THE VALUATION OF FOREIGN CURRENCY OPTIONS IN KENYA UNDER STOCHASTIC VOLATILITY

BY:

KAMBI ROBINSON MUNENE

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DECLARATION

This research project is my original work and has not been submitted for the award of a degree at any other university.

Signed…………………………………………………… Date………………………………….

Kambi Robinson Munene.

Registration Number: D61/63201/2011.

This research project has been submitted for examination with my approval as a University of Nairobi supervisor.

Signed…………………………………………………..Date………………………………….

Dr. Aduda Josiah O.

Senior Lecturer.

School of Business, University of Nairobi.

DEDICATION

I dedicate this research project to my loving family; my mother and three sisters all of whom have been a source of great inspiration in all my endevours.May the Almighty God bless them abundantly.

ACKNOWLEDGEMENTS

ABSTRACT

The main objective of this research project is to show how foreign currency options can be valued in Kenya under stochastic volatility and also to come up with a model for predicting variance and volatility of exchange rates. First the research sought to develop a model for predicting variance based on the USD and Kenya Shillings exchange rates in Kenya for a period of five years between 2008-2012.The research also sought to show how foreign currency options would be priced information from the available data.

This research used descriptive research design and the Garman Kohlhagen model for valuation of foreign currency options. The research uses Garch (1, 1) model to fit the variance regression line which was used to predict variance and subsequently the volatility that together with other variables isplugged into the Garman Kohlhagen model. to price the foreign currency options.

The research gave findings that were consistent with research done in the area of valuation of foreign currency options. The research shown that foreign currency options can be valued in Kenya by use of a Garch (1, 1) framework which was a good fit for the actual data as the coefficients of the model were within the model constraints of $(\beta+\alpha = 0.98)$ <1 for using Garch (1, 1) .The research found out that for call options when the spot exchange rate is below the strike price the option has statistically zero value and when above strike price the option has a positive value. On the other hand the price of a put currency option is positive when the spot exchange rate is below the strike price and statistically zero when the spot exchange rates are above the strike prices and the further away from the strike price the spot exchange rate is the higher the value of the option.

ABBREVIATIONS

ATM……………….. At-the-money

ARCH………………Auto Regressive Conditional Heteroscedasticity

BA-W……………….. Barone Adesi Whaley Model.

B-S…………………..Black Scholes Model.

CMA………………...Capital Markets Authority.

GARCH…………….Generalized Autoregressive Conditional Heteroscedasticity

GBP…………………Great Britain Pound

ITM…………….. …..In-the-money

JPY…………………..Japanese Yen.

NSE…………………Nairobi Securities Exchange.

OTC…………………Over the Counter.

OTM………………… Out-the-money

PHLX ……………….Philadelphia Stock Exchange

REITS………………Real Estate Investments Trusts.

USD…………………United States Dollar.

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CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Currency options are derivative financial instrument where there is an agreement between two parties that gives the purchaser the right, but not the obligation, to exchange a given amount of one currency for another, at a specified rate, on an agreed date in the future. Currency options insure the purchaser against adverse exchange rate movements. According to Mixon (2011) foreign exchange option markets were active during and after the First World War where call options on German marks were the dominant instrument, but calls on French francs, Italian lira, and other currencies also traded. The largest clientele for the options consisted of optimistic investors of German heritage. Initially there were fixed exchange rate regimes in operation and hence this limited growth of the foreign currency options market.

Trading in foreign currency options began in 1970's and 1980's in listed futures and options market of Chicago, Philadelphia and London but from 1990's the trading in foreign currency options shifted to the over the counter market.While options on foreign currencies are traded on several organized exchanges, liquidity in currency options trading is predominant in (OTC) market. Liquidity in currency options trading is centered in (OTC) market. In fact, according to Malz (1998), the prices of OTC currency options provide a better expression of changing views of future exchange rates than do prices of exchange traded currency options. According to Chance (2008) the currency options are therefore a useful tool for a business to use in order to reduce costs and increase benefits from having increasing certainty in financial transactions that involve currency conversions.

In pricing of foreign currency options there are various terms as defined in Welch (2009) :First a derivative financial instrument as a financial instrument that derives its value from an underlying asset which in foreign currency options is the exchange rate, there are two types of foreign currency options a call currency option and a put currency option. A call optionon a particular currency gives the holder the right but not an obligation to buy that currency at a predetermined exchange rate at a particular date and a foreign currency put option gives the holder the right to sell the currency at a predetermined exchange rate at a particular date. The seller or writer of the option, receives a payment, referred to as the optionpremium, that then obligates him to sell the exchange currency at the pre specified price known as the strike price,if the option purchaser chooses to exercise his right to buy or sell the currency. The holder will only decide to exchange currencies if the strike price is a more favorable rate than can be obtained in the spot market at expiration.

Foreign currency options can either be European style that can only be exercised on the expiry date or American style that can be exercised at any day and up to the expiry date .Foreign currency options can either be traded in exchange markets which occur in developed financial markets that have an option market or be traded over the counter. Over the counter traded foreign currency options are better for they can be customized further to offer more flexibility. The majority of currency options traded over the counter (OTC) are European style. The date on which the foreign currency option contract ends is called the expiration date. Currency options can be at the money (ATM) where currency options have an exercise price equal to the spot rate of the underlying currency, in the money (ITM) where currency options may be profitable,

excluding premium costs, if exercised immediately or the foreign currency options may be Out the money (OTM) options would not be profitable, excluding the premium costs, if exercised.

According to Kotz'e (2011) the holder of a call option on a currency will only exercise the option if the underlying currency is trading in the market at a higher price than the strike price of the option. The call option gives the right to buy, so in exercising it the holder buys currency at the strike price and can then sell it in the market at a higher price. Similarly, the holder of a put option on a currency will only exercise the option if the spot currency is trading in the market at a lower price than the strike price. The put option gives the right to sell, so in exercising it the holder sells currency at the strike price and can then buy it in the market at a lower price. From the point of view of the option holder, the negative profit and loss represent the premium that is paid for the option. Thus, the premium is the maximum loss that can result from purchasing an option.

1.1.1. Capital Market in Kenya and Foreign Currency Options

According to Aloo (2011) in the emerging markets capital account liberalization has increased currency exposures of both domestic and foreign entities. The demand for instruments to manage the currency risk associated with portfolio investment, as well as foreign direct investment, is expanding quickly. In Kenya the capital account has been liberalized hence leading to increased currency risk exposure hence the need to develop an appropriate foreign currency option pricing framework so as to provide an additional tool to hedge against this risk. Currency options have

gained acceptance as invaluable tools in managing foreign exchange risk and are extensively used and bring a much wider range of hedging alternatives as a result of their unique nature.

The capital market in Kenya is regulated by the capital markets authority (CMA) which is an independent public agency that was established in 1989.The capital market in Kenya is composed of the primary and secondary market. The primary market the equity market that offers trading in shares through the Nairobi securities exchange (NSE).The secondary market debt financial instruments like treasury bonds, corporate bonds, preference shares, infrastructure bonds. The derivatives market in Kenya is still at its infant stage of development. The (CMA) is undertaking major reforms in the capital markets to introduce financial instruments of hybrid OTC bond trading. There is an ongoing drive to introduce the derivatives and commodities futures in Kenya and also real estate's investments trusts (REITS) are being introduced. The securities and investment bill 2011 seeks to provide additional framework necessary for the introduction of all these additional financial instruments.

Aloo (2011) in his exploratory study of currency options in the Kenyan financial market with a specific focus on the use or lack of use of currency options in the Kenyan financial market found out that currency options markets did exist in Kenya but only to a limited extent as only 4.1% of respondents said that the commercial banks they worked for offered currency options as one of their treasury products. Twenty three percent of respondents attributed the slow growth of a currency options market to low risk appetite by Kenyan commercial banks. There existed demand from clients to support the growth of a currency option market as 56% of the respondents said they had received inquiries for currency options.

The Kenya shilling is usually very volatile hitting highs of 107 as it did in October 2011 whereas it has also hit lows of 61 in 2008.Most of the trading in imports and exports involve the dealing with the USD and hence development of foreign currency options market will enable hedge against foreign exchange risk. Most of the trading in currency options in Kenya today is OTC by various commercial banks like the Kenya commercial bank and Commercial bank of Africa offer currency options but on a limited scale. Understanding the valuation of currency options will be important in development of an efficient currency options market in Kenya.

1.2. Statement of the Problem

There are two views in pricing of foreign currency options. One assumes that the volatility used in the valuation of currency options is known and is constant and the other argues that volatility is stochastic. Garman and Kohlhagen (1983) developed a variation of (B-S) used in the valuation of currency options. Black and Scholes (1973) developed the landmark paper in valuation of options. Most of pricing models today seek to relax the assumptions made by Black and Scholes (1973) and most focus on stochastic volatility develop a model for predicting volatility which is then plugged into the (B-S) model and Garman Kohlhagen Model.

Various studies have been done in Kenya relating to derivatives but most of the studies done so far have been exploratory in nature, Alaro (1998) studied the conditions necessary for the existence of a currency options market in Kenya. His study analyzed the conditions necessary for the operation of currency options by reviewingavailable literature. He concluded that main conditions for an options market to exist were a growing economy, supported by the Central Bank of Kenya, a fairly independent exchange rate mechanism, market liquidity and

efficiency, a regulatory organization and a strong and developing banking system. The study recommended the strengthening of the regulatory framework to provide clear guidelines as to the operation of currency option markets.

Aloo (2011)in his exploratory study of currency options in the Kenyan financial market with a specific focus on the use or lack of use of currency options in the Kenyan financial market. The study found that currency markets did exist in Kenya but only to a limited extent as only 4.1% of respondents said that the commercial banks they worked for offered currency options as one of their treasury products. Twenty three percent of respondents attributed the slow growth of a currency options market to low risk appetite by Kenyan commercial banks. There existed demand from clients to support the growth of a currency option market as 56% of the respondents said they had received inquiries for currency options.Orina (2009) in a survey to a survey of the factors hindering the trading of financial derivatives in the NSE found out that there existed factors of lack of adequate regulation and lack of adequate demand that hindered the trading of financial derivatives at NSE.

In Kenya few researches have been done in the area of foreign currency options and the ones that have been done are exploratory in nature. This research seeks to fill this research gap and show how foreign currency options can be priced in Kenya. This research will important especially now that derivatives' trading is being introduced in Kenya and it will offer useful insights into foreign currency options pricing.

1.3. Research Objectives

This research seeks to achieve the following key research objectives:

1. To develop an appropriate model for predicting volatility of USD/KSHS exchange rate.

2. To conduct variance analysis for USD/KSHS foreign currency options.

3. To value foreign currency options in Kenya using the predicted volatility values.

1.4 Significance of the Study

The research into valuation of foreign currency options in Kenya is very important in hedging against foreign exchange risk exposures. Foreign currency exchange rates in Kenya are unpredictable and are not stable due to the opening up of the foreign exchange market by the central bank. The exchange rates are determined by the market hence foreign currency options will be of Importance to the following: This research will use the USD/KSHS exchange rates.

The first are the importers who have to pay for their imports in the foreign currency and by the use of the pricing framework brought by this foreign currency options pricing. Here the importers can first buy a call option on the foreign currency which gives the importer the right to buy the foreign currency at a certain fixed price. Under if the Kenya shilling depreciates against the USD the importer exercises the call option to cover the downside risk and on the other hand if the Kenya shilling appreciates against the USD the importer will exercise the put option then he can sell the currency in the market at a higher rate and earn a profit.

