Exchange-Rate Volatility and the Contagion and Spill-Over Effect: Evidence from SADC Economies

Abstract

This paper investigates the transmission of the South African exchange-rate volatility to other countries in the SADC region since most countries in the region have high intra-trade shares with South Africa. An analysis of the spill over effect, with a specific focus on the contagion of the financial crises can assist in the development of a responsive policy. The analysis is rounded off with an evaluation of the issue of monetary policy in the SADC States: both during and after the 2008 financial crisis. The study used the GARCH (p, q) model and the Exponential GARCH model to address the objective of the study. The period under investigation extended from 2 January 2007 to 31 December 2011. The key finding of the paper confirms the presence of the Rand volatility-contagion effect during the crisis period, as well as its spillover effect during tranquil periods to most currency markets in the region. These results show that the Central Banks of SADC countries should take policy action to cushion the devastating effects following a large exchange rate shock. Therefore, the results on the exchange-rate volatility and its contagion/spill-over effect are useful for policy makers to formulate and implement appropriate policies in the event an adverse shock is observed in SADC exchange markets where contagion/spill-over effect is empirically manifested.

***Keywords**: Exchange Rate Volatility, Contagion, Spill-Over Effect, GARCH Model, EGARCH Model*

1. Introduction

Previous financial crises, especially those since the 1990s, have an interesting trajectory in that they might start in one country, but then spread from one country to another, and from one region to another. This phenomenon was experienced in Latin America in 1994, in East Asia in 1997, in Russia in 1998, and in the United States in 2008. In particular, the 1997 and 2008 financial crises spread to many regions and countries without the exception of any of the SADC countries (Kohler, 2010, p. 39). For instance, between August 2008 and February 2009 the Mauritius Rupee, South African Rand, and Zambian Kwacha depreciated by 28.8, 37.1 and 60 % respectively, against the U.S. Dollar (Aizenman & Hutchison, 2010, p. 14).

The Asian and United States crises led to a fall in share prices on many securities markets around the globe. These events have drawn the interest of many researchers on contagion and the spill over effects of financial crises across different countries. Such literature has mainly measured the contagion and spill over effects using stock-market returns, interest rates and exchange rates, without clearly distinguishing these effects during the tranquil periods, as well as the relatively well documented crises periods. Furthermore, these studies mainly focus on developed countries with some attention paid to developing countries in Latin America and East Asia, and tend to bypass countries on the African continent.

The contagion and spill-over effect are used as two distinct concepts in this paper: contagion refers to the transmission of an economic shock from one country to another during a crisis period, while the transmission of an economic shock from one country to another during the tranquil period is termed a spill-over effect. This paper has a particular interest in studying the exchange-rate volatility contagion and spill over effect between South Africa and the selected countries in the SADC during the crisis and tranquil period. South Africa was selected because it is the country with the biggest and most diverse economy in SADC, and since most countries in the region have high intra-trade shares with South Africa.

Despite high fluctuations in Rand exchange rates, the Rand remains significant in terms of trade in the region. One of the reasons that makes that Rand volatile is its exposure to international exchange markets. The South African economy is open to both SADC and to countries outside the SADC region. According to the World Trade Organization (WTO) (2013), South African trade dominates intra-SADC trade. In 2010, South African exports were about 68.1 % of intra-SADC exports and was the main export destination for three of the fifteen SADC countries, as well as the main import destination for eight of fifteen countries of the SADC region. This has led to increase in Rand influence in the region. The increase in influence of the Rand in the region emanates from the progress made by the FTA in the region and propelled by the decision by SACU to offer tariff-free access to the other SADC members. This has made the Rand a greatly traded currency in the Region and hence, the necessity and urgency to investigate the impact of its volatility on other currencies in the region.

Section 2 provides the review of the theoretical literature relating to currency, financial crises and their contagion and spill over effects. Section 3 gives the empirical literature survey on the topic. Section 4 outlines the methodology used to investigate the study questions. Section 5 presents the empirical results of the investigation and an analysis and interpretation of these. Various facets of the study question are linked and discussed in terms of their implications for SADC economies and policy-makers. Section 6 concludes the study.

