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Article

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Academic Journal of Economic Studies
Vol. 3, No. 3, September 2017, pp. 47–53
ISSN 2393-4913, ISSN On-line 2457-5836

The Asymmetric Effect in the Volatility of the South African Rand

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Abstract *This study investigates the behaviour of the volatility in the South African Rand/USD exchange rate and its impact on the value of the Rand between 2001 and 2017. The key objectives were to assess the impact of its volatility on its market value, and determine the presence of asymmetric effect in the times path of the volatility, resulting from shocks to its market value. From the estimates of our EGARCH-M (1,1) model, we found the value of the Rand to respond negatively to volatility it is time path, suggesting that the Rand appreciates more in value under conditions of less tranquillity. In addition, we found evidence of asymmetric effect, of shocks to the conditional mean, in the conditional variance of the Rand. The asymmetric effect is such that negative shocks to the conditional mean, which causes the Rand to appreciate, have more impact on next point volatility in the Rand than positive shocks of the same magnitude, which causes depreciation in its value.*

Key words South African Rand, exchange rate, volatility, asymmetric effect, EGARCH-M (1,1)

JEL Codes: E44, F31, C58

1. Introduction

Over the years, policy makers as well as economists have been concerned with the effective management of exchange rates of currencies. This is because exchange rate volatility brings uncertainties which have negative impact on the growth of real output and exports of countries (Rahman and Serletis, 2009; Kandil and Nergiz, 2008). This should be a reference template for South African which has seen its currency, the Rand, exhibit some degree of volatility in recent times. However, attempts at stabilizing the Rand would require empirical exposition of the true behaviour and consequences of the volatility in its value. This was the goal of this paper. Specifically, this paper sought to achieve the following two (2) objectives; the first being to investigate the impact of the volatility in the time path of the South African Rand on the future and contemporaneous realizations of the exchange rate of the Rand, and the second was to analyse the asymmetric effect of shocks to the exchange rate process on the volatility of the exchange rate.

The South Africa Rand was officially launched as a legal tender on 14th February 1960, and it is mostly traded against US dollar. Since its introduction, the Rand has remained strongly valued against US dollar until early 1980s when the apartheid government introduced a policy to restructure the financial system in South Africa. This consequently led to the abolition of the financial Rand exchange rate system in South Africa and ultimately caused Rand to lose its value in the international market. By 1985, the value of South African Rand depreciated significantly against the US Dollar to R2.23. However, since the inception of the post-apartheid government in 1994, the economy of South Africa has experienced normalcy in international relations, but its exchange rate has remained downward trending against US dollar. This situation was exacerbated by the 2001 September 11 attack on the World Trade Centre in the United States. Evidences from the South African Reserve Bank shows the attack on the World Trade Centre caused the Rand to skyrocket to R13.84 against the US Dollar. Economically speaking, the downward trending of South African Rand against US dollar portends worrisome implications, especially the vulnerability to pass-through the effect of exchange rate shocks on domestic prices.

In this paper, we applied an EGARCH model to investigate the behaviour of the volatility in the South African Rand/USD exchange rate between 2001 and 2017. Our result reveals a negative feedback effect between the volatility in the Rand and its value. Also, we found the presence of asymmetric effect in the volatility of the Rand. This asymmetric effect is of the form that volatility in the Rand is more responsive to appreciation in the value of the Rand than depreciation in its value.

2. Literature review

The consequences of exchange rate volatility are well documented in empirical literature. Crosby, (2001), Kandil and Nergiz Dincer (2008), Rahman and Serletis (2009), Demez and Ustaoğlu (2012), and Agiomirgianakis *et al.* (2014), have provided interesting accounts. The uniqueness of the findings from these studies is the unanimous claim that a volatile exchange rate significantly affects the trade and real economy positions of countries. However, they do not absolutely agree on the size and magnitude as well as the direction of these impacts. Specifically, Crosby's paper suggests that the direction of the impact of exchange rate volatility on the real economy depends heavily on the country and the time period under consideration as well as the statistical approach used in the study. The rest of the studies as mentioned in the recital hold that a volatile exchange rate impedes international trade and as such, has a significant pass-through effect to domestic price level. In a recent work by Mpofu (2016) on the determinants of exchange rate volatility in South Africa between the period of 1986-2013, using the new open economy macroeconomics model advanced by Obstfeld and Rogoff (1996) and Hau (2002), Mpofu found that the switching to a floating exchange rate regime has a significant positive effect on the volatility in the Rand. The result also revealed that trade openness significantly reduces Rand volatility only when bilateral exchange rates are used, rather than multilateral exchange rates are used.

