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Modelling Real Exchange Rate Volatility in a Developing Country

Baba Insah
School of Business, Wa Polytechnic P.O.Box 553, Wa, Upper West Region, Ghana
Email of author: nsahbaba@yahoo.com

Abstract

Existing studies have provided empirical evidence on volatility clustering on exchange rate. This presents a situation of uncertainty and risks for future outcomes. This paper investigated the presence and nature of real exchange rate volatility in the Ghanaian Economy. This study would inform and guide policy-makers on currency risks and currency crises management. A Breusch-Pagan test for ARCH effects was performed. Further, an ARCH(1) and GARCH(1,1) processes were explicitly modelled to measure volatility. The major empirical and methodological contribution of this study is the explicit modelling of the conditional mean and conditional variance processes. The GARCH(1,1) model was the right model for exchange rate risk modelling in Ghana. The exchange rate regime change from fixed to floating caused a spike in volatility from 1983 to 1986. Over the period, there have been intermittent spikes in volatility indicating that Ghana's international competitiveness deteriorated over the period of study. However, from 2001 to 2010, the volatility has been minimal.

Keywords: GARCH, Uncertainty, Volatility clustering, Exchange rate, Ghana.

1. Introduction

The importance of time varying and conditional variance in pricing derivatives, calculating measures of risk and hedging against portfolio risk cannot be underrated. Exchange rate, which is the price of one currency in terms of another currency is an important concept in financial economics. In small open economies, exchange rate volatility affects imports and exports and consequently influences the particular country's balance of payment. This ultimately affects the rate of economic growth. Exchange rate movements would thus have an impact on the volume and value of foreign trade and investment. Theory suggests that the real exchange rate (RER) depreciation lowers the relative costs of domestic to foreign goods, causing import substitution to take place and promoting exports. Such effect would tend to increase the level of production and economic growth (Lothian and Taylor, 1997).

According to Frenkel and Goldstein (1986), RER volatility refers to short-term fluctuations of the RER about their longer-term trends. Furthermore, Williamson (1985), noted that volatility is measured by short-term fluctuations in the exchange rates as measured by their absolute percentage changes during a particular period. Commenting on the effect of RER volatitily, McKinnon and Ohno (1997) opined that RER volatility has been known to reduce the level of economic growth by creating uncertainty about the profits, unemployment, and poverty. They noted further that it may restrict the international flow of capital by reducing direct investment portfolio investment. Increased RER volatility may lead to higher prices of internationally traded goods by causing traders to add a risk premium to cover unanticipated exchange rate fluctuations.

This study is relevant because exchange rate volatility is an important determinant for pricing currency derivatives. Modelling and forecasting exchange rate would assist explore the impact of exchange rate volatility and uncertainty on trade, investment and economic growth. Existing studies have found that exchange rate volatility can affect trade directly and indirectly. In the direct channel, it affects it through uncertainty and adjustment costs and indirectly through its effect on the structure of output and investment. (Cote, 1994 and Cheong, 2004).

The gap this study seeks to fill is to explicitly model the conditional mean and conditional variance of RER. This would facilitate the investigation and analysis of episodes of the presence of exchange rate risk that can serve as an indicator of vulnerability. To the best of my knowledge no existing study has adopted this approach to investigate RER volatility in Ghana.

The rest of the paper is organized as follows: Next is a review of relevant literature in section 2. This is followed by section 3 as the methodology and the econometric model used for the estimation. Section 4 is the presentation of findings of the study. The conclusion and policy relevance is presented in section 5.

2. Literature Review

An attempt at the description of volatility would require an explanation of the concept of volatility. According to Abdalla (2012), volatility refers to the spread of all likely outcomes of an uncertain variable. The spread of asset returns is usually the interest in financial markets. Sample standard deviation is often used to measure volatility. According to Poon (2005), risk is usually associated with undesirable outcomes, whereas volatility as a measure strictly for uncertainty could be due to a positive outcome.

Exchange rates, stock returns and other financial series are known to exhibit certain characteristics which are critical for the specification, estimation and forecasting of a model. Since the early work of Mandelbrot (1963a) and Fama (1965), empirical research has established some facts describing these series. One of these characteristics is Fat Tails. A fat-tailed distribution is a probability distribution (also known as heavy-tailed distributions) that exhibit extremely large skewness or kurtosis. This observation is also referred to as excess kurtosis. A comparison of the distribution of financial time series such as exchange rate with the normal distribution reveals fatter tails. The standardized fourth moment for a normal distribution is three (3) whereas for many financial time series, the standaridsed time series is above three (3) (Mandelbrot, 1963 and Fama, 1963).

