$$\sum_{i=1}^{m} \left[- Ln(v_i) - \frac{\mu_i^2}{v_i} \right]$$

The σ obtained is then substituted into the Black Scholes fomulas to find the value of a put and call option.

6.2 The Dollar against the Kenya Shilling

The data used are the exchange rates of the shilling against the USD from July 2005 upto December 2007.
The variables of interest are calculated using the fomulas already discussed.
The weights assigned to the GARCH (1,1)equation are found by searching iteratively from the exchange rate data.
The values of the weights assigned to the variables must sum up to one.
After searching iteratively the values of the weights are as follows;

$$\gamma = 0.0000015$$

$$\alpha = 0.07463$$

$$\beta = 0.92534$$

These values are found to maximise the following function as required.

$$\sum_{i=1}^{m} \left[- Ln(v_i) - \frac{\mu_i^2}{v_i} \right]$$

We use the GARCH (1,1) equation to find the value of σ_n.
These values yield

$$\sigma_n^2 = 0.0006746$$

Therefore

$$\sigma_n = 0.025973$$

The σ_n obtained can now be intergrated into the BSM option pricing formulas.

The Strike price K is calculated as follows;

$$k = S_o e^{(-r_f T)}$$

$$k = 62.675 * e^{0.0336*1/2} = 61.6309$$

The strike price K is thus 61.6309

Where μ is the expected return on the currency. In this case we use the foreign risk free rate of interest since it is the return expected on the currency if one invests in a security denominated by the particular currency.
$S_o = 62.675$
The foreign interest rate r_f is 0.0336
Time T is 1/2
We use these figures to find d_1 and d_2 as follows.

$$d_1 = \frac{\ln\left(\frac{S_o}{K}\right) + \left(r - r_f + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln\left(\frac{S_o}{K}\right) + \left(r - r_f - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

Thus

$$d_1 = \frac{\ln\left(\frac{62.675}{61.6309}\right) + \left(.06868 - 0.0336 + \frac{0.025973^2}{2}\right)0.5}{0.025973\sqrt{0.5}}$$

$$= \mathbf{1.87893}$$

and

$$d_2 = \frac{\ln\left(\frac{62.675}{61.6309}\right) + \left(0.06868 - 0.0336 - \frac{0.025973^2}{2}\right)0.5}{0.025973\sqrt{0.5}}$$

$$= \mathbf{1.86057}$$

The call price and put price of the options will therefore be;

C=$S_o e^{-r_f t} N(d_1) - K e^{-rt} N(d_2)$

P=$K e^{-rt} N(-d_2) - S_o e^{-r_f t} N(-d_1)$

r the domestic interest rate is 0.06868.
This is the interest that was earned on the 91 day treasury bill in December 2007.

r_f the foreign interest rate is 0.0336.
This is the interest earned on the three month US treasury bill in 2007.

We substitute the figures into the fomulas.

$N(d_1) = 0.96987$
$N(-d_1) = 0.03031$
$N(d_2) = 0.96860$
$N(-d_2) = 0.03140$
C=$62.675e^{-0.0336(0.5)} N(1.87893) - 61.6309e^{-0.06868(0.5)} N(1.86057)$

$= \mathbf{3.00314}$

P=$61.6309e^{-0.06868(0.5)} N(-1.86057) - 62.675e^{0.0336(0.5)} N(-1.87893)$

$= \mathbf{0.01857}$

The call price of an option whose underlying asset is the value of the Kenya shilling against the USD is 3.1163.
The put price of the same option is 0.01857.
The delivery date for this option is the end of June 2008, six months after its issue. The contract size is at the discretion of the issuer.

6.3 The Euro against the Kenya Shilling

The values for the weights to be used in the GARCH equation are as follows;
$\alpha = 0.0862$
$\beta = 0.91377$
$\gamma = 0.00000034$
Using these figures we obtain σ_n.
$\sigma_n^2 = 0.0005732$
and
$\sigma_n = 0.02394$
Using the data we let $S_o = 90.168$ and Time to maturity T = 0.5.