2. Theoretical Considerations of the Financial Crises Episodes

The episodes of the financial crises are different from one another. This stimulated the research interests to find the causes for each crisis and to provide possible ways to come out of such crisis and prevent future occurrences. Hence, different scholars have come up with different models to predict and explain the advent of financial crises and their contagion. The first-generation crisis model, as pioneered by Krugman (1979), asserts that fiscal policy is inherently unstable and a combination of unstable policies with a fixed exchange-rate regime results in a financial crisis. For instance, massive money creation in the way in which budget deficits are funded could reduce reserves and increase the cost of maintaining a peg. The Russian financial crisis of 1998 was the result of the perception that the weak government was about to be financed by the printing of more money (Chiodo and Owyang, 2002, p. 7; Sojli and Fry, 2011, p. 499).

However, the second-generation crisis model rejects the notion of political instability. It proclaims that the crisis itself drives policy change, which makes a crisis self-validating. In other words, the crisis may be driven by self-fulfilling expectations (Eichengreen, Rose, and Wyplosz, 1996, p. 467). For instance, if investors expect a devaluation of currency, the cost of maintaining a peg would increase, due to the increase in interest rates (Drazen, 2003, p. 39). This was exemplified by the UK financial crisis of 1992 (Rajan, 2002).

In the case of the Asian crisis, the focus diverged from the first two models – when the economy was doing well – before the currency melt-down. This led to the creation of a third-generation model, which put all the blame onto the banking system (Krugman, 1999, p. 460). Hence, the third generation models were developed to include the financial sector indicators derived from the aggregate balance sheet of banks. This generation of models paid attention to the contagion effect as the cause of a financial crisis (Tularam and Subramanian, 2013, p. 103).

This paper extends from the available literature on the contagion and spill-over effect of the currency and financial crisis to study, in particular, the exchange rate volatility transmission within SADC economies and from South African Rand market to other currency markets in the region during the 2008 financial crisis and tranquil period.

3. Empirical Literature Review

There is a growing literature on exchange-rate volatility and contagion and spill over effects ever since the currency crises of the 1990s and 2008. A sizeable number of studies have found empirical evidence for the association between volatility and contagion/spill-overs among countries' asset prices. However, there is limited empirical literature on the exchange-rate volatility and its contagion. These studies could be divided into two groups: some are based on univariate models (Granger-causality tests and vector auto-regression (VAR) models) while others are based on multivariate GARCH methodologies.

In this section, we start off by reviewing the empirical literature that employed the univariate models. This will be followed by the studies that used the multivariate GARCH models.

Khalid and Rajaguru (2006) examined the spread of the contagion in the Asian financial markets during the 1997/1998 financial crisis. They applied a Granger-causality test, using the daily data. Their results show strong links among Asian currency markets during crises.

Inagaki (2007) employed a residual cross-correlation model in his study. The Inagaki (2007) study's aim was to examine the Granger causality in the spot exchange-rate volatility spill over of the British Pound/US Dollar and the Euro/US Dollar. The author specifically used the sample's cross-correlation function between the squared standardised residual obtained from univariate GARCH models to apply the Granger-causality test. The results showed a unidirectional exchange-rate volatility spill over from the Euro to the British Pound. In other words, the Euro Granger-causes the British pound; but the British pound does not Granger-cause the Euro.

Similarly, Nikkinen, Sahlstrom, and Vahamaa (2005) reached the same conclusion on the exchange-rate volatility transmission between the British Pound, the Euro and the Swiss Franc, using the same model. Their findings show a unidirectional volatility transmission from the Euro to the British pound and the Swiss franc. Therefore, the Euro Granger-causes the British Pound and the Swiss Franc; but not the opposite. A univariate model is popular in this regard, because of its simplicity in application compared to the multivariate model; as it does not require simultaneous modelling. Inagaki (2007) argues that the uncertainty about the possible interaction between time series could complicate the formulation of the multivariate GARCH models.

A growing number of studies have found that the multivariate GARCH models are more appealing than the VAR and univariate GARCH models (Engle and Kroner, 1995; Bollerslev, 1990; Calvet, Fisher and Thompson, 2006). These researchers argue that because of advanced econometric software, the application of the multivariate GARCH models becomes relatively easy.

Bollerslev (1990) applied a Multivariate GARCH model to study the exchange-rate volatility spill-overs in European countries against the United States – by using the weekly data. The author identified the co-movements in the exchange-rate volatility of five countries: the Deutsche Mark, the French Franc, the Italian Lira, the Swiss Franc; and the British Pound.

Habib (2002) studied the impact on the behaviour of interest rates and exchange rates in Central and Eastern Europe, using the mean-exponential GARCH model in six developing countries. The results show that this model explains the exchange rate future's daily dynamic behaviour better than do other models.