Another characteristic of financial time series is volatility clustering and persistence. Here, large and small values in the log-returns tend to occur in clusters. Periods of large changes tend to be followed by large changes and periods of small changes tend to be followed by small changes. When volatility is high, it has the tendency to remain high and when it is low it has the tendency remain low (Mandelbrot, 1963). Closely related to volatility clustering and persistence is Long Memory. Two propositions exist for modelling persistence: unit root and long memory processes. These propositions are based on the observation that for high-frequency data like exchange rates, volatility is highly persistent and there exists evidence of near unit root behaviour of the conditional variance process (Longmore and Robinson, 2004).

A further characteristic that is worth investigating is Leverage Effects. The leverage effect refers to the relationship between stock returns and volatility, both implied and realized. A fall in stock price leads to an increase in volatility. A downward movement (depreciation) is always followed by higher volatility. This phenomenon exhibited by percentage changes in financial data is termed leverage effects. Empirical studies have revealed that price movements are negatively correlated with volatility. Black (1976), noted that for stock returns, volatility is higher after negative shocks than after positive shocks of the same magnitude. This asymmetry, he alluded to leverage effects. Longmore and Robinson (2004) have observed that in the case of foreign market, a shock, which increases the volatility of the market, tends to increase the risk of holding the currency.

Asset return volatility is not constant over time. This fact has existed since the time of Fama (1965) and

Mandelbrot (1963a, 1963b). Brunetti and Lildholdt (2002), have provided empirical evidence on volatility clustering. Volatility clustering is the situation where periods of large changes in the nominal exchange rate tend to be followed by periods of large changes in either direction. It is noted that time varying volatility and volatility clustering are both captured by the Generalised Autoregressive Conditional Heteroscedasticity (GARCH) model. As noted by Baillie and Bollerslev (1989), the GARCH class of models have the ability to capture the volatility dynamics of exchange rates at daily, weekly and monthly frequencies. The GARCH(1,1) models have proved to adequately describe exchange rate volatility dynamics. According to Brunetti et al. (2003), low exchange rate changes are associated with low volatility (ordinary regime). On the other hand, high exchange rate devaluations are associated with high volatility.

As noted by Azid et al. (2005) ARCH Models allow the error term to have a time varying variance. Here, the variance is considered to be conditional on the past behaviour of the series. Engle (1982) introduced the Autoregressive Conditional Heteroscedasticity (ARCH) models. The GARCH (Generalised ARCH) which is an extension of the ARCH model was developed by Bollerslev (1986). This model offers a more parsimonious model that lessens the computational burden. According to Kroner and Lapstrapes (1993), Grier and Perry (2000), and Arize (1998), these models are widely used in various branches of econometrics, especially in financial time series analysis. Many other studies have found that the distribution of large and small changes in returns are bell shaped, symmetric and fat-tailed and also tend to cluster over time.

The ARCH and GARCH models and their extensions in modelling and forecasting normally capture these features. Hsieh (1988) was the first to apply the ARCH model to the currency exchange rate. In a related study, Hsieh(1989) investigated for nonlinearities in daily changes in five major exchange rates. He found that there was no linear correlation in the additive form except in the multiplicative form. He added further that for a large part of the nonlinearities in the exchange rates, the ARCH (GARCH) model could offer an explanation. Applications of the ARCH (GARCH) models to currency exchange rates have gained much popularity. Such work include, Bollerslev (1990), Pesaran and Robinson (1993), Hopper (1997) and Choo et al. (2002).

According to Engle and Patton (2001), positive and negative shocks are unlikely to have the same impact on volatility with regard to equity returns. This asymmetry, they noted may be ascribed to a leverage effect and a risk premium effect. With the leverage effect, as the price of a stock falls, its debt to equity ratio rises, risk premium falls, increasing the volatility of returns to equity holders. With the risk premium effect, news of increasing volatility reduces the demand for a stock because of risk aversion. Other studies have found evidence of volatility been negatively related to equity returns (Nelson, 1991, Christie, 1982, and Glosten et al., 1993). Following the works of Engle et al. (1990) and Brenner et al. (1996), a similar asymmetry arises from the boundary of zero interest rates. They explained further that when rates fall, the become less volatile in many models and many estimates.

According to Adjasi et al. (2008) the financial position of a country is susceptible to its foreign exchange volatility. Considering households, firms and the state, they opined that foreign exchange market developments have cost implications. Similarly that exchange rate volatility has real economic costs that affect price stability, firm profitability and a country's stability (Benita and Lauterbach, 2007). Using daily exchange rate between the US Dollar and 43 other currencies in 1990-2001, Benita and Lauterbach (2007), studied the daily volatility of the exchange rate. Controlling for macroeconomic variables, economy uncertainty, wealth, and openness to international markets were used as proxies. They used the GARCH model to account for volatility. They found out that exchange rate volatility was positively correlated with the real domestic interest rate and with the degree of central bank intervention.