The foreign interest rate to be used $r_f = 0.0393$ Which is the bond yield for the Euro for the year 2007.

We then use these to find the strike price K.
K is found as follows;

$$k = S_o e^{(-r_f T)}$$

$$K = 90.168 e^{(-0.0393*0.5)}$$

$$= 88.4135$$

We now find the values of $d_1$andd_2. using their respective fomulas.

$$d_1 = \frac{\ln\left(\frac{S_o}{K}\right) + (r - r_f + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

and

$$d_2 = \frac{\ln\left(\frac{S_o}{K}\right) + (r - r_f - \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

$$d_1 = \frac{\ln\left(\frac{90.168}{88.4135}\right) + (0.06868 - 0.0393 + \frac{0.0005732}{2})0.5}{0.02394\sqrt{0.5}}$$

$$= \mathbf{2.03704}$$

$$d_2 = \frac{\ln\left(\frac{90.168}{88.4135}\right) + (0.06868 - 0.0393 - \frac{0.0005732}{2})0.5}{0.02394\sqrt{0.5}}$$

$$= \mathbf{2.02011}$$

We use the BSM fomulas to find the call and put prices for an option whose underlying value is the exchange rate of the Kenya shilling against the Euro.

$$\text{C}=\text{S}_o\text{e}^{-r_f t}\text{N}(d_1)-\text{K}e^{-rt}\text{N}(d_2)$$

$$\text{P}=\text{K}e^{-rt}\text{N}(-d_2)-\text{S}_o\text{e}^{-r_f t}\text{N}(-d_1)$$

$N(\text{d}_1) = 0.97918$
$N(\text{d}_2) = 0.97831$
$N(\text{-d}_1) = 0.02082$
$N(\text{-d}_2) = 0.02169$

By substituting the figure into the equations we get;

$$C=90.168e^{-0.0393(0.5)}N(2.03704)-88.4135e^{-0.06868(0.5)}N(2.02011)$$

$$\mathbf{C=2.99676}$$

$$P=88.4135e^{-0.06868(0.5)}N(-2.02011)-90.168e^{-0.0393(0.5)}N(-2.03704)$$

$$\mathbf{P=0.012184}$$

This is the call and put price of an option whose underlying value is determined by the exchange rate between the Euro and the Kenya Shilling. The delivery date for this option is the end of June 2008, six months after its issue. The contract size is at the discretion of the issuer.

6.4 The Pound Sterling against the Kenya Shilling

Using the Exchange rates from July 2005 upto December 2007 we can iteratively search for the values of the weights required to be used in the GARCH(1,1) equation.
The values are as follows;
$\gamma = 0.00000102$
$\alpha = 0.08432$
$\beta = 0.9147$
The value of σ_n obtained using the above values is;
$\sigma_n^2 = 0.0007262$
$\sigma_n = 0.02786$
Using the data $S_o = 124.322$.

The foreign exchange rate r_f to be used is the British pound London Interbank Offered Rate, GBP-LIBOR rate for December 31st 2007 for the 3 month treasury bill.
$r_f = 0.0599375$

Time to maturity T = 0.5

To find the strike price K we use the fomula;

$$k = S_o e^{(-r_f T)}$$

$$K = 124.322 e^{(-0.0599375*0.5)}$$

$$= 120.651$$

These can now be used to to find the values of d_1 and d_2.

$$d_1 = \frac{\ln\left(\frac{S_o}{K}\right) + (r - r_f + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

and

$$d_2 = \frac{\ln\left(\frac{S_o}{K}\right) + (r - r_f - \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}$$