Exporters on the other hand usually receive the payment for their exports in foreign currency equivalent of their Kenya shillings price and here they can buy some call and put options.

Whereby if the Kenya shilling appreciates against the USD they will exercise the call options to cover the downside risk and if the Kenya shilling depreciates they will exercise the put options on the USD so as to gain a profit.

Banks also will find this pricing framework very important as they will be able to offer new financial instruments to their customers to hedge against foreign exchange risk by selling both call and put options on various currencies. Here the banks will be able to also hedge their downside risk relating to foreign currency and also profit at the same time.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter seeks to analyze the literature relating to foreign currency options pricing. The chapter will have three broad areas where various theories of foreign currency options will first be analyzed. The chapter will show how the pricing of foreign currency options has evolved by analyzing three theories of Black and Scholes (1973) model, Garman and Kohlhagen (1983) model and the binomial option pricing model. Once the various theories of foreign currency option pricing have been analyzed empirical studies will then be analyzed showing clearly findings of various researchers who have ventured into the area of foreign currency option valuation.

The chapter will show clearly the various empirical findings done by the researchers in this area of foreign currency option pricing. The chapter will show clearly the different researches done and how they differ from each other and also show the similarities of the various studies done by different researchers. The evolution of the research into the area of foreign currency pricing will be clearly stipulated showing how the valuation of foreign currency options has evolved from the seminal paper to date. Then finally the chapter will offer a conclusion that can be drawn from the literature review showing what are the major themes of the literature on pricing of foreign currency options. Major contestations will also be spelt out in the literature review and research gaps identified.

2.2 Review of Theories

2.2.1 Black-Scholes Model

Black and Scholes (1973) developed (B-S) Model and suggested the following stochastic differential equation as a model for the dynamics of a stock price process:

$$dS_t = \mu S t dt + \delta S t dWt \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (i)$$

Where St is the stock price at time t, μ is the return on the stock and δ is the volatility of the stock, defined as the standard deviation of the log returns and Wt *is* a standard Brownian motion. The first term of the right hand side is called the drift. It is the deterministic part of the equation, and contributes to driving the process value St in a deterministic way. The second part, called the diffusion, is the stochastic part. It adds a random noise to St. This random noise is amplified by the volatility.

From the above we can apply simple arbitrage arguments to get a derivative pricing formula. By solving the above equation we get solution below:

$$1 \quad S_t = S_0 e \left(\mu - \frac{1}{2}\delta^2 \right) t + \delta Wt \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots(ii)$$

The above is sometimes called a geometric Brownian motion. The stock price in this model is log-normally distributed.

The (B-S) option pricing model is a function of the parameters of the diffusion process describing the dynamics of the underlying asset price. The no arbitrage principle states that if options are correctly priced in the market it should not be possible to make a guaranteed profit by creating portfolios of long and short positions in options and their underlying assets. By respecting this principle they derived a theoretical valuation formula for European options on common stocks. It is derived for a geometric Brownian motion with a constant volatility

parameter σ. The (B-S) formula was initially developed for the shares but the spot exchange rate can also replace the share price as the underlying asset.

The (B-S) model for pricing of currency options has various assumptions which can be summarized as:

1. Frictionless Markets -No taxes, transaction costs, no restrictions on taking long or short positions, and no market control.

2. Interest rates are riskless, continuously compounded, and constant.

3. Spot rates change instantaneously and they have a normal distribution

$$c = S_0 \, N(d_1) - X \, e^{-rT} N(d_2) \qquad \text{...} (iii)$$

$$p = X \, e^{-rT} \, N(-d_2) - S_0 \, N(-d_1) \text{ ....} (iv)$$

$$\text{where} \quad d_1 = \frac{\ln(S_0 / X) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}} \text{...} (v)$$

$$d_2 = \frac{\ln(S_0 / X) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \text{...} (vi)$$

Where:

S_0= Current market of underlying asset-Spot Exchange rate.

X= Option's exercise price

r= Risk free rate of interest

T= time, in years, until the option expires

σ = Volatility (as measured by the standard deviation) of the price of underlying asset.

Ln = Natural log

e = a mathematical constant number: 2.718...

N= Cumulative area under the normal curve.

For the Black-Scholes model, the only input that is unobservable is the future volatility of the underlying asset. One way to determine this volatility is to select a value that equates the theoretical (B-S) price of the option to the observed market price. This value is often referred to as the implied or implicit volatility of the option. Under the (B-S) model implied volatilities from options should be the same regardless of which option is used to compute the volatility.

2.2.2 Garman and Kohlhagen model

Garman and Kohlhagen (1983) extended the Black Scholes model to cover the foreign exchange market, Garman and Kohlhagen suggested that foreign exchange rates could be treated as non-dividend paying stocks. Where they allowed for the fact that currency pricing involves two interest rates and that a currency can trade at a premium or discount forward depending on the interest rate differential. The Garman and Kohlhagen formula applies only to European options. Garman and Kohlhagen (1983) extended the (B-S) to cope with the presence of two interest rates the domestic interest rate and the foreign currency interest rate.

The model assumed that It is easy to convert the domestic currency into the foreign currency and that we can invest in foreign bonds without any restrictions. The standard Garman and Kohlhagen foreign currency option pricing model has the following form:

$$C = Se^{r_f t} N(d_1) - Ke^{r_d t} N(d_2) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (vii)$$

$$P = -Se^{-r_f t} N(-d_1) + Ke^{r_d t} N(-d_2) \dots\dots\dots\dots\dots\dots\dots\dots\dots (viii)$$

Where:

$$d_1 = \frac{\text{Ln}\left(\frac{S}{K}\right) + (r_{d-r_f} + \frac{\sigma^2}{2})}{\sigma\sqrt{t}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (ix)$$

$$d_2 = d_1 - \sqrt[\sigma]{t}\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\ (x)$$

And,

C: Theoretical price of a call option

P: Theoretical price of a put option

S: Price of the underlying currency

K: Strike price

t: Time to expiration in years

σ: Annual volatility

r_f : Risk-free rate in the foreign currency

r_d : Risk-free rate in the foreign currency

N (d_1) and N (d_2): the cumulative normal distribution function.

This model is similar to the black Scholes model but was adapted to be used in valuation of currency options and the key difference is that it uses two interest rates the domestic risk free rate and the foreign currency interest rate.Garman and Kohlhagen (1983) suggested that foreign exchange rates could be treated as non-dividend-paying stocks.

2.2.3 Binomial option pricing model

Cox, Ross and Rubinstein (1979) developed the binomial option pricing model that is a discrete time model which contains the continuous time (B-S) model as a special limiting case. Despite its simplicity, the model can be applied to European and American style options. Furthermore, it is applicable for the valuation of a variety of complex derivatives.In the binomial model as indicated by the name the price of the underlying stock S is assumed to follow a multiplicative binomial process over discrete time periods. We can also say that the stock price follows a

random walk, because in each period, it may either move up by a certain percentage amount u-1 where u > 1 or down by a certain percentage amount 1 - d where d < 1. We denote the (physical) probability of an upward move as p and the (physical) probability of a downward move as 1 - p.

Let f_0 be the current value of a European style option, whereas f can be either a call (c_0) or a put (p_0) option. Then f_u (c_u or p_u) is the option's price if the stock price moves upward, and f_d (c_d or p_d its price if the stock price moves downward:

$$f_u \text{With probability p}$$

$$f_0$$

$$f_d \text{With probability 1 -p}$$
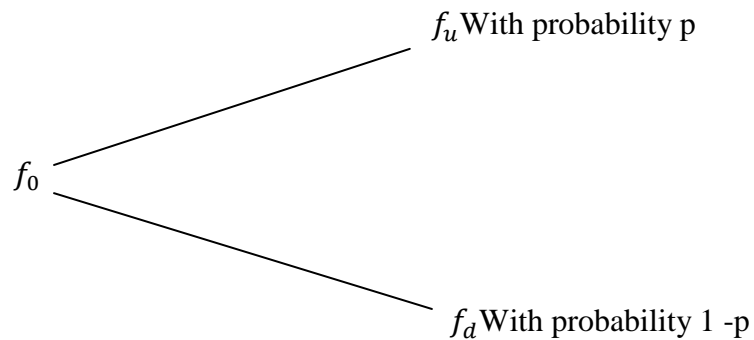
If the call option is only away one period from expiration, Then f_u (c_u or p_u and f_d (c_d or p_d are given by

c_u = max (S_0 u - K; 0) or P_u = max (K -S_0 u; 0);

c_d = max (S_0 d - K; 0) or P_d = max (K -S_0 d; 0);

2.3 Review of Empirical Studies

Fabozzi, Hauser and Yaari (1990) conducted a research that compared the performance of the Barone Adesi Whaley (BA-W) model for currency options and Garman Kohlhagen model in pricing American currency options. It was shown that the (BA-W) model is superior to the Garman Kohlhagen model in pricing out-of-the-money long-term put options and inferior in pricing in-the-money short-term put options. The two models performed equally well in pricing call options. The research further shown that the interest rate differential across countries has a greater effect on the probability of gainful early exercise in foreign currency puts than that of calls. The American model identified a large number of opportunities in our sample for gainful early exercise among in-the-money options maturing in less than 45 days. These findings suggest the need for a further investigation of the ex-post consequences of early exercise decisions based on the (BA-W) model. In combination with our results, such an investigation was found to be useful in the developments of trading strategies and the testing of market efficiency.

Campa and Chang (1995, 1998) conducted a research to test the suitability of the (B-S) model argue that the (B-S) model generates accurate option values even though it may be misspecified,and use (B-S) implied volatilities to forecast exchange rate variance and the correlations between exchange rates.

Hamilton and Susmel (1994) present a regime switching model in which each regime is characterized by a different ARCH process. In their model, the null of a single regime would be equivalent to a single ARCH process governing innovations. In this sense their regime switching model nests a standard ARCH process. However, as Hamilton and Susmel point out, the general

econometric problem of regime switching models remains: the null of a single regime is not testable in the usual way since parameters of the other regimes are not identified. Hamilton and Susmel rely on standard linear regression statistics as a simple measure of relative fit.

Bollen et al (2003) compares the performance of three competing option valuation models in the foreign exchange market, one based on a regime-switching process for exchange rate changes, one based on a GARCH process, and the other based on jump diffusion. Three tests are executed based on the parameter values implicit in option prices. The first test compares in sample fit of option prices. The study found out that GARCH model is superior to the regime-switching model for the GBP, but the two models perform about the same for the JPY. Both models dominate an ad hoc valuation model based on Black Scholes, but both are dominated by the jump diffusion model. The second test compares out-of-sample fit of option prices. Here the GARCH model performs better than the regime-switching model for both exchange rates, and again both are superior to an ad hoc valuation model. The jump-diffusion model offers only modest improvement over the others for the GBP options. The third test simulates the role of a market maker who sells options and uses the competing valuation models to hedge the positions. In this test, the GARCH and regime-switching models perform almost identically. An ad hoc strategy is superior for the GBP and is inferior for the JPY. The jump-diffusion model performs as well as the ad-hoc strategy for the GBP and is superior to all others for the JPY options.