3. Methodology and Theoretical Framework

3.1 Model and methodology

A good starting point for the analysis is to introduce an ARCH model. The AR is autoregressive and comes from the fact that these models are autoregressive models in squared returns. The conditional also comes from the fact that next period's volatility is conditional on current periods volatility. Heteroscedasticity means non constant variance. The assumption of constant variance in a standard linear regression allows for the use of ordinary least squares to estimate. However, when the variance of the residuals is not constant, we can use weighted least squares to estimate the regression coefficients. Assuming that the return on an asset is given as

$$r_t = \mu + \sigma_t \varepsilon_t \quad (1)$$

where ε_t is a sequence of N(0,1) i.i.d. random variables, the residual at time t, $r_t - \mu$, can be defined as

$$a_t = \sigma_t \varepsilon_t \quad (2)$$

In a basic ARCH(1) process,

$$\sigma_t^2 = \gamma_0 + \gamma_1 u_{t-1}^2 \quad (3)$$

where $\gamma_0 > 0$ and $\gamma_1 \geq 0$ to ensure positive variance and $\gamma_1 < 1$ for stationarity. If the residual μ_t is large in magnitude, forecasts for next periods conditional volatility will be large. In that case, the model has conditional normal returns. Further, the ARCH(q) model simultaneously models the mean and the variance of the series in the following form:

$$y_t = \alpha + \beta' X_t + u_t \quad (4)$$

$\mu_t | \phi_t \sim$ iid N(0,h_t)

$$h_t = \gamma_0 + \sum_{j=1}^{q} \gamma_i u_{t-j}^2 \quad (5)$$

where ϕ_t is the information set. Equation (4) is the mean equation and equation (5) is the variance equation.

The ARCH(1) model says that when a big shock occurs in period t-1, it is more likely that the value of u_t in absolute terms will be bigger as well. According to Engle (1995), one of the draw backs of the ARCH specification is that it looks more like a moving average. Extending to a GARCH model, Bollerslev (1986) included the lagged conditional variance terms as autoregressive terms. This is similar in spirit to an ARMA model. A GARCH(1,1) model is as

$$h_t = \gamma_0 + \delta_1 h_{t-1} + \gamma_1 u_{t-1}^2 \quad (6)$$

Where $\gamma_0 > 0$, $\gamma_1 > 0$, $\delta_1 > 0$ and $\gamma_1 + \delta_1 < 1$, so that the next period forecast of the variance is a combination of last period squared return and and last period forecast. With only three unknown parameters, this specification is easy to estimate and also performs very well. Unlike the ARCH(p) model, the GARCH(p,q) model has the following form:

$$y_t = \alpha + \beta' X_t + u_t \tag{7}$$

$\mu_t | \phi_t \sim$ iid $N(0,h_t)$

$$h_t = \gamma_0 + \sum_{i=1}^{p} \delta_i h_{t-i} + \sum_{j=1}^{q} \gamma_i u_{t-j}^2 \tag{8}$$

For the GARCH model, the value of the variance scaling parameter, h_t, now depends on both the past values of the shocks and on past values of itself.

The exchange rate considered in this study is the log of the real effective exchange rate. This rate is the Ghana cedi against the United States dollar. A ratio of the foreign price to the domestic price is obtained and multiplied by the nominal exchange rate.

4. Empirical results

4.1 Estimating the ARCH model

The ARCH model will be estimated by first testing for the presence of ARCH(1) effects. This test is performed along the lines of Breusch-Pagan test where an OLS estimation is carried out to obtain the residuals. An auxiliary regression of the squared residuals on the squares of the lagged terms and a constant is run. The computed R-squared times T (the number of observations) is 17.54 and has a probability limit of 0.0000 that follows a Chi-squared distribution with *q* degrees of freedom. This clearly suggests the rejection of the null hypothesis of homoscedasticity suggests evidence of ARCH(q) effects. Furthermore, a highly statistically significant lagged squared residual shows that ARCH model would provide reliable results. The ARCH(1) test results are presented in table 1.