By substituting into the respective fomulas;

$$d_1 = \frac{\ln\left(\frac{124.322}{120.651}\right) + (0.06868 - 0.0599375 + \frac{0.00077617}{2})0.5}{0.02786\sqrt{0.5}}$$

$$= 1.75321$$

and

$$d_2 = \frac{\ln\left(\frac{124.322}{120.651}\right) + (0.06868 - 0.0599375 - \frac{0.00077617}{2})0.5}{0.02786\sqrt{0.5}}$$

$$= 1.73369$$

$N(\mathrm{d}_1) = 0.96022$
$N(\mathrm{d}_2) = 0.95851$
$N(\text{-}\mathrm{d}_1) = 0.03978$
$N(\text{-}\mathrm{d}_2) = 0.04149$

The price of a call or put option whose underlynig value is the exchange rate between the pound sterling and the Kenya shilling can now be calculated using the BSM fomulas.

$$\mathrm{C}{=}\mathrm{S}_o\mathrm{e}^{-r_f t}\mathrm{N}(d_1){-}\mathrm{K}e^{-rt}\mathrm{N}(d_2)$$

$$\mathrm{P}{=}\mathrm{K}e^{-rt}\mathrm{N}(-d_2){-}\mathrm{S}_o\mathrm{e}^{-r_f t}\mathrm{N}(-d_1)$$

By substituting the values.

$$C=124.322e^{-0.0599375(0.5)}N(1.75321)-120.651e^{-0.6868(0.5)}N(1.73369)$$

$$= \mathbf{4.11064}$$

$$P=120.651e^{-0.06868(0.5)}N(-1.73369)-124.322e^{-0.0599375(0.5)}N(-1.75321)$$

$$= \mathbf{0.037312}$$

This is the call and put price of an option whose underlying value is determined by the exchange rate between the Sterling Pound and the Kenya Shilling. The delivery date for this option is the end of June 2008, six months after its issue. The contract size is at the discretion of the issuer.

6.5 Forecasting Volatility using GARCH (1,1) Model

The expected value of the volatility at a future time T = n+k denoted as δ_{n+k} is given by the following GARCH(1,1) equation;

$$E(\sigma^2_{n+k}) = V_L + (\alpha + \beta)^k(\sigma^2_n - V_L)$$

This is the expected volatility on day (n+k) using the information at the end of day (n-1).
We can use this equation to find the volatility for June 2008 which is six months after the last month on the data that has been used in this paper.

6.5.1 Forecasting the vilatility of the exchange rate of the US Dollar against the Kenya shilling

The values to be used in the equation are;
$V_L = 0.0707107$
$\alpha = 0.07463$
$\beta = 0.92534$
$n + k = 0.5$
The expected σ^2_{n+k} is therefore given by;

$$E(\sigma^2_{n+k}) = 0.0707107+(0.0746+0.92534)^{0.5}(0.0006746 - 0.0707107)$$

$$E(\sigma^2_{n+k}) = 0.000677$$

This is the expected volatility for June 2008 for the exchange rate of the Dollar against Kenya shilling.

6.5.2 Forecasting the volatility of the exchange rate of the Euro against the Kenya Silling

The GARCH(1,1) equation to be used is;

$$E(\sigma^2_{n+k}) = V_L + (\alpha + \beta)^k(\sigma^2_n \text{ - } V_L)$$

The values to be used are;
$V_L = 0.106458$
$\alpha = 0.0862$
$\beta = 0.91377$
$n + k = 0.5$
The expected σ^2_{n+k} is therfore given by;

$$E(\sigma^2_{n+k}) = 0.106485 + (0.0862{+}0.91377)^{0.5}(0.00057321 - 0.106458)$$

$$E(\sigma^2_{n+k}){=}\ 0.000575$$

This is the volatility of the exchange rate of the Euro against the Kenya Shilling for June 2008 six months after the final date of the data we are using for this paper.