Hassan (2012), Stavarek (2007 and 2010), McKenzie (2002) have conducted extensive studies on the asymmetric effects of exchange rate volatility in selected European countries. They all found the presence of asymmetry in the volatility of the currencies in the countries considered. Specifically, using a univariate GARCH and an EGRACH model, Hassan (2012) revealed that the Euro and British Pounds significantly exhibit asymmetry in their conditional variance. Hence, appreciations of exchange rate tend to cause more volatility than depreciation. This conclusion is similar to earlier studies by Stavarek (2007), Stavarek (2010) and McKenzie (2002) which considered the asymmetry effects of the exchange rate volatility in Turkey, Slovakia and Australia respectively.

There is an unending debate on the best econometric models that can adequately explain volatility in high frequent time series. On this note, McKenzie and Mitchell (2002), Narayan *et al.* (2009), Gupta and Kashyap (2016), Bošnjak *et al.* (2016), and Barunik *et al.* (2016) all admit that GARCH models remain the best models in capturing volatility in the time path of a series. However, the question of which version(s) of GARCH models are the most parsimonious, remains indecisive.

The work of Narayan *et al.* (2009) on the modelling the exchange rate volatility in Fiji, which relied on the result of an estimated EGARCH model, shows the stability and adequacy of the model in explaining the volatility in the Fiji exchange rate. They conclude that a positive effect on exchange rate volatility arises from conditional shocks, and that these shocks to conditional mean have asymmetric but non-permanent effect on exchange rate volatility. These findings have been apparently echoed in the recent papers by Gupta and Kashyap (2016), and Barunik *et al.* (2016). Gupta and Kashyap's paper focuses on the volatility in the British Pounds and the Indian Rupee, using traditional GARCH and EGARCH models with an application of Artificial Neural Networks (ANN). Their findings indicate that shocks to the British Pounds and Indian Rupee have asymmetric effects on exchange rate volatility of these countries. While Barunik *et al.* (2016) proposed a Realized Jump-GARCH model in an attempt to modelling and forecasting exchange rate volatility in time-frequency domain with particular interest on the influence of different time scales on volatility forecasts in the British Pound, Swiss Franc and Euro future exchange rate. The estimations of this model were in two versions. The first version used maximum likelihood and the second version used observation-driven estimation framework of generalized autoregressive scores. Their main conclusion in the paper is that most of the information for future volatility comes from high frequency part of the spectra representing very short investment horizons.

Morana (2009) applied Fractionally Integrated Factor Vector Autoregressive (FI-F-VAR) Model in studying the causes of exchange rate volatility in the G-7 Countries. His result revealed significant long-term linkages and trade-offs between macroeconomic (output, money supply and inflation) volatility and exchange rate volatility for the G-7 countries. Furthermore, the established causality is stronger from macroeconomic volatility to exchange volatility than the other way round. Similarly, Giannellis and Papadopoulos (2011) investigate the causes of exchange volatility in selected European Economic and Monetary Union (EMU) countries. Their findings indicate that the Polish and Hungarian exchange rates are more influenced by monetary variables; the French, Italian and Spanish exchange rates are affected by both monetary and real shocks; while the Irish exchange rate was only influenced by real shocks. Mavee *et al.* (2016) investigate the possible drivers of volatility in the South African Rand since the onset of the global financial crisis. Their study suggested that the rand volatility was mainly driven by commodity price volatility, global market volatility, as well as domestic political uncertainty.

3. Methodology of research

3.1. Data and techniques of analysis

The dataset used in this study is the daily exchange rate of the South African RAND to the US dollar, between September 11, 2011 and March 24, 2017. The start date is significant because the Terrorist attack in United States of America on the said date transmitted significant shock to the value of the RAND, causing it to experience significant volatility on that day. This data was sourced from the database of the Central Bank of South Africa. The variable to be modelled, in line with Abdalla (2012), is DLNRAND, defined as the percentage daily exchange rate return, which is the first difference of the natural logarithm of the exchange rate.

The methodology of this study involved the estimation of a Generalized Autoregressive Conditionally Heteroscedastic (GARCH) model. GARCH models are improvements over the traditional Autoregressive Conditionally Heteroscedastic (ARCH) models. And as an advantage, and according to Enders (2004) and Brooks (2014), GARCH models are more parsimonious versions of the ARCH models. This is because it allows, by continuous iteration, the re-writing of an infinite ARCH model as a GARCH (1,1) model. They have been applied severally in different research of similar investigations with satisfactory results.