Table 1. Testing for ARCH(1) effects in lnRER

	Value	**Probability**
F-statistic	39.0142	0.0000
R squared times T	17.1389	0.0000
RESID^2(-1)	0.6817	0.0000

Source: Author's construct

The condition $\mu_t | \phi_t \sim$ iid $N(0,h_t)$ holds for the error terms in both ARCH(1) and GARCH(1,1) models presented. The z-Statistics are presented in the fourth column of table 2. The estimates of the mean equation are highly significant at the 1% level with probability limits of 0.0000. However, it is interesting to note that the estimate of γ_1 is not significant. The estimates of α and β have changed greatly and become less significant. An ARCH model does not therefore fit the estimation though ARCH effects were detected using the Breusch-Pagan test. The ARCH(1) model results are shown in table 2.

Table 2. Summary Results of ARCH(1) Model

	Coefficient	**Std. Error**	**z-Statistic**	**Probability**
MEAN EQUATION (lnRER as Dependent Variable)				
Constant	-0.7082	0.0827	-8.5657	0.0000
RER_{t-1}	0.9499	0.0137	69.1056	0.0000
VARIANCE EQUATION (h_t as Dependent Variable)				
Constant	0.0252	0.0127	1.9884	0.0468
u_{t-1}^2	0.6119	0.4465	1.3705	0.1705
Adj. R^2=0.99, DW=1.41, AIC=0.30, SIC=0.49				

Source: Author's construct

Since the the ARCH(1) models results are not desirable in explaining the short-run volatilities of the series, an extension to a GARCH(1,1) model would be made. Further, according to Engle (1995), the ARCH specification seemed more like a moving average than an autoregression. In GARCH(1,1) model, the estimates of α and β are significant with a probability limit of 0.0000. Similar to the ARCH(1) model, the estimate of α is negative whereas that of β is positive. Moreover, the estimate of δ is highly significant and positive while that of γ is also highly significant but negative. It can thus be inferred that GARCH models perform well in modelling the exchange rate.

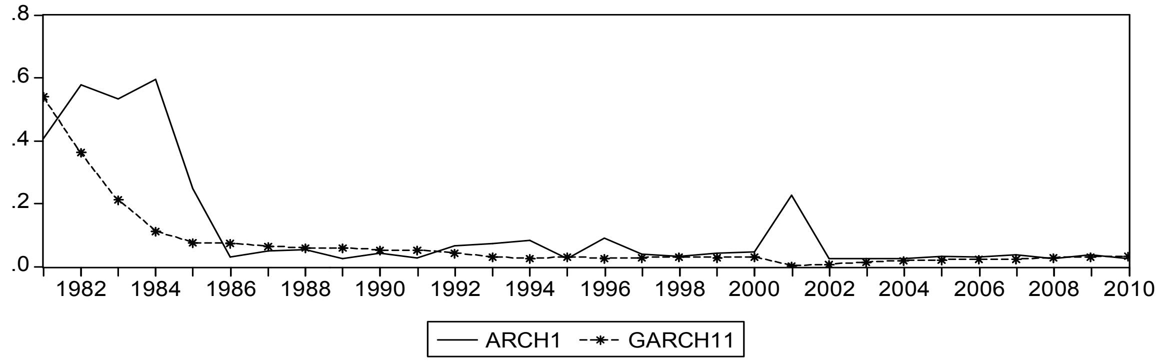
Table 3. Summary Results of GARCH(1,1) Model

	Coefficient	**Std. Error**	**z-Statistic**	**Probability**
MEAN EQUATION (lnRER as Dependent Variable)				
Constant	-0.7919	0.0821	-9.646	0.0000
RER_{t-1}	0.9442	0.012	78.4173	0.0000
VARIANCE EQUATION (h_t as Dependent Variable)				
Constant	0.0066	0.0029	2.2646	0.0235
h_{t-1}	0.8851	0.0568	15.591	0.0000
u_{t-1}^2	-0.1119	0.0261	-4.2867	0.0000
	Adj. R^2=0.99, DW=1.36, AIC=0.09, SIC=0.32			

Source: Author's construct

A plot of the conditional variance series of the two models are not identical. This is because the GARCH model provides better estimates for exchange rate risk in Ghana. Therefore it is better to estimate a GARCH model rather than an ARCH for real exchange rate. This is shown in figure 1.