6.5.3 Forecasting the volatility of the exchange rate of the Pound Sterling against the Kenya shilling

The GARCH(1,1) equation to be used is;

$$E(\sigma^2_{n+k}) = V_L + (\alpha + \beta)^k(\sigma^2_n - V_L)$$

The values to be used are;
$V_L = 0.0322617$
$\alpha = 0.08432$
$\beta = 0.9147$
$n + k = 0.5$
The expected σ^2_{n+k} is therfore given by;

$$E(\sigma^2_{n+k}) = 0.0322617+(0.08432+0.9147)^{0.5}(0.000776169 - 0.03229)$$

$$E(\sigma^2_{n+k}) = 0.000763$$

This is the future volatility of the exchange rate of the pound sterling against the shilling for June 2008.

6.6 Modification of The BSM Model

In order to be able to calculate the prices of call and put options for currency derivatives the BSM fomulas have had to be modified.

The foreign rate of interest has been incorporated.

The volatitlity used is found using the GARCH(1,1) Model and it varies with the passing of time contrary to the BSM Model whose Volatility is constant.

The strike price K is found using the initial price S_o and the respective rate of interest whereas K is normaly given or known.

7 Discussion, Conclusion and Recommendations

7.1 Discussion

The calculation of put and call option prices is dependent on accurate evaluation of the market data in stable markets.
In the Kenyan market data is not always readily available and especially in real time i.e as it is happening. This makes it difficult for very short term transactions like those taking a day or even hours very difficult to be evaluated.
Therfore to be able to accurately price options in the Kenyan market one has to use a longer time period in order to allow for time to get the relevant data.

Stability of the market

Given that the Kenya shilling's exchange rate is determined by the market forces of supply and demand.
How stable the economy is percieved to be has a direct impact on the Kenya shilling.
This has resulted in the volatility of the shilling not being forecast accurately.
Due to this, pricing of options becomes very difficult.

Monetary Policy

This directly affects the value of the shilling. Whereas the Central bank of kenya does not directly intervene in determining the value of the shilling against major currencies, some actions taken by the bank affect the value of the shilling e.g the auctioning of dollars that is done whenever there is a shortage of the dollar in the market.

Market Perception

How a country is percieved by the outside market is as important as the actual situation in the market. This is because the demand for the local currency will be determined by the confidence the market players have in the market.
If confidence in the market is low even if there is no reason for this, then the currency value depreciates.

7.2 Assumptions

That there are no major disruptions in the market that would cause the volatility of the Kenya shilling to vary inexplicably.

7.3 Limitations of study

There are no currency derivatives traded in the country therefore comparing the results to actual derivatives is not possible.

7.4 Conclusion

Option trading is currently non-existent in the Kenyan market.
The comencement of options trading in this market will be of great benefit to businesses that are in urgent need of hedging some of the risks they encounter in the course of doing business in the country.
More currencies that are commonly used could be valued and have options whose underlying value is derived from them being traded.This will diversify the financial instruments available in the market.
In view of the objectives that were set out for this paper to achieve, the design of a derivative that can be used to hedge against exchange rate exposure has been achieved.
Competitive pricing of the derivatives was not completely achieved because there are no derivatives traded in the Kenyan market, therefore comparison to other derivatives is not possible and the pricing can not be competitive if there is nothing to compete with.
The derivatives have had their specifications convieniently set with the maturity of the derivatives designed, being six months and the size of the contracts being at the discretion of the issuer.

7.5 Recommendation

An improvement in the data handling of the bourse in order for real time data to be accessible whenever is needed.

The central bank of Kenya to interfer in the foreign currency market as little as possible

More institutions to be allowed to deal in foreign currency so that the financial instruments derived from forex can be accessed easily.