In suit with the increasing literature on exchange-rate volatility-transmission studies, this study views the multivariate GARCH models as being more appropriate for this purpose, especially, the Exponential GARCH model. High-frequency data will be used for this paper.

4. Data and Methodology

4.1. Data Sources and Variable Description

To empirically analyze the exchange-rate contagion and the spill-over, this paper has made use of the daily data of the normal exchange rate measured in EUROs for seven SADC sample countries over the period from 2 January 2007 to 31 December 2011. The EURO is used in this paper since it is one of the most internationally traded currencies. Another reason for this paper to measure the currencies against the EURO, rather than the U.S. dollar for the purpose of analyzing the volatility transmission is because of the currencies in the region that are tightly pegged to the U.S. Dollar. Consequently, when the U.S. dollar is used as a measure of the volatility, the trends are not clear. For comparing the crisis and the non-crisis periods, the data are divided into two: The Crisis (02 July 2007-31 December 2009) and the post-crisis (04 January 2010-31 December 2011) periods. The forward-exchange rate would be preferable as it is useful in eliminating the central bank intervention in the foreign market, thereby, reflecting the true exchange-rate movements. However, forward-exchange rates are not available for most of the sample countries. For this reason, this paper uses the spot-exchange rate measured in local currency per EURO obtained from the Data Stream. The currencies that are used for the analysis are the Angolan Kwacha (AOK), the Botswana Pula (BWP), the Malawian Kwacha (MWK), the Seychelles Rupee (SCR), the South African Rand (ZAR), the Tanzanian Shilling (TZS) and the Zambian Kwacha (ZMK).

Following previous empirical studies that used spot-exchange rates data, the exchange-rate data are transformed into the first-log difference, as expressed below:

$$R_{i,t} = \log(S_{i,t}) - \log(S_{i,t-1}) = \log\left(\frac{S_{i,t}}{S_{i,t-1}}\right) \tag{1}$$

Where $R_{i,t}$ represents the exchange-rate return on currency i between the current and previous times; S_t denotes the spot-exchange rates of currency i at time t measured in EUROs for other SADC countries.

4.2. The Unit-Root Test

When a study makes use of macro-economic time-series data, the test for Stationarity becomes important. In order for this study to confirm the extent these time series split the univariate integration properties the Augmented Dickey-Fuller (ADF) test of Dickey and Fuller (1981) was used.

4.3. The GARCH Model

The ARCH and GARCH models, developed by Engle (1982) and Bollerslev (1986), respectively, are mostly used to model the volatility clustering and persistence in economic variables. Even though these two models are very similar – even in their interpretation – recent literature seems to favour the GARCH model rather than the ARCH model, because of its flexibility. The GARCH model has only three coefficients that allow for an infinite number of squared residuals to explain the volatility.

The GARCH (p, q) model is employed in this study to model the exchange-rate volatility; and it is specified as follows:

$$\sigma_t^2 = \omega + \sum_{j=1}^{q} \alpha_q e_{t-1}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-1}^2 \tag{2}$$

Where, e_{t-1}^2 denotes the previous squared residuals, σ_{t-1}^2 is the previous conditional variance, p represents the lagged terms of the lagged σ^2 and q represents the lagged terms of the lagged ε^2 term. The coefficients α_q and β_j capture how the magnitude of previous squared residuals and the previous conditional variance changes the current variance or risk of exchange rate, respectively. The GARCH (p, q), is designed to allow the current conditional variance to be determined by previous conditional variances and previously squared residuals. The GARCH (q, p) model is estimated in this study, using the Quasi-Maximum Likelihood (QML) estimator under a normal (Guassian) distribution assumption.

4.4. The EGARCH Model

Although the GARCH model is able to capture the volatility clustering, it has some limitations in capturing the leverage effect, due to the inability of a conditional variance to capture the sign. In other words, the GARCH model assumes the positive and negative sign to have an equal impact on volatility, whereas in practice, the negative relationship between returns and volatility tends to be strong in financial markets. This means that high volatility mostly translates into negative returns, rather than positive returns. This asymmetric association is termed the leverage effect. To account for the asymmetric relationship, this study employs the EGARCH model of Nelson (1991), which is written as follows:

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^{q} \alpha_i g(z_{t-1}) + \sum \beta_k \log(\sigma_{t-k}^k) \tag{3}$$

$$g(z_t) = \theta \cdot z_t + (|z_t| - E|z_t|), \qquad z_t = \frac{v_t}{\sigma_t} \tag{4}$$

$\alpha, \beta, \omega, \theta$ are coefficients; where θ measures the magnitude of the impact of the sign effect.