We specify and estimated a modified version of the Exponential-GARCH (EGARCH) of Nelson (1991) in capturing the behaviour of the volatility in the Rand. The EGARCH model has the advantage of relaxing the restriction of non-negative conditional variance imposed in other versions of GARCH model as it models the log of the conditional variance of a process. Our specification includes a GARCH term in its conditional mean equation. This is to enable the evaluation of feedbacks between the conditional variance and conditional mean of the Rand. For this reason, the EGARCH model, presented below, is an EGARCH-M (1,1) model.

$$DLNRAND_t = a_0 + \psi\, ln(\sigma_t^2) + u_t \quad (1)$$

$$ln(\sigma_t^2) = \alpha_1 + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \propto \left[\frac{|u_{t-1}^2|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}}\right] + \beta ln(\sigma_{t-1}^2) + v_t \quad (2)$$

Equation 1 and 2 are the respective conditional mean and conditional variance equations in the EGARCH model. Here, a_0 is the constant term in the conditional mean equation, $ln(\sigma_t^2)$is the log of conditional variance in the conditional mean equation, $\frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}}$ is the weighted lagged residual of the conditional mean, $\left[\frac{|u_{t-1}^2|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}}\right]$ is the asymmetric term in the conditional variance equation, and $ln(\sigma_{t-1}^2)$is the log of lagged GARCH term in the conditional variance equation. Finally, u_t and v_t are the error terms in the conditional mean and conditional variance equations, respectively.

However, before the estimation of the model, the DLNRAND was subjected to unit root tests using the Augmented Dickey Fuller (ADF) proposed by Dickey and Fuller (1979), the Phillip Peron (PP) test of Phillip and Peron (1988), and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) proposed by Kwiatkowski *et al*. (1992).

The ADF test was conducted using all three of equation 3-5 below. This test involves the testing the statistical significance of ψ in the equations.

$$\Delta \text{DLNRAND}_t = \mu + \beta t + \psi \text{DLNRAND}_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \text{DLNRAND}_{t-i} + u_t \quad (3)$$

$$\Delta \text{DLNRAND}_t = \beta t + \psi \text{DLNRAND}_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \text{DLNRAND}_{t-i} + u_t \quad (4)$$

$$\Delta \text{DLNRAND}_t = \psi \text{DLNRAND}_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \text{DLNRAND}_{t-i} + u_t \quad (5)$$

$\Delta \text{DLNRAND}_t$ is the first difference of the percentage daily exchange rate return, DLNRAND_{t-1} is the one period lag of DLNRAND, μ is the intercept, βt is the trend and u_t is the error term. We applied the steps similar to those in Itodo *et al.* (2017), in conducting the unit root tests of the ADF, PP and KPSS. This involves, first, estimating the test equation with Trend and Intercept and evaluating the statistical significance of the Trend and Intercept in each case. In cases where the trends and intercepts were found insignificant, they were dropped and the test equations re-estimated. This means inferences on the unit root status of DLNRAND depended on selecting the most appropriate test equation, depending on whether trend or intercept or both, are included in the test equation or not. The Schwarz Information criterion (SIC) was used to specify the optimum lag in all three tests.

4. Analysis of results

4.1. Data presentation

Table 1 below gives a summary of the descriptive statistic of the exchange rate of the RAND over the sample period. With a total of 3885 observations, the mean, median, maximum, minimum value of the RAND are given as 8.898, 7.94, 16.89, 5.615 and 34570 respectively. The standard deviation, which expresses how much the observations differ from the mean value, is 2.48.