Kalivas and Dritsakis (1997) in their study dealing with volatility forecasting techniques and volatility trading in the case of currency options they sought to provide evidence on how foreign exchange rates are moving under time varying volatility. They sought to identify the existence of

heteroscedasticity then applied widely acclaimed methods in order to estimate future exchange rates under changing volatility. They then used different methods for estimating future foreign exchange volatility, such as implied volatility and historical volatility approaches.In their study implied and historical volatility were compared and it was found, that historical volatility is the best approximation. The white's test for existence of heteroscedasticity showed that there was time variation in volatility.

Abken and Nandi (1996) model the volatility in such a way that the future volatility depends on a constant and a constant proportion of the last period's volatility. They used the ARCH framework to predict volatility.Thus, ARCH models provide a well-established quantitative method for estimating and updating volatility.

Natenberg (1994) proposed a forecast by using a weighting method, giving more distant volatility data progressively less weight in the forecast. The above weighting characteristic is a method which many traders and academics use to forecast volatility. It depends on identifying the typical characteristics of volatility, and then projecting volatility over the forecasting period.

Melino and Turnbull (1990) found that the stochastic volatility model dominates the standard option valuation models. In addition, they pointed out that a stochastic volatility model yield option prices which coincide with the observed option prices market prices.They generalized the model to allow stochastic volatility and they report that this approach is successful in explaining the prices of currency options. Though this model has the disadvantage that their models do not

have closed form solutions and require extensive use of numerical techniques to solve two dimensional partial differential equations.

Scott and Tucker (1989) examined the relative performance of three different weighting schemes for calculating implied volatility from American foreign exchange call options on the British pound, Canadian dollar, Deutschemark, Yen; and Swiss franc. They found no evidence that one of the three weighting schemes is superior to the others.

Kroner et al. (1995) found out implied volatility being higher than historical volatility due to the fact that if interest rates are stochastic, then the implied volatility will capture both asset price volatility and interest rate volatility, thus skewing implied volatility upwards, and that if volatility is stochastic but the option pricing formula is constant, then this additional source of volatility will be picked up by the implied volatility.Kroner et al (1995) also point out that, since expectations of future volatility play such a critical role in the determination of option prices, better forecasts of volatility should lead to a more accurate pricing and should therefore help an option trader to identify over- or underpriced options. Therefore a profitable trading strategy can be established based on the difference between the prevailing market implied volatility and the volatility forecast.

Dontwi, Dedu and Biney (2010)in pricing of foreign currency options in a developing financial Market. They conducted a research seeking to develop a suitable approach to the valuation of foreign currency options in an underdeveloped financial market in Ghana. Volatility analysis was done. This included the application of the GARCH model which resulted in the marginal

volatility measure. Further, the pricing of basic foreign currency options in the local market was obtained from the marginal volatility measure. The research had the following findings and conclusions: The resulting GARCH specification volatility measure can then be implemented as an input in the pricing of theoretically formed currency options in the local market. This analysis can form the basis for the pricing of currency options in developing financial the local markets. Implementation of the standardized instruments is expected to follow the further development of the domestic Forex market, its size, liquidity and legislative framework. In the beginning the further Pricing of Foreign Currency Options in a Developing Financial Market implementation of forward and swap contracts is appropriate, until the volume of trading reaches levels That would require standardization of contracts and their variety. More complex pricing schemes would then be available and adequate Forex management schemes created. This opens avenue for further research directions.

Heston (1993) proposed a closed form solution for options with stochastic volatility with applications to bond and currency options where he used a new technique to derive a closed-form solution for the price of a European call option on an asset with stochastic volatility. The model allows arbitrary correlation between volatility and spot asset returns. He introduced stochastic interest rates and shows how to apply the model to bond options and foreign currency options. Simulations show that correlation between volatility and the spot asset's price is important for explaining return skewness and strike-price biases in the Black Scholes (1973) model. The solution technique is based on characteristic functions and can be applied to other problems.

Chen and Gau (2004) investigates the relative pricing performance between constant volatility and stochastic volatility pricing models, based on a comprehensive sample of options on four currencies, including the British pound, Deutsche mark, Japanese yen and Swiss franc, traded frequently in the Philadelphia Stock Exchange (PHLX) from 1994 to 2001. The results show that Heston model outperforms the (G-S) model in terms of sum of squared pricing errors for all currency options and the adjustment speed toward the long-run mean volatility in the currency market is faster than that in the stock market.

Posedel (2006) analyzed the implications of volatility that changes over time for option pricing. The nonlinear-in-mean asymmetric GARCH model that reflects asymmetry in the distribution of returns and the correlation between returns and variance is recommended. He used the NGARCH model for the pricing of foreign currency options. Possible prices for such options having different strikes and maturities are then determined using Monte Carlo simulations. The improvement provided by the NGARCH model is that the option price is a function of the risk premium embedded in the underlying asset. This contrasts with the standard preference-free option pricing result that is obtained in the Black-Scholes model.

Aloo (2011)in his exploratory study of currency options in the Kenyan financial market with a specific focus on the use or lack of use of currency options in the Kenyan financial market. The study found that currency markets did exist in Kenya but only to a limited extent as only 4.1% of respondents said that the commercial banks they worked for offered currency options as one of their treasury products. Twenty three percent of respondents attributed the slow growth of a currency options market to low risk appetite by Kenyan commercial banks. There existed

demand from clients to support the growth of a currency option market as 56% of the respondents said they had received inquiries for currency options.

Akinyi (2007) did a study where she compared the classical B-S model and the Garch option pricing model in Kenya and she looked at the consequences of introducing heteroscedasticity in option pricing. The analysis showed that introducing heteroscedasticity results in a better fitting of the empirical distribution of foreign exchange rates than in the Brownian model. In the Black-Scholes world the assumption is that the variance is constant, which is definitely not the case when looking at financial time series data. The study priced a European call option under a Garch model Framework using the Locally Risk Neutral Valuation Relationship. Option prices for different spot prices are calculated using simulations. The study used the non-linear in mean Garch model in analyzing the Kenyan foreign exchange market.

2.4 Conclusion from literature review

The original option pricing model was developed by Black and Scholes (1973). Since then, it has been extended to apply to foreign currency options in Garman and Kohlhagen, 1983; Grabbe, (1986). Garman and Kohlhagen (1983) suggested that foreign exchange rates could be treated as non-dividend-paying stocks. From the initial studies of foreign currency option valuation various assumptions were made by Black and Scholes (1973) and research from that time has been focused of relaxing some of the assumptions. From the literature volatility is the main variable involved where by most researchers now focus on developing a model of predicting future volatility based on either historical data or implied volatility.

Volatility forecasts have many practical applications such as use in the analysis of market timing decisions, aid with portfolio selection and the provision of estimates of variance for use in option pricing models. Thus, it follows that it is important to distinguish between various models in order to find the model which provides the most accurate forecast the literature provides conflicting evidence about the superiority of each method. One the one hand, some researchers stress that relatively complex forecasts (ARCH) and (GARCH) models and implied volatility forecasts provide estimations with the best quality.

From the literature review we can conclude that most of the models of option pricing are based on the initial model of Black and Scholes and almost all the models start there and go on and relax some of the unrealistic assumptions made by the black Scholes model of option pricing. In general we can say that Black & Scholes assumed that the financial market is a system that is in equilibrium.

Most research on pricing of currency options have concentrated in developed markets and there is a research gap to conduct research in valuation of developing and emerging markets like the Kenya market. The financial markets of developed countries where most of the research on the valuation of foreign currency options has been carried out is different from the financial market in Kenya in terms of efficiency and the way they are structured .Also there is currently no market for trading of options in Kenya and some data used in the model is not readily available as in the developed financial markets. Due to the above differences in the financial markets in developed economies and Kenya's financial market there is need to come up with a model that properly fits the available data in Kenya hence the model developed specifically for Kenya will give more accurate results in valuation of foreign currency options in Kenya compared to using the already developed models for developed countries.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the type of research methodology used in the study. First the research design used is discussed and it's very important to select the appropriate research design as this will enable you to achieve the research objectives. The population of the study is then defined and the sample that will be used is then selected and justified. Data collection methods and data analysis methods that will be used are then discussed. Then the conceptual and empirical models are then defined and various variables defined and then finally the data validity and reliability is explained.

3.2 Research design

Research design refers to how data collection and analysis are structured in order to meet the research objectives through empirical evidence economically Schindler (2006).

This research uses descriptive research design which is a scientific method which involves observing and describing the behavior of a subject without influencing it in any way. The research looks at USD/KSHS exchange rate in the past and analyses it to come up with a pricing model for foreign currency options in Kenya.

3.3 Population

Cooper and Emory (1995) define population as the total collection of elements about which the researcher wishes to make inferences. The population of interest in this study is the foreign currency exchange rates in Kenya.

3.4 Sample

The sample for this research will be the daily USD/KSHS exchange rate for 5 years from 2008 to 2012.The exchange rates used in formulating the model for predicting volatility are the mean daily exchange rates from January 2008 to December 2012 with 1253 daily data exchange rates for the USD against the KSHS. The exchange rate for the USD against the Kenya Shilling range from a low of 61.51 in May 2008 to a high of 105.91 in October 2011 but the majority of the exchange rates lie between 70-90 against the USD. For the simulation of the foreign currency option pricing exchange rate data for January 2013 is used. The USD is used for it's the most traded currency and most transactions in Kenya are pegged against the USD which also acts as the intermediary in triangular currency transactions. The exchange rates are given by appendix 3.

3.5 Data Collection

This study will use secondary data for the various variables that will be put into the model. The secondary data will be obtained from Central bank of Kenya and Kenya bureau of statistics. The secondary data collected will cover a period of five years from 2008 to 2012.

3.6 Data Analysis

This study will use both descriptive and inferential statistics to analyze the data. Analysis will be done using the Statistical package for social scientists (SPSS Version 20).Secondary data will be collected then regression analysis will be carried out to model the volatility equation and the gained volatility estimate used in the valuation of foreign currency options.

3.7 Conceptual model

This study will use GARCH (1, 1) which estimates current volatility as a function of the long-run average variance, a single lagged squared return and a single lagged variance. The model is based is based on the original propositions of Black and Scholes model as adjusted by the Garman Kohl Hagen Model. Under this model the foreign currency call (C) and put (P) option is a function of the following six variables below

C/P= f (S, K, T,r_d r_f σ).

Where: (S) is the current currency spot rate,(K) the strike price,(T) the time to expiration,(r_d) the local risk free interest rate, ,(r_f) the foreign risk free interest rate and(σ) is the volatility.

3.8 Empirical model

A standard GARCH (1, 1) model is used to estimate the volatility of the foreign currency option. GARCH is an approach to estimating conditional volatility. GARCH (1, 1) estimates current volatility as a function of the long-run average variance, a single lagged squared return and a single lagged variance.

$$\sigma_t^2 = \omega + \beta\sigma_{t-1}^2 + \alpha\varepsilon_{t-1}^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{ (xi)}$$

Where:

σ_t^2 Is the conditional variance of the return at time t.

ε_{t-1}^2: The squared random component of the return in the previous period,

σ_{t-1}^2 The previous period historical variance.

And $\varepsilon_t = Ln\dfrac{E_t}{E_{t-1}}$

The analysis entails the fitting of the GARCH (1, 1) specification for the (KSHS) and (USD) exchange rate and the implementation of the gained volatility measure in the pricing of foreign

currency options in the Kenyan market. Once the variance is estimated standard deviation which represents the volatility is attained by finding the square root of the variance. The volatility is estimated on monthly basis and is assumed to be constant over that month.