The specification of the model is given as:

$$\log(\sigma_t^2) = \alpha_0 + \alpha_1(|z_{t-1}| - E|z_{t-1}|) + \theta z_{t-1} + \beta \log(\sigma_{t-1}^2) \qquad \text{where } z_t = \frac{v_t}{\sigma_t} \tag{5}$$

The term $(|z_{t-1}| - E|z_{t-1}|)$ takes into account the magnitude effect of the previous innovations (error terms) on the current volatility of the exchange rates; and z_{t-1} caters for the sign effect of the past error terms. The persistence of the volatility depends on the size of the β parameter. As proposed by Nelson (1991), the EGARCH (q, p) model employed in this study is estimated by using the Quasi-Maximum Likelihood (QML) estimator under a Generalised Error Distribution (GED).

4.5. Exchange-Rate Volatility-Transmission Model

The presence of volatility transmissions across currency markets may be consistent with increasing financial and economic integration (Engle, Ito and Lin, 1990; Pramor and Tamirasa, 2006:08). To identify the currency-volatility transmissions within the SADC region, the study includes the conditional variance of the South African Rand (exogenous variable) in GARCH (1, 1) Equation (2). The South African Rand is made the exogenous variable in the model; because it is the most-traded currency in the region; and South African economy is the biggest in the region. Therefore, South Africa's currency volatility transition to other currency markets in the region is worth the investigation. For this purpose, the GARCH (1, 1) model expressed in Equation (2) can now be specified as follows:

$$\sigma_t^2 = \omega + \sum_{j=1}^{q} \alpha_q e_{t-1}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-1}^2 + \lambda ZAR\_EURO_t \tag{6}$$

Where ZAR_EURO in the equation (6) represents the exogenous regressor of each sample currency conditional variance. Therefore, λ measures the exchange-rate volatility transmission from South African currency market to other selected currency markets. The null hypothesis that there is no volatility transmission is accepted, if the coefficient λ is positive and statistically different from zero.

5. Empirical Results

5.1. Preliminary Data Analysis and Summary Statistics

Figure 1 and Figure 2 show the first logarithm differences in daily-spot exchange-rate returns of SADC countries against the EURO for the crisis period from 02 July 2007 to 31 December 2009 and the post-crisis period, which extends from 04 January 2010 to 31 December 2011. Figure 2 shows that all the currencies for the sample countries had high volatility in the third quarter of 2008. This was during the crisis period, when most of the SADC countries were starting to feel the 2008 financial crisis. This could be an indication of the volatility contagion during such crisis periods.

Except for Malawi, the Seychelles and Tanzania, the rest of the sampled countries became even more volatile after December 2009. The results in this section mean that the currencies in this region were flexible against EURO.

Table 1 displays a summary of the daily exchange-rate statistics. The returns are computed by taking the first differences in the exchange rates based on the model (1). The mean values in the crisis period show the positive values for all returns. Interestingly, the standard deviations of the spot exchange-rate returns in the crisis period for the hard-pegged currencies (MWK, SCR and TZS) are the smallest; and they are equal. These results concur with the reviewed literature, which states that fixed currencies tend to be less volatile compared to flexible currencies. The kurtosis values for the South African Rand and three fixed currencies (Angolan Kwacha, Malawian Kwacha and Tanzanian shilling) were relatively smaller in the crisis period, thereby indicating more stability in the data compared to the other sample countries. However, the currencies with the excess kurtosis values in the crisis period indicated that their kurtosis values had significantly declined in the post-crisis period.

The standard deviations for the Angolan Kwacha (AOK), the Botswanan Pula (BWP), the South Africa Rand (ZAR) and the Zambian Kwacha (ZMK), in particular, had declined from 0.0263, 0.0193, 0.0119 and 0.0131 in the crisis period – to 0.0066, 0.0082, 0.0075 and 0.0078 in the post-crisis period, respectively. This indicates that the currencies were stabilizing in the post-crisis period.