8 Bibliography

References

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[2] Currency Derivatives *F. DeRosa*

[3] Options Futures and Other Derivatives *J. Hull*

9 Appendix

Shilling Exchange Rates

	US Dollar	Pound Sterling	Euro	
2005				
July	76.044	133.460	92.227	
August	75.696	135.186	92.421	0.00210
September	74.078	130.433	89.134	-0.03557
October	73.606	130.375	88.690	-0.00498
November	74.486	128.150	87.819	-0.00982
December	72.367	124.984	85.911	-0.02173
2006				
January	71.982	127.405	87.090	
February	73.198	127.416	86.823	-0.00307
March	71.872	125.365	87.305	0.00555
April	71.158	128.205	89.158	0.02122
May	72.270	136.127	93.056	0.04372
June	73.880	135.606	93.985	0.00998
July	73.617	136.970	93.852	-0.00142
August	72.624	138.340	93.198	-0.00697
September	72.679	138.250	92.304	-0.00959
October	72.020	136.874	91.589	-0.00775
November	69.948	136.318	92.121	0.00581
December	69.397	136.316	91.387	-0.00797
2007				
January	70.537	138.380	91.434	
February	69.733	136.840	92.167	0.00802
March	68.781	135.004	91.766	-0.00435
April	63.306	136.197	93.405	0.01786
May	66.966	132.292	89.969	-0.03679
June	66.564	133.304	89.513	-0.00507
July	67.509	136.985	92.476	0.03310
August	66.989	135.052	91.542	-0.01010
September	66.971	135.309	94.784	0.03542
October	67.114	138.852	96.827	0.02155
November	64.424	132.806	94.939	-0.01950
December	62.675	124.322	90.168	-0.05025

Year	Month	US Dollar	Ui	Ui^2	Vi		Vl	lnVi+Ul/Vl
2005								
	July	76.044						
	August	75.696	-4.5763E-03	2.0943E-05				
	September	74.078	-2.1375E-02	4.5689E-04	2.0943E-05	1.1043E+01	2.0943E-05	-1.1043E+01
	October	73.606	-6.3717E-03	4.0598E-05	5.3627E-05	-9.0764E+00	4.8771E-05	9.0960E+00
	November	74.486	1.1956E-02	1.4294E-04	5.2803E-05	-7.1420E+00	4.8401E-05	6.9329E+00
	December	72.367	-2.8448E-02	8.0931E-04	5.9678E-05	3.8347E+00	5.4553E-05	-5.0190E+00
2006	January	71.982	-5.3201E-03	2.8304E-05	1.1577E-04	-8.8194E+00	1.0262E-04	8.9087E+00
	February	73.198	1.6893E-02	2.8538E-04	1.0939E-04	-6.5118E+00	9.8052E-05	6.3195E+00
	March	71.872	-1.8115E-02	3.2816E-04	1.2267E-04	-6.3309E+00	1.1009E-04	6.1334E+00
	April	71.158	-9.9343E-03	9.8691E-05	1.3815E-04	-8.1728E+00	1.2409E-04	8.1992E+00
	May	72.270	1.5627E-02	2.4421E-04	1.3535E-04	-7.1034E+00	1.2262E-04	7.0149E+00
	June	73.880	2.2278E-02	4.9629E-04	1.4362E-04	-5.3928E+00	1.3049E-04	5.1410E+00
	July	73.617	-3.5598E-03	1.2672E-05	1.7009E-04	-8.6047E+00	1.5387E-04	8.6971E+00
	August	72.624	-1.3489E-02	1.8195E-04	1.5849E-04	-7.6018E+00	1.4505E-04	7.5841E+00
	September	72.679	7.5733E-04	5.7354E-07	1.6038E-04	-8.7344E+00	1.4754E-04	8.8175E+00
	October	72.020	-9.0673E-03	8.2215E-05	1.4860E-04	-8.2610E+00	1.3836E-04	8.2914E+00
	November	69.948	-2.8770E-02	8.2770E-04	1.4379E-04	-3.0909E+00	1.3494E-04	2.7769E+00
	December	69.397	-7.8773E-03	6.2052E-05	1.9498E-04	-8.2244E+00	1.7907E-04	8.2812E+00
2007	January	70.537	1.6427E-02	2.6985E-04	1.8520E-04	-7.1370E+00	1.7179E-04	7.0984E+00
	February	69.733	-1.1398E-02	1.2992E-04	1.9166E-04	-7.8819E+00	1.7817E-04	7.9036E+00
	March	68.781	-1.3652E-02	1.8638E-04	1.8720E-04	-7.5877E+00	1.7525E-04	7.5858E+00
	April	63.306	-7.9600E-02	6.3362E-03	1.8728E-04	2.5250E+01	1.7611E-04	-2.7335E+01
	May	66.966	5.7814E-02	3.3425E-03	6.4632E-04	-2.1726E+00	5.6736E-04	1.5832E+00
	June	66.564	-6.0030E-03	3.6037E-05	8.4767E-04	-7.0305E+00	7.4370E-04	7.1554E+00
	July	67.509	1.4197E-02	2.0155E-04	7.8722E-04	-6.8910E+00	6.9891E-04	6.9776E+00
	August	66.989	-7.7027E-03	5.9331E-05	7.4364E-04	-7.1242E+00	6.6748E-04	7.2231E+00
	September	66.971	-2.6870E-04	7.2200E-08	6.9270E-04	-7.2748E+00	6.2901E-04	7.3712E+00
	October	67.114	2.1353E-03	4.5593E-06	6.4114E-04	-7.3452E+00	5.8922E-04	7.4290E+00
	November	64.424	-4.0081E-02	1.6065E-03	5.9376E-04	-4.7234E+00	5.5225E-04	4.5925E+00
	December	62.675	-2.7148E-02	7.3703E-04	6.6947E-04	-6.2081E+00	6.2194E-04	6.1976E+00
						-1.3432E+02		**1.2996E+02**
						1.3432E+02		