The above volatility model is used to predict volatility for the next period which is the month that follows .The volatility will be predicted by the above model then the resultant volatility plugged into the Garman and Kohlhagen model stipulated below. All the variables below are observable except volatility which will be estimated from the above model.

$$C = Se^{r_f t} N(d_1) - Ke^{r_d t} N(d_2) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(vii)}$$

$$P = -Se^{-r_f t} N(-d_1) + Ke^{r_d t} N(-d_2) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(viii)}$$

Where:

$$d_1 = \frac{\text{Ln}\left(\frac{S}{K}\right) + (r_{d-r_f} + \frac{\sigma^2}{2})}{\sigma\sqrt{t}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(xi)}$$

$$d_2 = d_1 - \sigma\sqrt{t} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(x)}$$

And,

C: theoretical price of a call option

P: theoretical price of a put option

S: price of the underlying currency

K: strike price-(Simulated values are used).

t: time to expiration in years

σ: annual volatility

r_f : The risk-free rate in the foreign currency

r_d The risk-free rate in the Kenya economy.

N (d_1) and N (d_2): the cumulative normal distribution function

All the above variables are observable except annual volatility which will be estimated by the Garch (1, 1) model above and the foreign currency call and put options will be valued at various simulated strike prices.

3.9 Data Validity & Reliability

The data validity and reliability will be assured for this study will use secondary data from trusted sources of Central bank of Kenya and the Kenya national bureau of statistics.

CHAPTER FOUR

DATA ANALYSIS AND PRESENTATION

4.1 Introduction

This of data analysis and presentations has two major parts. First the data is clearly presented and defined, data analysis methods used for the research is also discussed and finally summary and findings are clearly interpreted.

4.2 Data Presentation

4.2.1   Variance

The variance is a measure of the squared deviations of the observations from the mean. In this research first price relatives are calculated from the exchange rates given, then natural logs of the price relatives are now used as the variable by which the variance is estimated. In this research variance is assumed to follow an historical trend where the variance of today's period determines the variance of the following periods. The variance in this research is a function of two main dependent variable whereby current period's variance depends on previous period variance and previous period squared log returns. The variance used in the study is the historical variance which is calculated based on the returns of the USD/KSHS exchange rates and the variance period is thirty days.

4.2.2   Squared log Returns

Squared log returns is one of the independent variable is this research. For this research squared log returns for the exchange rates is used to estimate variance and consequently the volatility. The squared log returns has been determined to be a goon variable for estimating the variance

from previous studies done in this area of pricing of foreign currency options. To determine the squared log returns first the exchange price relative rates is calculated and the price relative relates the current daily exchange rate with the previous day's exchange rate and it'scomputed by dividing current daily exchange rate by the previous day exchange rate. The squared log returns is based on the natural logarithm of price relative of the USD/KSHS exchange rates as illustrated in appendix 1.

4.2.3 Risk free rate

Risk free interest rate is the theoretical rate of return of an investment with zero risk including the default risk. The risk free rate represents the interest that an investor would expect from an absolutely risk free investment over a given period of time.Risk free rate can be said to be the rate of interest with no risk. Therefore any rational investor will reject all the investments yielding sub risk free returns.The risk free rate is usually obtained from government securities which offer a guaranteed return with no risk. The risk free rates used are the 364 days Treasury bill rate for the domestic Kenya interest rate which in January 2013 averaged 11.67% and the foreign risk free rate the 1 year Treasury bill for USA was used in the study and the foreign risk free rate is as shown in appendix 2.

4.2.4 Strike price

The strike price is defined as the price at which the holder of currency options can buy in the case of a call option or sell in the case of a put option the underlying security when the option is exercised. Since we don't have the options market in Kenya the foreign currency options was priced based on simulated strike prices of 70,80,90 and 100.These four strike prices are adequate in this analysis as they help portray various pricing dynamics of foreign currency options

pricing.The strike prices selected will be adequate in illustrating the pricing of foreign currency options the exchange rate for the USD versus the Kenya shilling is usually within this range.

4.2.5 Time to maturity

The time to maturity is the period that remaining before the option expires. This research assumes that the currency options are European currency options that can only be exercised on the maturity date on their expiry date. The time to maturity used in this study is a foreign currency option of 6 months and this translates to a 0.5 fraction of a year.

4.2.6 Volatility

Volatility is one of the major variable in this research and coming up with a good volatility estimate is very key in coming up with an adequate and accurate foreign currency pricing model. Volatilityshows the variation in data in relation to the mean. If the data is close together, the standard deviation will be small. If the data is spread out, the standard deviation will be large. Volatility is estimated from a sample of recent continuously compounded returns .This research uses historical volatility estimates and assumes that volatility of the past will hold in the future and in this research variance from past data of the exchange rates for the USD against the Kenya shilling is calculated and a regression model based on the Garch (1, 1) framework is formulated to predict future volatility. From the predicted variance estimates we obtain the standard deviation by finding the square-root of the estimated variance which represents the volatility used in pricing of foreign currency options. The volatility used in this study is as predicted by the variance model and it's shown in appendix 2

4.3 Regression results analysis and application of model.

Regression analysis was conducted for the above model and produced the following results summarized below.

Table 1:Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995[a]	.990	.990	.000005765254121

Predictors: $\boldsymbol{\omega}$, ε_{t-1}^2, σ_{t-1}^2

Dependent Variable: σ_t^2

R square is the coefficient of determination and shows by what proportion the variations of the dependent variable are explained by the independent variables. From above the R Square statistic gives the goodness of fit of the model which shows how good the regression model approximates the real data points. An R square of 1.0 indicates that the regression line perfectly fits the data. The R square of this model is .990 which shows that the model is a good fit of the actual data. Coefficient of correlation ranges between -1 to 1 and in this model the coefficient of correlation is .995 which shows a high positive correlation between current period variance, previous period variance and previous period log returns.

Table 2:Coefficients

Model	Coefficients		T	Sig.
	B	Std. Error		
ω	4.153E-007	.000	2.139	.033
σ_{t-1}^2	.968	.003	321.410	.000
ε_{t-1}^2	.012	.002	6.589	.000

Dependent Variable: σ_t^2

Independent variable: ε_{t-1}^2, σ_{t-1}^2

From above the analysis of the data a variance model can be fitted for the exchange rate data of USD against Kenya Shilling. From the coefficients obtained above we have the following variance model which satisfies the Garch (1, 1) conditions as **$(\beta+\alpha)$ <1.**

$$\sigma_t^2 = 0.0000004153+0.968\ \sigma_{t-1}^2+0.012\ \varepsilon_{t-1}^2$$

The above model is the model that is used to predict variance then we find the square root of the estimated variance to get the standard deviation which will be used as the volatility in the Garman Kohlhagen model as illustrated below.

By use of simulation for a hypothetical foreign currency call and put option can be valued as shown below. Since strike price data is not available valuation of the currency option can be valued under for strike prices of 70, 80, 90 and 100 exchange rates for the USD. January 2013 USD/KSHS exchange rates are used to generate the variables inputted in the variance model which is used to estimate volatility for the period of January 2-15.

Table 3: Strike price at 70.

K=70							
Date-January 2013	Exchange Rate (S)	σ%	364 day T-Bill -CBK r_f		T	Call Price	Put price
2	86.0769	1.733955898	11.67%	15%	0.5	13.82490236	9.2527E-56
3	86.3569	1.735499828	11.67%	15%	0.5	14.08467053	1.78183E-57
4	86.4417	2.138661907	11.67%	15%	0.5	14.16334318	3.64191E-39
7	86.4264	2.157175963	11.67%	15%	0.5	14.1491487	1.77897E-38
8	86.4775	2.161130222	11.67%	14%	0.5	14.59870562	2.04321E-40
9	86.5242	2.160869074	11.67%	13%	0.5	15.04663167	1.55639E-42
10	86.6053	2.15883403	11.67%	14%	0.5	14.71786555	4.70173E-41
11	86.6722	2.171929076	11.67%	14%	0.5	14.7802427	6.98047E-41
14	86.6844	2.167331477	11.67%	14%	0.5	14.7916179	4.25082E-41
15	86.6853	2.014238296	11.67%	14%	0.5	14.79245705	3.70894E-47

First for the analysis of the model in practice first we look at the foreign currency option having a strike price of 70.The strike price of 70 is below the spot exchange rates which are above 86 for the simulation period of January 2013 and hence its advantageous for the currency call holders to exercise the calls as they would gain while for put holders they would lose out hence no put holder would exercise their put currency options. For this reason based on the laws of demand and supply and practical options trading we have a higher demand for currency call options hence the higher price compared to the currency put options. The price of the currency call option ranges between 13.82-15.04 while the currency put option prices for this period of simulation are statistically Zero as shown in the above table.

Table 4: Strike price at 80.

K=80							
Date-January 2013	Exchange Rate (S)	σ%	364 day T-Bill -CBK r_f		T	Call Price	Put price
2	86.0769	1.733955898	0.1167	0.2	0.5	4.391705456	3.77065E-07
3	86.3569	1.735499828	0.1167	0.2	0.5	4.651473354	9.95422E-08
4	86.4417	2.138661907	0.1167	0.2	0.5	4.730153592	7.68998E-06
7	86.4264	2.157175963	0.1167	0.2	0.5	4.71596094	9.51329E-06
8	86.4775	2.161130222	0.1167	0.1	0.5	5.165510195	1.85385E-06
9	86.5242	2.160869074	0.1167	0.1	0.5	5.613434708	3.12876E-07
10	86.6053	2.15883403	0.1167	0.1	0.5	5.284669412	1.141E-06
11	86.6722	2.171929076	0.1167	0.1	0.5	5.347046442	1.02458E-06
14	86.6844	2.167331477	0.1167	0.1	0.5	5.358421556	9.33874E-07
15	86.6853	2.014238296	0.1167	0.1	0.5	5.359259933	1.56162E-07

Now looking at the option prices at strike price of 80 where the strike price of 80 is below the spot exchange rates which are above 86 for the simulation period of January 2013 and hence its advantageous for the currency call holders to exercise the calls as they would gain while for put holders they would lose out hence no put holder would exercise their put currency options. For this reason based on the laws of demand and supply and practical options trading we have a higher demand for currency call options hence the higher price compared to the currency put options. The price of the currency call option ranges between 4.39-5.61 while the currency put option prices for this period of simulation are statistically Zero as shown in the above table. From above we can see that the call prices are lower that for the strike price of 70 and this is for the reason that the strike price of 80 is closer to the spot exchange rate than that of 70.

Table 5: Strike price at 90.