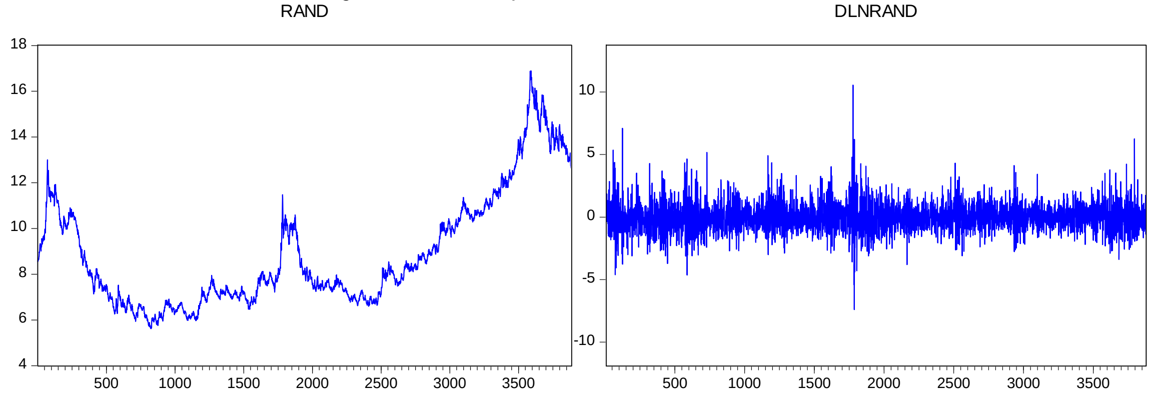
Vol. 3 (3), pp. 47–53, © 2017 AJES

Table 1. Descriptive Statistic of the RAND

Mean	Median	Maximum	Minimum	Std. Dev.	Sum	Observations
8.898	7.94	16.89	5.615	2.48	34570	3885

The graphs of the RAND/US-dollar ratio and the percentage daily exchange rate return of the RAND/US-dollar ratio (DLNRAND) are presented in figure 1 below. The plot of the RAND reveals significant fluctuations in its time path value over the sample period. The plot of DLNRAND clearly shows the presence of volatility clustering, with its time path being highly volatile in most of the period across the sample period.

Figure 1. The Graph of the Rand and DLNRAND



4.2. Unit Root Tests

Table 2 below presents the estimates of the ADF, PP and KPSS unit root tests on DLNRAND. While the ADF and PP tests are conducted under the null hypothesis of 'Unit Root in the Series', the KPSS test, which is a confirmatory test, is conducted under the null hypothesis of 'No Unit Root in the Series'. This result shows that DLNRAND is stationary as the null hypothesis is rejected under the ADF and PP tests at 1% level of significance. Similarly, LNRAND is stationary under the KPSS test, as the null hypothesis of 'No Unit Root in DLNRAND' is not rejected even at 10% level of significance. This means DLNRAND satisfies the condition for the application of the GARCH family models.

Table 2. Unit Root Tests Results

Level	Statistic	
ADF	-64.29514*	(μ, βt)
	-64.28986*	(μ)
	-64.29353*	(*)
PP	-64.33333*	(μ, βt)
	-64.32704*	(μ)
	-64.33048*	(*)
KPSS	0.050	(μ, βt)
	0.164	(μ)

*Significant at 1%, $(\mu, \beta t)$ Intercept and Trend, $(\mu,)$ Trend no Intercept $(*)$ No Intercept and Trend

4.3. ARCH effect

In order to test for the presence of ARCH effect in DLNRAND, we applied the Heteroskedasticity LM Test proposed by Engle (1982). This test involves estimating a dynamic regression of the residual of an estimated conditional mean equation, and then conducting a restricted F-test on its parameters. This test is conducted under the null hypothesis of 'No ARCH Effect in the lagged residuals'. As presented in table 3 below, we found the presence of ARCH effect in the series as we failed to reject the null hypothesis as both the F-statistic and estimated Chi-square are statistically significant at 1%. The implication is that DLNRAND has ARCH effect and as such, meets the precondition for modelling its conditional variance with the proposed EGARCH model.

Table 3. Heteroskedasticity Test: ARCH

F-statistic	153.2078*
Obs*R-squared	147.4653*

**Significant at 1%*

4.4. Estimates of the EGARCH-M (1,1)

The result of the estimated EGARCH model is presented in table 4 below. In the upper part of the table, which contains the result of the conditional mean equation, the coefficient of log of the conditional variance is negative and significant at 5%

level of significance. This implies there is a feedback effect between the volatility in the RAND and its value; the volatility in the RAND causes the RAND to appreciate in value rather than depreciate (a decrease in the conditional mean of a currencies exchange rate indicates an appreciation in its value). This is surprising considering that the RAND has been depreciating in recent times.

In the conditional variance equation (lower part of table 4), all estimated parameters are statistically significant at 1%. Here, the asymmetric term (0.143278) is positive, implying that negative shocks, which cause the exchange rate to fall, would increase volatility in the RAND by a size greater than the impact of positive shocks of the same magnitude, which causes the exchange rate of the RAND to rise. Volatility in the RAND is therefore more responsive to appreciation in the value of the RAND than depreciation in its value. The coefficient of the weighted lagged residual in the conditional mean equation (0.033504) is also positive and significant, implying that the overall impact of shocks to the time path of the exchange rate of the RAND is an increase in its conditional variance. Shocks to the exchange rate process therefore, causes the RAND to become more volatile. The coefficient of the log of the lagged GARCH term in the conditional variance equation suggests the presence of volatility clustering. This coefficient is positive and significant, implying that there is a tendency for large volatility to follow large volatility in the next point, and small volatility to follow smaller ones in the next.