α=0.07463
β=0.92534
ω=0.0000015

σ^2= 6.7460E-04
σ= 0.025973056

VL= 0.070710678
Long term volatility 7.07%

Ksh/Euro

		Euro exchange rate	Ui	Ui^2	Vi	lnVi+Ui/Vi
2005						
	July	92.227				
	August	92.421	0.002104	4.42474E-06		
	September	89.134	-0.035565	1.26491E-03	4.42474E-06	-2.73543E+02
	October	88.690	-0.004981	2.48130E-05	1.13112E-04	8.86777E+00
	November	87.819	-0.009821	9.64466E-05	1.05531E-04	8.24259E+00
	December	85.911	-0.021727	4.72041E-04	1.04779E-04	4.65855E+00
2006	January	87.090	0.013724	1.88335E-04	1.36468E-04	7.51936E+00
	February	86.823	-0.003066	9.39909E-06	1.40969E-04	8.80030E+00
	March	87.305	0.005552	3.08194E-05	1.29657E-04	8.71292E+00
	April	89.158	0.021224	4.50477E-04	1.21167E-04	5.30053E+00
	May	93.056	0.043720	1.91145E-03	1.49584E-04	-3.97077E+00
	June	93.985	0.009983	9.96650E-05	3.01487E-04	7.77621E+00
	July	93.852	-0.001415	2.00256E-06	2.84115E-04	8.15908E+00
	August	93.198	-0.006968	4.85589E-05	2.59822E-04	8.06862E+00
	September	92.304	-0.009592	9.20157E-05	2.41637E-04	7.94727E+00
	October	91.589	-0.007746	6.00027E-05	2.28767E-04	8.12052E+00
	November	92.121	0.005809	3.37393E-05	2.14246E-04	8.29090E+00
	December	91.387	-0.007968	6.34855E-05	1.98714E-04	8.20416E+00
2007	January	91.434	0.000514	2.64501E-07	1.87086E-04	8.58253E+00
	February	92.167	0.008017	6.42677E-05	1.71010E-04	8.29798E+00
	March	91.766	-0.004351	1.89294E-05	1.61838E-04	8.61195E+00
	April	93.405	0.017861	3.19003E-04	1.49548E-04	6.67478E+00
	May	89.969	-0.036786	1.35321E-03	1.64185E-04	4.72500E-01
	June	89.513	-0.005068	2.56888E-05	2.66708E-04	8.13304E+00
	July	92.476	0.033101	1.09570E-03	2.45958E-04	3.85553E+00
	August	91.542	-0.010100	1.02008E-04	3.19232E-04	7.73005E+00
	September	94.784	0.035415	1.25425E-03	3.00532E-04	3.93651E+00
	October	96.827	0.021554	4.64587E-04	3.82768E-04	6.65433E+00
	November	94.939	-0.019499	3.80199E-04	3.89843E-04	6.87450E+00
	December	90.168	-0.050253	2.52540E-03	3.89034E-04	1.36039E+00
						-9.76611E+01