K=90							
Date-January 2013	Exchange Rate (S)	σ%	364 day T-Bill -CBK r_f	T		Call Price	Put price
2	86.0769	1.7339559	11.67%	15%	0.5	5.60391E-08	5.041492255
3	86.3569	1.73549983	11.67%	15%	0.5	13.22109375	4.781724252
4	86.4417	2.13866191	11.67%	15%	0.5	2.42756E-05	4.703075651
7	86.4264	2.15717596	11.67%	15%	0.5	2.67182E-05	4.717272569
8	86.4775	2.16113022	11.67%	14%	0.5	0.000120705	4.267809642
9	86.5242	2.16086907	11.67%	13%	0.5	0.000462891	3.820225774
10	86.6053	2.15883403	11.67%	14%	0.5	0.000172297	4.148701303
11	86.6722	2.17192908	11.67%	14%	0.5	0.000225534	4.086377394
14	86.6844	2.16733148	11.67%	14%	0.5	0.000227066	4.075003721
15	86.6853	2.0142383	11.67%	14%	0.5	8.32143E-05	4.074020715

Now looking at the option prices at strike price of 90 where the strike price of 90 is now above the spot exchange rates which are above 86 for the simulation period of January 2013 and hence its advantageous for the currency put holders to exercise the puts as they would gain for they can buy the currency from the foreign currency market at a lower exchange rate of 86 and then sell it at 90 hence gaining from exercising their put options. while for call holders they would lose out by exercising the currency call options as they will be buying the currency at 90 and can only sell the currency to the market at only 86 hence no call holder would exercise their call currency options. For this reason based on the laws of demand and supply and practical options trading we have a higher demand for currency put options hence the higher price compared to the currency call options. The price of the currency put option ranges between 3.82-5.04 while the currency call option prices for this period of simulation are statistically Zero as shown in the above table.

Table 6: Strike price at 100.

K=100							
Date-January 2013	Exchange Rate (S)	σ%	364 day T-Bill -CBK	r_f	T	Call Price	Put price
2	86.0769	1.733955898	11.67%	15%	0.5	1.87413E-43	14.4747
3	86.3569	1.735499828	11.67%	15%	0.5	8.08449E-42	14.2149
4	86.4417	2.138661907	11.67%	15%	0.5	4.17392E-28	14.1362
7	86.4264	2.157175963	11.67%	15%	0.5	1.01088E-27	14.1504
8	86.4775	2.161130222	11.67%	14%	0.5	6.15026E-26	13.7009
9	86.5242	2.160869074	11.67%	13%	0.5	2.53207E-24	13.253
10	86.6053	2.15883403	11.67%	14%	0.5	1.50311E-25	13.5817
11	86.6722	2.171929076	11.67%	14%	0.5	4.7899E-25	13.5193
14	86.6844	2.167331477	11.67%	14%	0.5	4.21789E-25	13.508
15	86.6853	2.014238296	11.67%	14%	0.5	1.12311E-28	13.5071

Now finally looking at the option prices at strike price of 100 where the strike price of 100 is now above the spot exchange rates which are above 86 for the simulation period of January 2013 and hence its advantageous for the currency put holders to exercise the puts as they would gain for they can buy the currency from the foreign currency market at a lower exchange rate of 86 and then sell it at 100 hence gaining from exercising their put options. while for call holders they would lose out by exercising the currency call options as they will be buying the currency at 100 and can only sell the currency to the market at only 86 hence no call holder would exercise their call currency options. For this reason based on the laws of demand and supply and practical options trading we have a higher demand for currency put options hence the higher price compared to the currency call options. The price of the currency put option ranges between 13.25-14.47 while the currency call option prices for this period of simulation are statistically Zero as shown in the above table. From above we can see that the currency put prices are higher for the strike price of 100 compared to that of 90 and this is due to the fact that at strike price of 100 is further away from the spot exchange rates of 86 hence you will be gaining more when you exercise the put currency options hence the higher price.

4.4 Summary and Interpretation of Findings

The research used a two-step approach in pricing of foreign currency options in Kenya by first developing a model for predicting volatility and then plugging the predicted volatility estimates into the Garman Kohlhagen model to obtain the price of the foreign currency options in Kenya. The research used regression analysis and the Garch (1, 1) model to formulate a model for predicting variance. The predicted variance estimates are then converted into volatility estimates that are in turn used in valuation of foreign currency options. The Garch (1, 1) model obtained yields an appropriate model which has a high coefficient of determination of 0.990 and this implies that the Garch (1, 1) is a good model for fitting volatility using the USD/KSHS daily exchange rate data. The model also satisfies Garch (1, 1) condition for the coefficients in the model ($\beta+\alpha = 0.98$) <1and this shows that the model is a good fit for actual data.The selected independent variables of the previous day squared log returns and previous day's variance determine to a large extent current day's variance estimates.

From the above simulated foreign currency option prices as shown in tables 3-6 where we have strike prices of 70,80,90 and 100 the foreign currency call price is higher than the currency put price which is almost statistically zero when the strike price is below the daily spot exchange rates for the strike prices of 70 and 80. This is due to the fact that when the strike is below the spot exchange rate exercising the currency call options a holder of the currency call option would gain as he can buy the currency at the lower strike price and sell it in the market at the higher exchange rate. While for the foreign currency put option holders they would lose out if they exercised the puts for they would have to sell the currency at a lower price than that that they can freely obtain from the foreign exchange market.

When the strike price is above the daily spot exchange rate as shown in tables 5 and 6 the foreign currency options the foreign currency put price is higher than the currency call price which is almost statistically zero when the strike price is above the daily spot exchange rates for strike prices of 90 and 100. This is due to the fact that when the strike is above the spot exchange rate exercising the currency put options a holder of the currency put option would gain as he can buy the currency at the lower spot exchange rate and sell it at the higher spot exchange rate. While for the foreign currency call option holders they would lose out if they exercised the calls for they would have to pay more than the market spot exchange rate for the currencyand hence they would not exercise them.

From above simulation as shown in tables 3, 4, 5 and 6 using January 2013 USD/KSHS exchange rate data foreign currency options can be valued in Kenya and the results obtained show that the valuation is consistent with previous literature and studies done on the valuation of foreign currency options especially the studies that used the GARCH pricing like inDontwi, Dedu and Biney (2010)in pricing of foreign currency options in a developing financial Market in Ghana. The exchange rates between January 2-15 range between 86.0769-86.6853 and using the strike prices of 70, 80, 90 and 100 this study yields results consistent with previous theories and literature. From theory and previous studies done in the area of currency options valuation for call options, the higher the strike price, the cheaper the currency call option and for put option the lower the strike price the cheaper the currency put option. This model results also shows that the Garch (1,1) also yields a good model for estimating the variance and the volatility used in pricing of foreign currency options.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The main objective of this study was to show how foreign currency options can be valued in Kenya under stochastic volatility and also to come up with a model for predicting variance and volatility of exchange rates. This research used descriptive research design which is a scientific method which involves observing and describing the behavior of a subject without influencing it in any way. The research looked at USD/KSHS exchange rate in the past and analyses it to come up with a pricing model for foreign currency options in Kenya. The research looked at various literatures on valuation of foreign currency options identifying the major models used. The research sought to show how currency options can be valued in Kenya under stochastic volatility.

The study used Garman Kohlhagen model for valuation of foreign currency options whereby two interest rates of domestic and foreign risk free rate. The study used Garch (1, 1) model to fit the variance regression line which was used to predict variance and subsequently the volatility that is plugged into the Garman Kohlhagen model. The research had various findings that were consistent with previous research done in the area of valuation of currency options. The research found out that for call options when the spot exchange rate is below the strike price the option has statistically zero value and when above strike price the option has a positive value. On the other hand the price of a put currency option is positive when the spot exchange rate is below the strike price and statistically zero when the spot exchange rates are above the strike prices and the further away from the strike price the spot exchange rate is the higher the value of the option.

5.2 Conclusions

From the findings various conclusions can be drawn. First from the findings the Garch (1, 1) model used for predicting variance used for predicting the volatility used in valuation of foreign currency yields an appropriate model which has a high coefficient of determination of 0.990 and this implies that the Garch (1,1) is a good model for fitting volatility using the USD/KSHS exchange rate data. The model also satisfies Garch (1, 1) condition for the coefficients in the model ($\beta + \alpha = 0.98$) <1and this shows that the model is a good fit for actual data

From the study another conclusion is that the prices of currency call and put option obtained from the model are consistent with historical literature and empirical studies in the area of foreign currency options valuation. From the research findings we can conclude that if the spot exchange rate is below or above the strike price of the foreign currency determines to a great extent thee price of the foreign currency option.

When the spot exchange rate is below the currency option strike price the price of the currency call option is statistically zero and the price of the currency put option is positive as a holder of the put option would gain from exercising them hence high demand and price subsequently. On the other hand when the spot exchange rate is above the strike price the price of the currency put option is statistically zero and the price of the currency call option is positive as the holders of the currency options would gain by exercising the call options and hence high demand and price of the currency call options. Hence the further the spot exchange rate is from the strike price the higher the price of the foreign currency calls and put option.

5.3 Policy Recommendations

For introduction of currency options in Kenya the first policy recommendation is to formulate a good and robust regulation framework. Under this the Central bank of Kenya should formulate an adequate regulatory framework for introduction of derivative trading in Kenya. The regulatory framework should give definitions of the various derivative instruments like swaps, calls, puts and clearly spell out the procedures that will be followed when trading in the derivatives trading. For currency options the regulatory framework should indicate the minimum trade of the currency options allowable, clearly spell out conditions that you need to fulfill in order to be allowed to trade in the currency options for the dealers.

The Central Bank of Kenya and the Capital markets authority should also spearhead faster introduction of an options market in Kenya where options and other derivatives and futures can be traded. The options market will be very important as it will provide increased liquidity in the financial market. The options market will also be another source of capital and it will be very essential in management of risks associated with various underlying assets like foreign exchange rates which are volatile. The options market will also enhance stability of importers and exporters cash flows and this will in turn lead to a more stable economy.

The Central bank of Kenya should adopt measures to improve market efficiency especially in the foreign exchange market whereby stable macroeconomic policies should be adopted and the foreign exchange market left to operate more freely devoid of interference. Exchange rates should be determined by market forces of demand and supply and be more liberalized and with the increased efficiency in the foreign exchange market this will lead to better and more accurate models of valuation of foreign currency options in Kenya.

5.4 Limitations of the Study

When conducting this various limitations were encountered. The first limitation was the lack of an options market in Kenya and this is the main limitation to this study for one to ascertain how good the model is in valuation of foreign currency options you need to compare the price obtained from the model and the prices that are in the options market. The prices given by model should of valuation of foreign currency options should be consistent with the prices of the same options in the actual options market for foreign currency options.

Another limitation is the lack of high levels of efficiency in the foreign exchange market especially informational efficiency and the foreign exchange market in Kenya is subject to interference through various macroeconomic policies and the market is even subject to political interference. This interference inhibits the foreign exchange market which affects foreign exchange rates which in turn affects the quality of the model obtained.

Another limitation of the study is the assumptions in the study of no taxes and no transaction costs some of which are not realistic. This has an impact for in today's financial markets taxes are in all financial transactions and transaction costs are in all financial dealings as the financial intermediaries usually charge a commission and in this study we assume no transaction costs which in reality is not possible in reality of today's financial markets.

Another limitation of this study is that some variables used do not exist like the strike prices where valuation of the foreign currency options have to be valued by simulation of prices of the foreign currency options at various strike price of 70, 80, 90 and 100.

5.5 Suggestions for Further Studies

Further studies relating to this study can be done in the following areas. First valuation of currency options under constant volatility using Black Scholes model can be conducted and here volatility would be constant and not vary as in this study and the resulting valuation of currency options can be compared with the values of the foreign currency options obtained in this study.

The volatility risk premium embedded in currency options whereby volatility risk premium can be analyzed for over the counter currency options. Here we analyze if volatility has a term structure which volatility risk premium decreases towards maturity of the option. Here we look at volatility and how volatility varies in the life of the currency option up to the maturity date of the currency option.