Table 1: Descriptive statistics of daily exchange-rate returns

Panel A: Crisis Period

Currency	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability	Observations
AOK	0.0011	0.0263	21.646	516.389	6934673.	0.00	627
BWP	0.0008	0.0193	18.900	430.84	4819397.	0.00	627
MWK	8.19E-05	0.0080	0.3634	6.0787	261.42	0.00	627
SCR	8.19E-05	0.0080	0.3634	6.0786	261.40	0.00	627
TZS	8.19E-05	0.0080	0.3634	6.0786	261.40	0.00	627
ZAR	0.0002	0.0119	0.4429	5.5330	188.12	0.00	627
ZMK	0.0002	0.0131	4.6340	141.53	503564.6	0.00	627

Panel B: Post-Crisis Period

Currency	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability	Observations
AOK	-0.0002	0.0066	-0.1902	3.0784	3.2058	0.2013	510
BWP	-1.68E-05	0.0082	0.4410	9.6397	953.34	0.00	510
MWK	0.0013	0.0319	20.746	455.07	4379375.	0.00	510
SCR	0.0016	0.0338	20.882	459.56	4466528.	0.00	510
TZS	0.0007	0.0156	13.868	265.50	1480628.	0.00	510
ZAR	-7.28E-06	0.0075	0.1895	6.9676	337.57	0.00	510
ZMK	-0.0002	0.0078	-0.7123	8.5731	703.15	0.00	510

5.2. Preliminary Volatility Correlation Analysis

Before running the multivariate GARCH models, Table 2 displays the unconditional sample correlations among the SADC selected currencies for crisis and non-crisis/post-crisis periods. In the crisis period, the currencies for three small and relatively closed economies (Malawi, the Seychelles, and Tanzania) seemed to have identical currency volatilities, where their exchange-rate volatilities were 100 % correlated with one another. They also had uniform correlation values against all the other sample countries' currency volatilities; whereas in uniform, their exchange-rate volatilities are 29, 43, 3 and 59 % correlated with the Angolan Kwacha, the Botswana Pula, the South African Rand and the Zambian Kwacha volatilities, respectively. In the crisis period, the volatility correlation values between the AOK and the Rand, the BWP and the Rand, and the BWP and ZMK were -2.8, -4.5 and -16.6 %, respectively. This shows that there is a strong intra-regional contagion between Malawi, the Seychelles, and Tanzania, when compared to Angola, Botswana, South Africa and Zambia. This is also an indication that the former group of these countries (Malawi, the Seychelles, and Tanzania) sourced their volatility hugely from one inter-regional country (USA), to which they had all tightly pegged their currencies during the crisis period.

However, in the post-crisis period, the uniform correlation between the Malawian Kwacha, the Seychelles Rupee and the Tanzanian Kwacha declined from 100 % in the crisis period to 98.9 % between MWK and SCR; 92.1 % between MWK and TZS; and 91.6 % between SCR and TZS in the post-crisis period. This indicates a decline in volatility transmission among these currency markets in the post-crisis period. The decline in correlation of these currencies' volatility matches with their decline in the dollar peg in the same post-crisis period, as indicated in the literature. However, there are still similarities in volatility movements among these currencies. This shows that the volatility transmission is still present – even in the tranquil period.

Table 2: Correlation analysis of the currency volatility within the SADC countries

Panel: Crisis Period

	AOK	BWP	MWK	SCR	TZS	ZAR	ZMK
AOK	1.000000						
BWP	0.126903	1.000000					
MWK	0.291988	0.438451	1.000000				
SCR	0.291984	0.438450	1.000000	1.000000			
TZS	0.291983	0.438449	1.000000	1.000000	1.000000		
ZAR	-0.028199	-0.045358	0.033312	0.033313	0.033311	1.000000	
ZMK	0.172701	-0.166492	0.592820	0.592819	0.592819	0.001152	1.000000

Panel: Post-Crisis Period

	AOK	BWP	MWK	SCR	TZS	ZAR	ZMK
AOK	1.000000						
BWP	0.775676	1.000000					
MWK	0.178509	0.210498	1.000000				
SCR	0.169447	0.198286	0.989724	1.000000			
TZS	0.399740	0.402017	0.921286	0.916425	1.000000		
ZAR	0.127941	0.121243	-0.052180	-0.051843	-0.017148	1.000000	
ZMK	0.856958	0.785303	-0.017207	-0.016433	0.221027	0.096301	1.000000

Note: Volatility is calculated as the standard deviation of the currencies.

5.3. Unit-Root test Results

In order to verify the stationarity of the variables used for analysis in this section, preceding the GARCH models estimation, the ADF test is conducted. This test is necessary because the GARCH models' estimation requires the stationary data, in order to avoid spurious regression problems. Table 3 shows the results of the ADF tests for the log levels and the log first differences. It is evident from the table that all the log-level data – both in the crisis and in the post-crisis period yield p-values that are far greater than those of the 5 % level of significance – except for BWP in the crisis period. The logs' first difference data ADF test results show that all the variables are stationary; as the p-values are all less than the 5 % level of significance. These results imply that it is appropriate to continue with the analysis of the exchange rate when working with the first difference of the variables.