β=0.91377
α=0.0862
ω=0.00000034 **σ^2=** **5.73213E-04**

σ= **2.39419E-02**

Vl= **0.106458129**

Longterm volatility **10.65%**

		Pound Sterling £	Ui
2005			
	July	133.460	
	August	135.186	
	September	130.433	
	October	130.375	
	November	128.150	
	December	124.984	
2006	January	127.405	
	February	127.416	
	March	125.365	
	April	128.205	
	May	136.127	
	June	135.606	
	July	136.970	
	August	138.340	
	September	138.250	
	October	136 874	
	November	136.318	
	December	136.316	
2007	January	138.380	
	February	136.840	
	March	135.004	
	April	136.197	
	May	132.292	
	June	133.304	
	July	136.985	
	August	135.052	
	September	135.309	
	October	138.852	
	November	132.806	
	December	124.322	

ω=0.00000102

α=0.08432 **σ^2=**

β=0.9147 **σ=**

Vl=	**0.032261685**
Longterm Volatility	**3.23%**

	Ui^2	Vi	lnVi+Ui/Vi
0.012932714	0.000167255		
-0.035158966	0.001236153	0.000167255	1.305166591
-0.000444673	1.97734E-07	0.000258241	8.260852987
-0.017066155	0.000291254	0.000237249	7.11877211
-0.024705423	0.000610358	0.000242591	5.808134869
0.019370479	0.000375215	0.000274383	6.833497482
8.63388E-05	7.4544E-09	0.000283636	8.167791708
-0.01609688	0.00025911	0.000260463	7.258246148
0.022653851	0.000513197	0.000261113	6.28513764
0.061791662	0.003818209	0.000283133	-5.315968402
-0.003827308	1.46483E-05	0.000581953	7.42394944
0.010058552	0.000101174	0.000534568	7.344787884
0.01000219	0.000100044	0.00049852	7.403184844
-0.000650571	4.23243E-07	0.000465452	7.671591949
-0.009952984	9.90619E-05	0.000426805	7.5270827
-0.00406213	1.65009E-05	0.000399771	7.783342266
-1.46716E-05	2.15255E-10	0.000368082	7.907203989
0.015141289	0.000229259	0.000337705	7.314465587
-0.011128776	0.00012385	0.00032925	7.642537131
-0.013417129	0.000180019	0.000312628	7.494671014
0.008836775	7.80886E-05	0.00030216	7.846120037
-0.028671703	0.000822067	0.00028399	5.271868325
0.007649745	5.85186E-05	0.000330102	7.838834045
0.027613575	0.00076251	0.000307899	5.609245363
-0.014111034	0.000199121	0.00034695	7.392410852
0.001902971	3.6213E-06	0.000335165	7.990083353
0.026184511	0.000685629	0.000307901	5.858948336
-0.043542765	0.001895972	0.000340469	2.416478227
-0.063882656	0.004080994	0.000472315	-0.982536602
			170.4758999