Hedging with foreign currency options is another area where additional studies can be conducted and here one can look at how you can use the currency options to hedge against foreign currency risk. Here one will be able to come up with hedging strategies, whether to purchase a call or a put and the volume to purchase.

Another area that further studies can be conducted is the pricing of currency Swap. Currency swap is the best way to fully hedge a loan transaction as the terms can be structured to exactly mirror the underlying loan. It is also flexible in that it can be structured to fully hedge a fixed rate loan with a combined currency and interest rate hedge via a fixed-floating cross currency swap. The currency swaps will be an additional tool for hedging against financial risk.

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APPENDICES

APPENDIX 1:

Date	Exchange Rate-Mean Rate	ε_{t-1}^2	σ_{t-1}^2	σ_t^2	σ	$\sigma\%$
1	-					
2	86.0769	6.16E-07	3.95E-07	0.00000119	0.01733956	1.73395590
3	86.3569	3.15E-07	3.96E-07	0.00000120	0.01735500	1.73549983
4	86.4417	1.05471E-05	7.11E-07	0.00000182	0.02138662	2.13866191
5	-					
6	-					
7	86.4264	9.63322E-07	7.27E-07	0.00000185	0.02157176	2.15717596
8	86.4775	3.13338E-08	7.31E-07	0.00000185	0.02161130	2.16113022
9	86.5242	3.49375E-07	7.30E-07	0.00000185	0.02160869	2.16086907
10	86.6053	2.91469E-07	7.29E-07	0.00000185	0.02158834	2.15883403
11	86.6722	8.77727E-07	7.40E-07	0.00000187	0.02171929	2.17192908
12	-					
13	-					
14	86.6844	5.96249E-07	7.36E-07	0.00000186	0.02167331	2.16733148
15	86.6853	1.98107E-08	6.07E-07	0.00000161	0.02014238	2.01423830
16	86.6989	1.07795E-10	6.01E-07	0.00000160	0.02006569	2.00656887
17	86.7042	2.46104E-08	5.89E-07	0.00000157	0.01991544	1.99154423
18	86.8653	3.73678E-09	5.85E-07	0.00000157	0.01987272	1.98727215
19	-					
20	-					
21	86.8531	3.44591E-06	6.53E-07	0.00000170	0.02069584	2.06958378
22	86.9792	1.97282E-08	6.59E-07	0.00000171	0.02076970	2.07697040
23	87.3794	2.10489E-06	6.85E-07	0.00000176	0.02108362	2.10836233
24	87.4694	2.10731E-05	1.27E-06	0.00000292	0.02711344	2.71134395
25	87.5206	1.05979E-06	1.25E-06	0.00000287	0.02691404	2.69140404
26	-					
27	-					
28	87.5828	3.42431E-07	1.25E-06	0.00000287	0.02689871	2.68987101
29	87.5906	5.04721E-07	1.25E-06	0.00000287	0.02689653	2.68965263
30	87.5861	7.93072E-09	1.24E-06	0.00000285	0.02681749	2.68174903
31	87.6111	2.63956E-09	1.24E-06	0.00000285	0.02681997	2.68199696

APPENDIX 2:

Date	Exchange Rate (S)	σ%	364 day T-Bill -CBK	r_f	T
2	86.0769	1.733955898	11.67%	15%	0.5
3	86.3569	1.735499828	11.67%	15%	0.5
4	86.4417	2.138661907	11.67%	15%	0.5
7	86.4264	2.157175963	11.67%	15%	0.5
8	86.4775	2.161130222	11.67%	14%	0.5
9	86.5242	2.160869074	11.67%	13%	0.5
10	86.6053	2.15883403	11.67%	14%	0.5
11	86.6722	2.171929076	11.67%	14%	0.5
14	86.6844	2.167331477	11.67%	14%	0.5
15	86.6853	2.014238296	11.67%	14%	0.5
16	86.6989	2.006568866	11.67%	14%	0.5
17	86.7042	1.991544234	11.67%	14%	0.5
18	86.8653	1.987272153	11.67%	14%	0.5
21	86.8531	2.069583783	11.670%	14%	0.5
22	86.9792	2.076970402	11.670%	14%	0.5
23	87.3794	2.108362334	11.670%	15%	0.5
24	87.4694	2.711343947	11.670%	15%	0.5
25	87.5206	2.691404039	11.670%	15%	0.5
28	87.5828	2.689871006	11.67%	16%	0.5
29	87.5906	2.689652635	11.67%	15%	0.5
30	87.5861	2.681749027	11.67%	15%	0.5
31	87.6111	2.681996963	11.67%	15%	0.5

APPENDIX 3: Daily Mean Exchange Rates (January 2008-December 2012)

	Date	Mean Exchange Rate(Et)		Date	Mean Exchange Rate(Et)
	12/31/2007	62.5411		4/9/2008	64.6111
2008	1/2/2008	63.4		4/10/2008	62.9833
	1/3/2008	65.0571		4/11/2008	62.4333
	1/4/2008	67.1357		4/14/2008	62.3633
	1/7/2008	65.8222		4/15/2008	61.6722
	1/8/2008	65.3944		4/18/2008	62.1633
	1/9/2008	65.32		4/21/2008	61.7667
	1/10/2008	65.6111		4/22/2008	61.5206
	1/11/2008	65.3389		4/23/2008	61.5722
	1/14/2008	66.0472		4/24/2008	61.7056
	1/15/2008	67.0611		4/25/2008	62.0667
	1/16/2008	67.485		4/28/2008	62.1556
	1/17/2008	67.6063		4/29/2008	62.25
	1/18/2008	68.1511		4/30/2008	62.1356
	1/21/2008	68.9222		5/2/2008	61.9778
	1/22/2008	69.5163		5/5/2008	61.8333
	1/23/2008	70.2933		5/6/2008	61.7544
	1/24/2008	73.4722		5/7/2008	61.6044
	1/25/2008	69.8889		5/8/2008	61.6733
	1/28/2008	69.5833		5/9/2008	61.7011
	1/29/2008	72.7472		5/12/2008	61.5883
	1/30/2008	73.3722		5/13/2008	61.5106
	1/31/2008	70.5611		5/14/2008	61.5306
	2/1/2008	71.4667		5/15/2008	61.7028
	2/4/2008	69.9744		5/16/2008	61.9006
	2/5/2008	70.7056		5/19/2008	62.175
	2/6/2008	70.8156		5/20/2008	62.3611
	2/8/2008	72.5444		5/21/2008	62.1533
	2/11/2008	72.1756		5/22/2008	61.9722
	2/12/2008	71.9144		5/23/2008	61.9067
	2/13/2008	70.0083		5/26/2008	62.3056
	2/14/2008	70.0528		5/27/2008	62.15
	2/15/2008	69.9167		5/28/2008	61.9944
	2/18/2008	70.0278		5/29/2008	62.06
	2/19/2008	70.0367		5/30/2008	62.0289
	2/20/2008	69.8111		6/3/2008	62.0222
	2/21/2008	69.6833		6/4/2008	61.7978
	2/22/2008	69.8		6/5/2008	61.6611
	2/25/2008	69.6478		6/6/2008	62.4083
	2/27/2008	70.6611		6/9/2008	63.48
	2/28/2008	70.6389		6/10/2008	63.5456
	2/29/2008	68.9778		6/11/2008	63.6211
	3/3/2008	67.7833		6/12/2008	64.1939
	3/4/2008	67.6667		6/13/2008	64.2378
	3/5/2008	66.8811		6/16/2008	64.8189
	3/6/2008	64.9422		6/17/2008	64.1167
	3/7/2008	64.9211		6/18/2008	64.2061
	3/10/2008	65.6556		6/19/2008	64.1667
	3/12/2008	66.0556		6/20/2008	64.4172
	3/14/2008	65.8833		6/23/2008	64.4456
	3/17/2008	65.1056		6/24/2008	64.4689

	3/18/2008	64.2556		6/25/2008	64.4567
	3/19/2008	64.0189		6/26/2008	64.4267
	3/20/2008	62.9167		6/27/2008	64.47
	3/25/2008	62.8944		6/30/2008	64.6944
	3/26/2008	63.1111		7/1/2008	65.0156
	3/27/2008	63.8567		7/2/2008	65.3233
	3/28/2008	62.9333		7/3/2008	65.9028
	3/31/2008	62.8478		7/4/2008	65.8011
	4/1/2008	62.7689		7/7/2008	65.3906
	4/2/2008	62.75		7/8/2008	65.4139
	4/3/2008	62.8944		7/9/2008	66.0367
	4/4/2008	62.41		7/10/2008	66.7083
	4/7/2008	61.8389		7/11/2008	66.8444
	4/8/2008	62.3611		7/14/2008	67.0222
	7/15/2008	67.42		10/23/2008	79.5278
	7/16/2008	67.2944		10/24/2008	80.1222
	7/17/2008	67.2694		10/27/2008	79.7917
	7/18/2008	66.5583		10/28/2008	79.9606
	7/21/2008	66.375		10/29/2008	80.0722
	7/22/2008	67.3978		10/30/2008	79.9972
	7/23/2008	67.6867		10/31/2008	79.6528
	7/24/2008	67.35		11/3/2008	79.3361
	7/25/2008	67.3667		11/4/2008	78.9644
	7/28/2008	67.6389		11/5/2008	76.6361
	7/29/2008	67.6522		11/7/2008	76.4389
	7/30/2008	67.4044		11/10/2008	76.1467
	7/31/2008	67.3183		11/11/2008	76.6067
	8/1/2008	67.2439		11/12/2008	77.3139
	8/4/2008	67.1139		11/13/2008	79.0944
	8/5/2008	66.6511		11/14/2008	79.8861
	8/6/2008	66.4039		11/17/2008	78.1178
	8/7/2008	66.4556		11/18/2008	78.5444
	8/8/2008	66.7944		11/19/2008	78.4556
	8/11/2008	67.2972		11/20/2008	78.48
	8/12/2008	67.5117		11/21/2008	78.6389
	8/13/2008	67.2417		11/24/2008	78.775
	8/14/2008	67.2972		11/25/2008	78.76
	8/15/2008	67.4778		11/26/2008	78.7711
	8/19/2008	67.495		11/27/2008	78.6272
	8/20/2008	67.64		11/28/2008	77.8806
	8/21/2008	68.6306		12/1/2008	79.08
	8/22/2008	68.6311		12/2/2008	79.825
	8/25/2008	68.6344		12/3/2008	79.8944
	8/26/2008	68.7856		12/4/2008	79.6856
	8/27/2008	69.0722		12/5/2008	79.2828
	8/28/2008	68.7217		12/8/2008	79.2389
	8/29/2008	68.7333		12/9/2008	78.8833
	9/1/2008	68.8372		12/10/2008	78.6028
	9/2/2008	68.6972		12/11/2008	78.3728
	9/3/2008	68.9578		12/15/2008	77.8778
	9/4/2008	70.3644		12/16/2008	77.5867
	9/5/2008	70.4744		12/17/2008	77.4
	9/8/2008	70.2111		12/18/2008	76.9278