Table 3: Unit-Root Tests

Currency	Period	ADF (Trend and Intercept)	
		(Levels)	(First Difference)
AOK	Crisis	-1.213	-24.510***
	Post-Crisis	-2.110	-19.709***
BWP	Crisis	-3.459**	-25.195***
	Post-Crisis	-3.078	-21.717***
MWK	Crisis	-1.757	-24.769***
	Post-crisis	-1.913	-22.980***
SCR	Crisis	-1.757	-24.769***
	Post-crisis	-1.827	-22.977***
TZS	Crisis	-1.757	-24.769***
	Post-crisis	-1.380	-22.694***
ZAR	Crisis	-1.478	-24.127***
	Post-crisis	-2.381	-18.214***
ZWK	Crisis	-1.178	-24.749***
	Post-Crisis	-2.963	-19.535***

Notes: ***, ** and * denote rejection of the null hypothesis of the unit root for the ADF test at 1 %, 5 % and 10 % significance levels, respectively. The currencies for each country in these tests are expressed as the log first difference exchange rates against the EURO.

5.4. Residual-Test Results

The Ljung-Box Q statistic tests the null hypothesis that the data are free from serial correlation – against the alternative hypothesis that there is serial correlation at the 5 % level. The Q statistic is computed up to 10 lags for both return series and squared residuals. Specifically, a significant Q statistic is set up to reject the null hypothesis of no serial correlation in spot-exchange rate returns. On the other hand, a significant Q statistic for the squared spot exchange returns is set up to reject the null hypothesis of homoskedastic square returns. To complement the Ljung-Box Q statistic, the ARCH-LM statistic is used, where the decision rule of the test rests on the null hypothesis of no ARCH effects. It is evident from Table 4 that the Q statistics in both returns and squared returns are significant at the 5 % level for all the currencies. This suggests the presence of conditional heteroskedasticity in the residuals. This is also supported by the ARCH-LM test, which rejects the null hypothesis of the no-ARCH effect at the 5 % level of significance for all the currencies. These results support the decision of modelling the exchange-rate volatility by using the GARCH-family procedures.

Table 4: Residual tests results

	Crisis Period			Post-Crisis Period		
Currency	$Q(10)$	$Q^2(10)$	**LM ARCH(5)**	$Q(10)$	$Q^2(10)$	**LM ARCH(5)**
AOK	5655.1 (0.000)	5707.7 (0.000)	620.26 (0.000)	4421.9 (0.000)	3709.5 (0.000)	499.61 (0.000)
BWP	5862.2 (0.000)	5271.0 (0.000)	619.74 (0.000)	4097.6 (0.000)	3056.2 (0.000)	493.06 (0.000)
MWK	5761.3 (0.000)	4606.5 (0.000)	617.46 (0.000)	4643.8 (0.000)	4422.5 (0.000)	500.87 (0.000)
SCR	5761.3 (0.000)	4606.5 (0.000)	617.46 (0.000)	4643.7 (0.000)	4438.3 (0.000)	501.14 (0.000)
TZS	5761.3 (0.000)	4606.5 (0.000)	617.46 (0.000)	4812.6 (0.000)	4330.8 (0.000)	504.26 (0.000)
ZAR	5689.6 (0.000)	4422.7 (0.000)	615.71 (0.000)	4396.6 (0.000)	3590.5 (0.000)	501.13 (0.000)
ZMK	5916.4 (0.000)	5397.2 (0.000)	621.4566 (0.000)	3991.8 (0.000)	3044.4 (0.000)	492.35 (0.0000)

Notes: $Q(10)$ and $Q^2(10)$ comprise the Ljung-Box for serial correlation in the raw series and in the squared series, respectively. The P-values are in parenthesis.

5.5. GARCH and EGARCH Estimation Results

Table 5 presents the summary of the exchange-rate volatility results for each of the six countries in the sample, using both the GARCH and the EGARCH procedures. The GARCH (1, 1) shows that in both sub-sample periods, the lagged squared residuals and the lagged variance coefficients are positive in all the countries and significantly different from zero in most of the countries in the sample. In the crisis period, it is only AOK with an insignificant lagged-variance coefficient. In the post-crisis period; the AOK and the MWK have insignificant lagged-squared residual coefficients.