0.000776169
0.027859813

LIBOR RATES DECEMBER 2007

	Dec-07 3-Dec	4-Dec	5-Dec	6-Dec	7-Dec	10-Dec	11-Dec	12-Dec	13-Dec	14-Dec	17-Dec	18-Dec	19-Dec
GBP													
s/n-o/n	5.88750	5.84750	5.83750	5.74250	5.69125	5.68500	5.70000	5.68500	5.60875	5.60000	5.59750	5.59750	5.58750
1w	5.91000	5.91000	5.88375	5.77250	5.71000	5.71375	5.72000	5.71125	5.65500	5.64250	5.64125	5.63250	5.61125
2w	6.03000	6.02375	6.01500	5.89375	5.83500	5.85000	5.85125	5.85000	5.77500	5.74500	5.74000	6.51250	6.40750
1m	6.71500	6.74875	6.75000	6.74750	6.65750	6.69500	6.73875	6.74625	6.60375	6.59250	6.54125	6.49125	6.29750
2m	6.66250	6.69938	6.70188	6.69625	6.64125	6.65375	6.66875	6.67375	6.55625	6.54750	6.49625	6.44250	6.25000
3m	6.62000	6.64938	6.65000	6.64250	6.60625	6.61500	6.62500	6.62688	6.51375	6.49625	6.43125	6.38625	6.20563
4m	6.50688	6.52750	6.52625	6.51875	6.50000	6.50500	6.51625	6.52000	6.44125	6.42250	6.38250	6.33750	6.16875
5m	6.41188	6.43063	6.42625	6.41625	6.40625	6.41250	6.42313	6.42375	6.36500	6.34875	6.31375	6.27125	6.13125
6m	6.34375	6.35063	6.33875	6.32375	6.34375	6.34938	6.35250	6.35375	6.29000	6.27875	6.24938	6.21625	6.10000
7m	6.26875	6.27375	6.26313	6.25250	6.26500	6.27250	6.27750	6.27875	6.21875	6.20875	6.18563	6.15750	6.06500
8m	6.20375	6.21125	6.19813	6.18625	6.19625	6.20000	6.20125	6.20750	6.15375	6.14813	6.12813	6.10250	6.02625
9m	6.15250	6.15500	6.14188	6.12875	6.14000	6.14875	6.15125	6.15375	6.10000	6.09875	6.07875	6.05375	5.98625
10m	6.11063	6.11625	6.10250	6.09000	6.09875	6.10375	6.10938	6.11250	6.06250	6.05625	6.03750	6.01500	5.95000
11m	6.07688	6.07875	6.06313	6.05250	6.05875	6.06375	6.06688	6.07125	6.02625	6.02063	6.00250	5.98250	5.91500
12m	6.04375	6.04938	6.02875	6.01625	6.02750	6.03000	6.03125	6.03375	5.98875	5.98000	5.96375	5.94500	5.88000

20-Dec	21-Dec	24-Dec
5.56750	5.56125	5.56250
5.59625	5.59000	5.58125
6.30625	6.21875	6.18750
6.21875	6.14625	6.09750
6.18125	6.12750	6.08375
6.14375	6.09500	6.06125
6.10000	6.06750	6.03875
6.06625	6.03375	6.01125
6.03000	5.99875	5.97875
6.00250	5.97000	5.94875
5.97000	5.93500	5.91125
5.93625	5.90125	5.87750
5.89500	5.86625	5.84000
5.86000	5.83375	5.80688
5.82500	5.80000	5.77375

27-Dec	28-Dec	31-Dec
5.52250	5.40625	5.83500
6.03125	5.91875	5.80000
6.06875	5.96250	5.83125
6.06125	6.03500	5.95375
6.05500	6.02625	5.97375
6.04625	6.01750	5.99375
6.02250	5.99625	5.97625
5.99875	5.97250	5.95500
5.97000	5.95125	5.94000
5.93125	5.91500	5.90250
5.89000	5.87875	5.86875
5.85750	5.85000	5.84000
5.82125	5.81750	5.80375
5.78750	5.78125	5.77250
5.75500	5.75000	5.74375