	Date	Value		Date	Value
	9/9/2008	70.2583		12/19/2008	76.3067
	9/10/2008	70.4056		12/22/2008	75.6411
	9/11/2008	70.6222		12/23/2008	76.8778
	9/12/2008	70.7067		12/24/2008	77.0778
	9/15/2008	70.5311		12/29/2008	76.8389
	9/16/2008	70.7417		12/30/2008	77.6833
	9/17/2008	71.8639		12/31/2008	77.7111
	9/18/2008	72.8417	**2009**	**1/2/2009**	**78.2678**
	9/19/2008	72.9761		1/5/2009	78.8389
	9/22/2008	71.9306		1/6/2009	79.2822
	9/23/2008	72.8044		1/7/2009	78.7167
	9/24/2008	73.1022		1/8/2009	78.2317
	9/26/2008	73.8778		1/9/2009	77.4361
	9/29/2008	73.8267		1/12/2009	77.665
	9/30/2008	73.2189		1/13/2009	77.8944
	10/2/2008	73.1728		1/14/2009	78.6306
	10/3/2008	72.9678		1/15/2009	78.8306
	10/6/2008	72.9117		1/16/2009	79.7567
	10/7/2008	73.6728		1/19/2009	78.7417
	10/8/2008	73.7656		1/20/2009	78.9539
	10/9/2008	74.1772		1/21/2009	79.7028
	10/13/2008	74.3333		1/22/2009	80.0083
	10/14/2008	75.9722		1/23/2009	79.7339
	10/15/2008	75.5861		1/26/2009	79.7167
	10/16/2008	75.5894		1/27/2009	79.6139
	10/17/2008	77.2917		1/28/2009	79.7961
	10/21/2008	76.3944		1/29/2009	79.6317
	10/22/2008	78.1833		1/30/2009	79.5439
	2/2/2009	79.6461		5/11/2009	77.8833
	2/3/2009	79.4583		5/12/2009	77.4778
	2/4/2009	79.4789		5/13/2009	76.9361
	2/5/2009	79.4		5/14/2009	77.0522
	2/6/2009	79.3172		5/15/2009	78.3278
	2/9/2009	79.3983		5/18/2009	78.2139
	2/10/2009	79.2478		5/19/2009	78.3383
	2/11/2009	79.1028		5/20/2009	78.0972
	2/12/2009	79.05		5/21/2009	77.7894
	2/13/2009	79.6528		5/22/2009	77.975
	2/16/2009	79.55		5/25/2009	77.8756
	2/17/2009	79.6222		5/26/2009	77.9361
	2/18/2009	79.7478		5/27/2009	78.0472
	2/19/2009	79.7083		5/28/2009	78.1556
	2/20/2009	79.5878		5/29/2009	78.3483
	2/23/2009	79.69		6/2/2009	78.2111
	2/24/2009	79.8356		6/3/2009	77.9556
	2/25/2009	79.7667		6/4/2009	77.8933
	2/26/2009	79.7067		6/5/2009	77.9222
	2/27/2009	79.6872		6/8/2009	77.8717
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	3/3/2009	80.07		6/10/2009	78.075
	3/4/2009	80.3339		6/11/2009	78.1233
	3/5/2009	80.0367		6/12/2009	78.0139
	3/6/2009	80.025		6/15/2009	77.9944

	3/9/2009	79.9278		6/16/2009	77.9417
	3/10/2009	80.1756		6/17/2009	78.0828
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	3/12/2009	80.19		6/19/2009	77.885
	3/13/2009	80.1333		6/22/2009	77.8583
	3/16/2009	80.1172		6/23/2009	78.0289
	3/17/2009	80.2056		6/24/2009	77.9583
	3/18/2009	80.3928		6/25/2009	77.9789
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	3/20/2009	80.7722		6/29/2009	77.0206
	3/23/2009	80.6694		6/30/2009	77.1578
	3/24/2009	80.5828		7/1/2009	76.5167
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	3/26/2009	79.8578		7/3/2009	75.9372
	3/27/2009	79.9922		7/6/2009	75.9517
	3/30/2009	80.2678		7/7/2009	76.3978
	3/31/2009	80.4306		7/8/2009	76.925
	4/1/2009	80.305		7/9/2009	77.4078
	4/2/2009	80.1122		7/10/2009	76.7861
	4/3/2009	80.0189		7/13/2009	76.8572
	4/6/2009	79.94		7/14/2009	77.5417
	4/7/2009	80.3306		7/15/2009	77.445
	4/8/2009	80.5767		7/16/2009	77.3072
	4/9/2009	80.2139		7/17/2009	76.8161
	4/14/2009	80.0083		7/20/2009	76.83
	4/15/2009	79.9306		7/21/2009	76.8867
	4/16/2009	79.8839		7/22/2009	76.9044
	4/17/2009	79.8533		7/23/2009	76.8528
	4/20/2009	79.6756		7/24/2009	76.5528
	4/21/2009	79.5		7/27/2009	76.5389
	4/22/2009	78.9444		7/28/2009	76.6833
	4/23/2009	78.5889		7/29/2009	76.6233
	4/24/2009	79.1922		7/30/2009	76.6428
	4/27/2009	78.8583		7/31/2009	76.6067
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	5/6/2009	77.6222		8/10/2009	76.2411
	5/7/2009	76.3583		8/11/2009	76.1917
	5/8/2009	77.4333		8/12/2009	76.5667
	8/13/2009	76.595		11/19/2009	74.3339
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	8/17/2009	76.3817		11/23/2009	74.7528
	8/18/2009	76.4361		11/24/2009	74.6919
	8/19/2009	76.3944		11/25/2009	74.7436
	8/20/2009	76.3639		11/26/2009	74.5028
	8/21/2009	76.3222		11/27/2009	74.5389
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	8/28/2009	76.2261		12/3/2009	74.8158

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	9/7/2009	76.2317		12/11/2009	75.8442
	9/8/2009	76.1367		12/14/2009	75.6292
	9/9/2009	75.9328		12/15/2009	75.3508
	9/10/2009	75.9639		12/16/2009	75.3131
	9/11/2009	75.9272		12/17/2009	75.4553
	9/14/2009	75.8258		12/18/2009	75.455
	9/15/2009	75.8147		12/21/2009	75.1211
	9/16/2009	75.7106		12/22/2009	75.2669
	9/17/2009	75.5681		12/23/2009	75.9422
	9/18/2009	74.9547		12/24/2009	75.5361
	9/22/2009	74.8289		12/28/2009	75.6625
	9/23/2009	74.7389		12/29/2009	75.8
	9/24/2009	74.7381		12/30/2009	75.6889
	9/25/2009	74.4986		12/31/2009	75.82
	9/28/2009	75.1228	**2010**	**1/4/2010**	**75.8406**
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	10/2/2009	75.5128		1/8/2010	75.5708
	10/5/2009	75.4764		1/11/2010	75.3764
	10/6/2009	75.5403		1/12/2010	75.3619
	10/7/2009	75.1086		1/13/2010	75.5258
	10/8/2009	75.1806		1/14/2010	75.4269
	10/9/2009	75.1075		1/15/2010	75.4389
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	10/13/2009	75.3939		1/19/2010	76.0528
	10/14/2009	75.4111		1/20/2010	75.9911
	10/15/2009	75.1925		1/21/2010	75.9811
	10/16/2009	75.2153		1/22/2010	75.9339
	10/19/2009	75.2794		1/25/2010	75.9622
	10/21/2009	75.2994		1/26/2010	76.0989
	10/22/2009	75.0856		1/27/2010	76.2778
	10/23/2009	75.1117		1/28/2010	76.3236
	10/26/2009	75.1956		1/29/2010	75.8856
	10/27/2009	75.2839		2/1/2010	75.9653
	10/28/2009	75.3006		2/2/2010	76.0458
	10/29/2009	75.2428		2/3/2010	76.1231
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	11/2/2009	75.2297		2/5/2010	76.5819
	11/3/2009	75.245		2/8/2010	76.8764
	11/4/2009	75.4275		2/9/2010	76.9253
	11/5/2009	75.2039		2/10/2010	76.7242
	11/6/2009	74.9961		2/11/2010	76.4111
	11/9/2009	74.6903		2/12/2010	76.5042
	11/10/2009	74.3836		2/15/2010	77.0236
	11/11/2009	74.5583		2/16/2010	77.3736
	11/12/2009	74.4069		2/17/2010	77.3403
	11/13/2009	74.5042		2/18/2010	77.0403
	11/16/2009	74.6769		2/19/2010	77.045

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	11/18/2009	74.4722		2/23/2010	76.8386
	2/24/2010	76.9681		6/2/2010	79.8929
	2/25/2010	77.0556		6/3/2010	80.0085
	2/26/2010	76.8972		6/4/2010	80.2228
	3/1/2010	76.8083		6/7/2010	81.5586
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	3/3/2010	76.8931		6/9/2010	81.9486
	3/4/2010	76.8486		6/10/2010	81.7458
	3/5/2010	76.7447		6/11/2010	80.6889
	3/8/2010	76.7944		6/14/2010	80.6806
	3/9/2010	76.6653		6/15/2010	80.6958
	3/10/2010	76.7778		6/16/2010	80.55
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	3/15/2010	76.6639		6/21/2010	80.5264
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	3/22/2010	76.9539		6/28/2010	81.4694
	3/23/2010	77.0489		6/29/2010	81.7583
	3/24/2010	77.0531		6/30/2010	81.9167
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	4/9/2010	77.2767		7/14/2010	81.6839
	4/12/2010	77.1708		7/15/2010	81.6033
	4/13/2010	77.175		7/16/2010	81.4375
	4/14/2010	77.0978		7/19/2010	81.5417
	4/15/2010	76.9472		7/20/2010	81.5861
	4/16/2010	77.0281		7/21/2010	81.8403
	4/19/2010	77.3481		7/22/2010	81.8153
	4/20/2010	77.4953		7/23/2010	81.5783
	4/21/2010	77.2729		7/26/2010	81.4014
	4/22/2010	77.2854		7/27/2010	81.1506
	4/23/2010	77.3784		7/28/2010	80.6639
	4/26/2010	77.3048		7/29/2010	80.6806
	4/27/2010	77.3305		7/30/2010	80.2297
	4/28/2010	77.3442		8/2/2010	80.2667
	4/29/2010	77.3512		8/3/2010	80.1458
	4/30/2010	77.266		8/5/2010	79.9014
	5/3/2010	77.1642		8/6/2010	79.6019
	5/4/2010	77.2255		8/9/2010	79.4403
	5/5/2010	77.4243		8/10/2010	79.6408
	5/6/2010	77.7528		8/11/2010	79.705
	5/7/2010	78.0936		8/12/2010	80.0458