In terms of the EGARCH (1, 1) results, in the crisis period all the currencies display statistically significant reactions and resistance to shocks, as shown by α_1 and β. This means that the exchange-rate volatility reacts intensely to shocks for all the sample currencies; and that the shock to the volatility takes time to subside. Specifically, the α_1 values are positive for all the currencies. This indicates that the past innovations increase the current volatility or risk of exchange rate. Both in the crisis- and in the post-crisis periods, the Botswanan Pula, the

Malawian Kwacha, the Seychelles Rupee, the Tanzanian Shilling and the Zambian Kwacha display leverage effects, as shown by the negative and statistically significant value of θ. This implies that depreciations in these currencies increase the exchange-rate volatility more than the appreciations. However, in the case of the Angolan Kwacha and the South African Rand in the crisis period, the positive and significant values of θ imply that appreciations in exchange rates increase volatility more than depreciations in the exchange rate during crisis periods.

Even though the Angolan Kwacha displays a negative sign for coefficient θ in the post-crisis period, there is not enough evidence to infer the presence of the leverage effect; since the coefficient is not significant.

In the post-crisis period, countries in the sample, except for the Angolan Kwacha, the Botswana Pula, and the Zambian Kwacha, still show statistically significant reactions, as reflected by a_1. This implies that the past innovations still have an influence on the volatility in 2010 and 2011 in four currencies. However, the persistence coefficient is still significant in all the currencies, except for the Malawian Kwacha and the Seychelles rupee in the post-crisis period. This means that there is no evidence of volatility shocks' persistence after 2009 in the case of the Malawian Kwacha and the Seychelles Rupee.

Table 5: Estimates of conditional variance with GARCH and EGARCH

PANAL A: Crisis Period							
	GARCH			EGARCH			
Currency	ω	α_q	β_j	α_0	α_1	θ	β
AOK	-0.008597 (0.4821)	0.005658 (0.6972)	0.994342 (0.0000)	-7.738440 (0.0000)	1.960760 (0.0000)	1.471733 (0.0000)	0.249630 (0.0000)
BWP	-0.017635 (0.0437)	0.000209 (0.8981)	0.999791 (0.0000)	-6.596608 (0.0000)	1.738451 (0.0000)	-0.986940 (0.0000)	0.388831 (0.0000)
MWK	0.000283 (0.2783)	0.043118 (0.0225)	0.956882 (0.0000)	-0.132511 (0.0000)	0.062555 (0.0001)	-0.041013 (0.0021)	0.991164 (0.0000)
SCR	0.000283 (0.2783)	0.043118 (0.0225)	0.956882 (0.0000)	-0.132507 (0.0000)	0.062555 (0.0001)	-0.041013 (0.0021)	0.991164 (0.0000)
TZS	0.000283 (0.1300)	0.043118 (0.0000)	0.956882 (0.0000)	-0.132520 (0.0000)	0.062559 (0.0001)	-0.041012 (0.0021)	0.991163 (0.0000)
ZAR	-6.47E-05 (0.8753)	0.055355 (0.0078)	0.944645 (0.0000)	-0.286525 (0.0009)	0.109134 (0.0002)	0.074749 (0.0005)	0.977742 (0.0000)
ZMK	0.001546 (0.0220)	0.019763 (0.5143)	0.980237 (0.0000)	-6.946390 (0.0000)	1.417852 (0.0000)	-0.952768 (0.0000)	0.328311 (0.0000)
PANAL B: Non-Crisis Period							
	GARCH			EGARCH			
Currency	ω	α_q	β_j	α_0	α_1	θ	β
AOK	-0.000178 (0.5502)	0.029166 (0.0232)	0.970834 (0.0000)	-2.000678 (0.0616)	0.012620 (0.8092)	-0.060861 (0.1615)	0.801839 (0.0000)
BWP	-4.23E-05 (0.9114)	0.022740 (0.0483)	0.977260 (0.0000)	-0.887753 (0.0005)	0.050413 (0.1453)	-0.098277 (0.0000)	0.911430 (0.0000)
MWK	0.012830 (0.7972)	2.35E-05 (0.9932)	0.999976 (0.0000)	-9.803682 (0.0000)	0.922559 (0.0000)	-1.243151 (0.0000)	0.042016 (0.3104)
SCR	0.006975 (0.9432)	3.97E-05 (0.9880)	0.999960 (0.0000)	-9.835583 (0.0000)	1.228532 (0.0000)	-1.418671 (0.0000)	0.004609 (0.9024)
TZS	0.013034 (0.1453)	0.000573 (0.8527)	0.999427 (0.0000)	-9.173740 (0.0000)	1.167518 (0.0000)	-0.938689 (0.0000)	0.082185 (0.1011)
ZAR	-0.000215 (0.4789)	0.080041 (0.0091)	0.919959 (0.0000)	-2.635918 (0.0000)	0.229208 (0.0003)	0.237319 (0.0000)	0.753687 (0.0000)