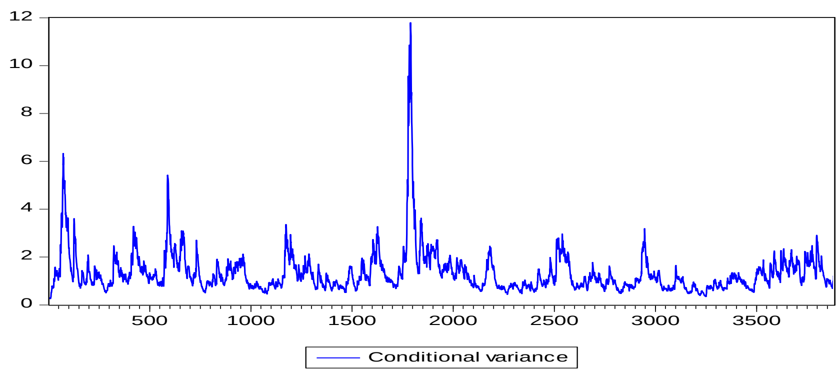
Table 4. The estimated EGARCH-M model

Mean Equation	**EGARCH-M**
Variable	Coefficient
ψ	-0.078787**
a_0	0.017494
Variance Equation	**EGARCH-M**
α_0	-0.106676*
γ	0.143278*
∝	0.033504*
β	0.976044*

Significant at 1%, **Significant at 5%, * Significant at 10%.*

Finally, the sum of the ARCH and GARCH terms in the conditional variance equation is approximately one (1). This is an indication that shocks to the conditional variance will be highly persistent. This can be seen in figure 2 below, which is a graphical plot of the conditional variance of the exchange rate of the RAND, generated from the estimated EGARCH model. This graph reveals that, except for few periods with very sharp spikes, most periods along its time path experience gradual decay.

*Figure 2.*The Graph of the Conditional Variance of the Rand



The reliability of the estimates of the model was evaluated by testing its residual for the presence of serial correlation. This test was conducted by testing the statistical significance of the Q-statistic of the residual of the estimated model. Usually, there is no serial correlation in the *p*th lag of the residual if the corresponding Q-statistic is insignificant. In our result, presented in table 6 below, we found all observed 12 lags of the residual of the estimated EGARCH model to be free from serial correlation. This is an indication that inferences made on the parameters of the model are reliable.

Table 6. Q-Statistic test for serial correlation in residual

Lags	1	2	3	4	5	6	7	8	9	10	11	12
Q-Stat	1.50	1.515	1.60	1.802	3.669	6.607	10.19	10.4	10.6	10.6	10.6	13.5
Prob*	0.22	0.46	0.65	0.77	0.59	0.35	0.17	0.23	0.29	0.38	0.46	0.33

5. Conclusions

This paper was set to investigate the behaviour of the volatility in the South African Rand/USD exchange rate and its impact on the value of the Rand between 2001 and 2017. The key objectives were to assess the impact of its volatility on its market value, and determine the presence of asymmetric effect in the times path of the volatility, resulting from shocks to its market value. We applied a EGARCH-M (1,1) in modelling percentage daily exchange rate return of the Rand (DLNRAND). However, the stochastic properties of DLNRAND were first verified by the application of the ADF, PP and KPSS unit root tests. DLNRAND was found to be without unit root. Next, we tested the residual of the conditional mean of DLNRAND process for the presence of ARCH effect. This was done within the context of the Heteroskedasticity LM Test proposed by Engle (1982). Our result found the presence of ARCH effect in the series. With this conditions met, we estimated the proposed EGARCH-M (1,1).

In the conditional mean equation, we found that the value of the Rand responds positively to the volatility in the RAND. The GARCH term was negative and statistically significant. This negative term should not be confused for positive impact on the value of the Rand, as decreases in the value of a currency actually means its value is appreciating, and vice versa. On the presence of asymmetric effect in the volatility of the Rand, we found that negative shocks exert more influence on the volatility than positive shocks of the same magnitude. With a positive and statistically significant asymmetric term in the conditional variance equation, it is safe to say Volatility in the RAND is more responsive (in this case, rising) to appreciation in the value of the RAND than when the Rand depreciates in value. Finally, we found the volatility to be highly persistent as the sum of the GARCH and ARCH terms in the conditional variance equation is approximately unity.

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