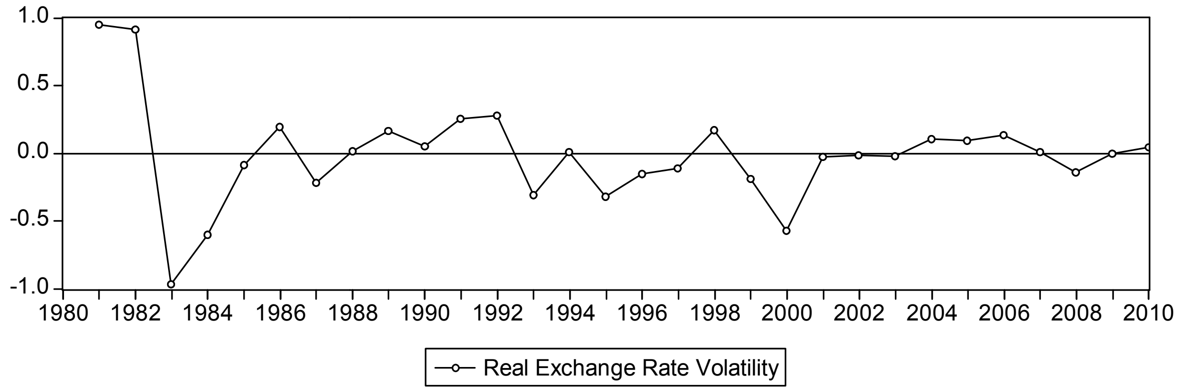
Figure 1. Plots of the Conditional Variance Series for ARCH(1) and GARCH(1,1)



Source: Author's construct

The exchange rate regime change from fixed to floating caused a spike in volatility from 1983 to 1986. However, from 2001 to 2010, the volatility has been minimal. This is shown in figure 2.

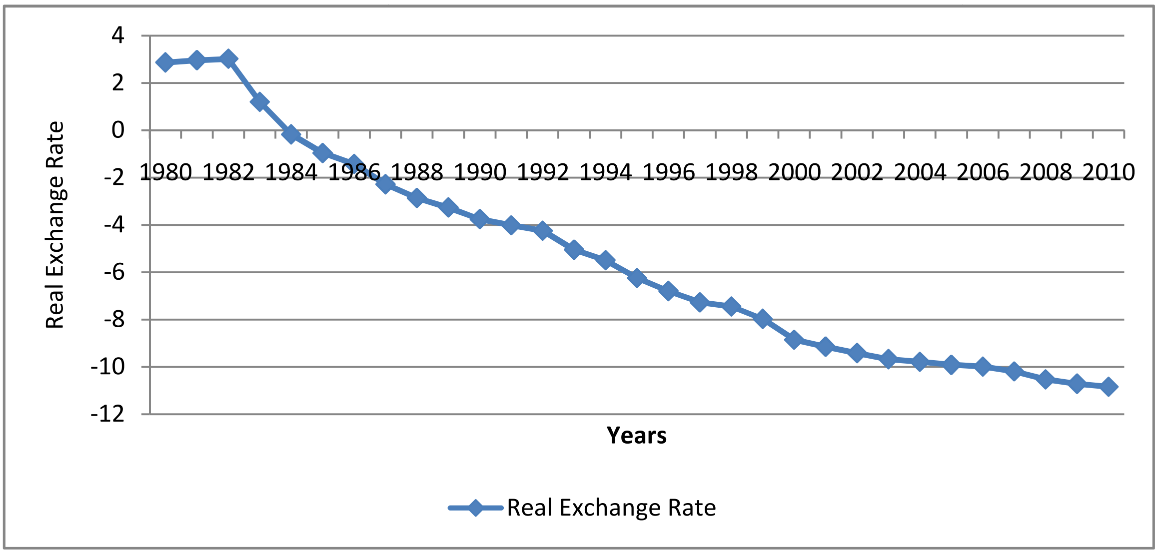
Figure 2. Real Exchange Rate Volatility-1981-2010



Source: Authors construct

Over the period, there have been intermittent spikes in volatility indicating that Ghana's international competitiveness deteriorated over the period of study. This is confirmed by observing the trend of exchange rate depreciation. This is depicted in figure 3.

Figure 3. Trend of Real Exchange rate:1980-2010



Source: Authors construct

5. Conclusion

Exchange rate volatility is of paramount importance to both businesses and policy makers alike. The importance of time varying and conditional variance in pricing derivatives, calculating measures of risk and hedging against portfolio risk cannot be underrated. This study utilized data for the period 1980 to 2010. Exchange rate volatility was modelled to determine the nature and existence of exchange rate risk in the Ghanaian Economy. Two different but related models were explored; ARCH(1) and a GARCH(1,1) models. The findings revealed that the GARCH(1,1) was a better model in investigating exchange rate uncertainty. Therefore it is better to estimate a GARCH model rather than an ARCH for real exchange rate. The exchange rate regime change from fixed to floating caused a spike in volatility from 1983 to 1986. However, from 2001 to 2010, the volatility has been minimal. There have been intermittent spikes in volatility indicating that Ghana's international competitiveness deteriorated over the period of study.

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