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	5/12/2010	77.8899		8/17/2010	80.4872
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	5/14/2010	78.0468		8/19/2010	80.7806
	5/17/2010	78.3497		8/20/2010	81.0153
	5/18/2010	78.6397		8/23/2010	81.085
	5/19/2010	78.7834		8/24/2010	81.3628
	5/20/2010	79.1712		8/25/2010	81.2428
	5/21/2010	79.4427		8/26/2010	80.7819
	5/24/2010	79.2471		8/30/2010	80.8731
	5/25/2010	79.5467		8/31/2010	81.0711
	5/26/2010	79.7868		9/1/2010	80.9742
	5/27/2010	79.7463		9/2/2010	80.7689
	5/28/2010	79.7171		9/3/2010	80.7272
	5/31/2010	79.7453		9/6/2010	80.6708
	9/7/2010	80.9442		12/10/2010	80.5578
	9/8/2010	81.1514		12/14/2010	80.5153
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	9/10/2010	81.2703		12/16/2010	80.6325
	9/13/2010	80.8933		12/17/2010	80.5375
	9/14/2010	80.9303		12/20/2010	80.5308
	9/15/2010	80.8592		12/21/2010	80.4886
	9/16/2010	80.8403		12/22/2010	80.4906
	9/17/2010	80.5903		12/23/2010	80.5733
	9/20/2010	80.7869		12/24/2010	80.5903
	9/21/2010	80.9917		12/27/2010	80.6625
	9/22/2010	80.8358		12/28/2010	80.6144
	9/23/2010	80.9486		12/29/2010	80.6292
	9/24/2010	81.1597		12/30/2010	80.6714
	9/27/2010	80.8917		12/31/2010	80.7519
	9/28/2010	80.9375	**2011**	**1/3/2011**	**80.7961**
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	10/4/2010	80.8361		1/7/2011	81.1444
	10/5/2010	80.8411		1/10/2011	81.1747
	10/6/2010	80.7172		1/11/2011	81.2181
	10/7/2010	80.63		1/12/2011	81.0708
	10/8/2010	80.5369		1/13/2011	80.9417
	10/11/2010	80.5589		1/14/2011	80.7431
	10/12/2010	80.735		1/17/2011	80.9736
	10/13/2010	80.7306		1/18/2011	81.0708
	10/14/2010	80.5861		1/19/2011	80.9333
	10/15/2010	80.5047		1/20/2011	81.0661
	10/18/2010	80.6694		1/21/2011	81.0764
	10/19/2010	80.7561		1/24/2011	81.0147
	10/21/2010	80.8406		1/25/2011	81.0217
	10/22/2010	80.8028		1/26/2011	81.0031
	10/25/2010	80.6428		1/27/2011	80.9986
	10/26/2010	80.6819		1/28/2011	81.025
	10/27/2010	80.75		1/31/2011	81.2722
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	11/3/2010	80.5586		2/7/2011	81.1472
	11/4/2010	80.5308		2/8/2011	81.2042
	11/5/2010	80.1356		2/9/2011	81.2167
	11/8/2010	80.3333		2/10/2011	81.2375
	11/9/2010	80.6236		2/11/2011	81.3014
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	11/12/2010	80.5986		2/16/2011	81.3583
	11/15/2010	80.5147		2/17/2011	81.3942
	11/16/2010	80.4572		2/18/2011	81.4456
	11/17/2010	80.45		2/21/2011	81.7936
	11/18/2010	80.1639		2/22/2011	81.8611
	11/19/2010	80.1006		2/23/2011	81.875
	11/22/2010	80.0397		2/24/2011	81.8917
	11/23/2010	80.1625		2/25/2011	81.9992
	11/24/2010	80.3486		2/28/2011	82.3639
	11/25/2010	80.2931		3/1/2011	82.6014
	11/26/2010	80.3892		3/2/2011	82.8031
	11/29/2010	80.7764		3/3/2011	82.9278
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	12/1/2010	80.8972		3/7/2011	83.0081
	12/2/2010	80.3208		3/8/2011	83.0833
	12/3/2010	80.4625		3/9/2011	83.4667
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	12/7/2010	80.4831		3/11/2011	84.6569
	12/8/2010	80.5525		3/14/2011	84.9294
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	3/17/2011	85.8108		6/24/2011	90.4486
	3/18/2011	85.0417		6/27/2011	90.4625
	3/21/2011	84.5917		6/28/2011	90.8278
	3/22/2011	85.1486		6/29/2011	90.0236
	3/23/2011	84.7847		6/30/2011	89.8639
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	3/25/2011	84.9444		7/4/2011	88.6856
	3/28/2011	84.2944		7/5/2011	88.4514
	3/29/2011	83.8206		7/6/2011	88.9694
	3/30/2011	83.5511		7/7/2011	89.8583
	3/31/2011	82.9889		7/8/2011	89.9389
	4/1/2011	83.1583		7/11/2011	90.2417
	4/4/2011	83.3722		7/12/2011	90.4417
	4/5/2011	83.7444		7/13/2011	89.6708
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	4/7/2011	84.7664		7/15/2011	89.5833
	4/8/2011	84.2917		7/18/2011	89.6847
	4/11/2011	84.1431		7/19/2011	90.1861
	4/12/2011	84.2428		7/20/2011	90.1681
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	4/14/2011	84.0736		7/22/2011	89.9611
	4/15/2011	84.1472		7/25/2011	90.2878

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4/19/2011	83.8417		7/27/2011	90.5111
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6/9/2011	87.5569		9/13/2011	95.4306
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6/21/2011	90.7333		9/23/2011	98.8944
6/22/2011	91.6556		9/26/2011	99.0556
9/27/2011	101.949		1/4/2012	85.5722
9/28/2011	102.011		1/5/2012	88.4403
9/29/2011	101.232		1/6/2012	87.0361
9/30/2011	99.8319		1/9/2012	86.9786
10/3/2011	100.479		1/10/2012	87.1778
10/4/2011	101.674		1/11/2012	87.3164
10/5/2011	101.715		1/12/2012	87.4208
10/6/2011	100.949		1/13/2012	87.5889
10/7/2011	101.947		1/16/2012	87.4958

	10/10/2011	102.811		1/17/2012	86.9583
	10/11/2011	103.908		1/18/2012	86.3331
	10/12/2011	105.961		1/19/2012	86.2197
	10/13/2011	104.01		1/20/2012	85.6778
	10/14/2011	101.426		1/23/2012	86.0444
	10/17/2011	100.512		1/24/2012	86.1
	10/18/2011	99.1861		1/25/2012	85.8444
	10/19/2011	99.5181		1/26/2012	85.3639
	10/21/2011	99.7014		1/27/2012	85.0306
	10/24/2011	100.117		1/30/2012	84.9167
	10/25/2011	100.596		1/31/2012	84.5875
	10/26/2011	101.443		2/1/2012	83.8833
	10/27/2011	100.632		2/2/2012	83.5861
	10/28/2011	99.0319		2/3/2012	83.8708
	10/31/2011	99.7783		2/6/2012	83.8125
	11/1/2011	99.3347		2/7/2012	83.4903
	11/2/2011	96.5222		2/8/2012	83.1403
	11/3/2011	96.8097		2/9/2012	82.7167
	11/4/2011	96.975		2/10/2012	83.9278
	11/7/2011	97.3819		2/13/2012	82.8125
	11/8/2011	96.9706		2/14/2012	82.9583
	11/9/2011	96.2694		2/15/2012	82.93
	11/10/2011	95.6903		2/16/2012	83.1667
	11/11/2011	94.7989		2/17/2012	83.0722
	11/14/2011	93.2164		2/20/2012	82.9097
	11/15/2011	93.7208		2/21/2012	83.2972
	11/16/2011	94.1458		2/22/2012	83.2944
	11/17/2011	93.6806		2/23/2012	82.7569
	11/18/2011	92.5433		2/24/2012	82.6986
	11/21/2011	91.0417		2/27/2012	82.6519
	11/22/2011	90.6722		2/28/2012	82.7514
	11/23/2011	90.0611		2/29/2012	82.9708
	11/24/2011	90.3097		3/1/2012	83.2625
	11/25/2011	90.2681		3/2/2012	83.2561
	11/28/2011	90.5611		3/5/2012	83.2347
	11/29/2011	90.1681		3/6/2012	83.3625
	11/30/2011	89.7208		3/7/2012	82.8222
	12/1/2011	89.5972		3/8/2012	82.8292
	12/2/2011	89.7125		3/9/2012	82.7514
	12/5/2011	89.8281		3/9/2012	84.1483
	12/6/2011	89.5467		3/9/2012	84.1483
	12/7/2011	89.6236		3/12/2012	82.7125
	12/8/2011	89.6669		3/13/2012	82.2686
	12/9/2011	89.4986		3/14/2012	82.2694
	12/13/2011	89.55		3/15/2012	82.3472
	12/14/2011	88.9764		3/16/2012	82.9617
	12/15/2011	87.2792		3/19/2012	82.9611
	12/16/2011	84.5972		3/20/2012	82.6344
	12/19/2011	83.6939		3/21/2012	82.8489
	12/20/2011	83.8306		3/22/2012	82.8611
	12/21/2011	83.5167		3/23/2012	83.1083
	12/22/2011	83.5542		3/26/2012	83.0324
	12/23/2011	83.6864		3/27/2012	83.1042
	12/27/2011	83.6472		3/28/2012	83.0278

	12/28/2011	83.7167		3/29/2012	83.0153
	12/29/2011	84.6667		3/30/2012	83.0556
	12/30/2011	85.0681		4/2/2012	83.1014
2012	**1/3/2012**	**85.0906**		4/3/2012	83.0694
	4/4/2012	83.1764		7/12/2012	83.9292
	4/5/2012	83.0667		7/13/2012	84.0265
	4/10/2012	83.1031		7/16/2012	84.1222
	4/11/2012	83.1961		7/17/2012	84.1889
	4/12/2012	83.2541		7/18/2012	84.1794
	4/13/2012	83.3681		7/19/2012	84.1558
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	4/20/2012	83.1969		7/26/2012	84.2292
	4/23/2012	83.2178		7/27/2012	84.2011
	4/24/2012	83.2293		7/30/2012	84.2014
	4/25/2012	83.2531		7/31/2012	84.2125
	4/26/2012	83.265		8/1/2012	84.2383
	4/27/2012	83.25		8/2/2012	84.2264
	4/30/2012	83.2164		8/3/2012	84.2506
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	5/3/2012	83.4053		8/7/2012	84.095
	5/4/2012	83.2806		8/8/2012	83.9367
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	5/9/2012	83.2958		8/13/2012	84.0506
	5/10/2012	83.3972		8/14/2012	83.8975
	5/11/2012	83.6181		8/15/2012	83.9333
	5/14/2012	83.6764		8/16/2012	83.9833
	5/15/2012	83.9469		8/17/2012	84.0672
	5/16/2012	84.9572		8/21/2012	83.975
	5/17/2012	84.5639		8/22/2012	84.0056
	5/18/2012	85.1625		8/23/2012	83.9903
	5/21/2012	84.9572		8/24/2012	84.0056
	5/22/2012	84.5639		8/27/2012	84.0236
	5/23/2012	85.1625		8/28/2012	84.0961
	5/24/2012	85.2558		8/29/2012	84.1181
	5/25/2012	85.3153		8/30/2012	84.1422
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	5/29/2012	85.5819		9/3/2012	84.1483
	5/30/2012	85.9556		9/4/2012	84.2667
	5/31/2012	86.825		9/5/2012	84.8653
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	6/15/2012	85.1306		9/19/2012	84.8847

	6/18/2012	84.8847		9/20/2012	84.8275
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	7/2/2012	84.1322		10/4/2012	84.925
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	7/4/2012	84.0278		10/8/2012	84.9153
	7/5/2012	84.0347		10/9/2012	85.1019
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	11/21/2012	85.7114			
	11/22/2012	85.7097			
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	11/28/2012	85.9708			
	11/29/2012	85.9431			
	11/30/2012	85.9347			
	12/3/2012	85.9111			

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12/27/2012	85.8628			
12/28/2012	85.9611			
12/31/2012	86.0286			

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