Notes: The estimation method is based on the Quasi-Maximum Likelihood. The P-values are in parentheses.

5.6. Exchange-Rate Volatility Transmission Results

In addition to the above volatility analysis, this sub-section focuses on the analysis of the volatility-transmission effect from the South African Rand to the other currencies of the SADC region. Given that the South African Rand is the most-traded currency in the region, and motivated by the preceding volatility analysis for each of seven currencies, the South African Rand is included in the GARCH (p, q) model, as the exogenous regressor. Table 6 provides the results on the exchange-rate volatility transmission from the South African Rand to the other countries in the region. These volatility contagion/spillover results are generated through GARCH (1, 1) model, where the rand is made the exogenous regressor.

The IGARCH-Wald χ^2 statistic for this paper tests the null hypothesis that $\alpha + \beta = 1$. If summation of the GARCH coefficients α and β is close to one, this indicates that the volatility shocks are quite persistent. When the summation is statistically equal to one, that suggests the presence of an integrated GARCH (IGARCH) effect, which means that the conditional volatility process is highly persistent. The Wald test rejects the null hypothesis that $\alpha + \beta = 1$ in all regressions at the 1 % level of significance in both the crisis and the post-crisis period. Therefore, the study infers that there is not enough statistical evidence to confirm the presence of the IGARCH effect. For this reason, these results are run from GARCH (1, 1) regressions; and they converge to the condition of changing their conditional variance and the constant unconditional variance; since it is a normality when $\alpha + \beta < 1$.

The results show that both crisis and non-crisis estimations perform well for most regressions when using the GARCH (1, 1) model, as the coefficients for both the lagged-squared residuals and the lagged variance are statistically different from zero.

In the crisis period, the coefficients of the South African Rand for the Malawian Kwacha, the Seychelles Rupee and the Tanzania Shilling are positive and significantly different from zero at the 1 % significance level, signifying the volatility-contagion effect from the South African exchange-rate market to their currency markets. As for the Angola Kwacha, the Botswanan Pula and the Zambian Kwacha, the regressions to the Rand coefficients are significant at the 1 % significance level; but otherwise negative, which means that high volatility in the South African Rand corresponds with low volatility in these currency markets.

In the post-crisis period, the results show the absence of any volatility spill-over effect linkages between the Rand market and the Angolan Kwacha market. This suggests that the exchange rate shocks in this period affected the Angola currency market independent of the South Africa currency market. In this period, only the Botswanan Pula showed the positive and significant Rand coefficient in its regression. The MWK, SCR, TZS and ZMK regressions show negative spill-over effects. The results in this section concur with the results of the preliminary correlation analysis of the exchange rates in section 5.2.

Table 6: Estimates of the regressors ZAR - EURO in a GARCH (1.1) model of the exchange-rate returns, both in crisis and post-crisis periods

PANEL A: Crisis Period						
	AOK	**BWP**	**MWK**	**SCR**	**TZS**	**ZMK**
C	0.000620 (0.1020)	2.22E-05 (0.0000)	3.02E-07 (0.0351)	3.02E-07 (0.0351)	3.02E-07 (0.0351)	0.000141 (0.0000)
ε_{t-q}^{2}	-0.004279 (0.0000)	3.727769 (0.0000)	0.034672 (0.0000)	0.034672 (0.0000)	0.034672 (0.0000)	0.149159 (0.0000)
σ_{t}^{2}	0.567402 (0.0306)	0.074191 (0.0000)	0.960627 (0.0000)	0.960626 (0.0000)	0.960626 (0.0000)	0.595080 (0.0000)
ZAR-EURO	-0.015521 (0.0000)	-0.000330 (0.0619)	0.000163 (0.0178)	0.000163 (0.0178)	0.000163 (0.0178)	-0.007427 (0.0000)
$Wald\ \chi^{2}$ **/IGARCH**	1.42E+11 (0.0000)	24100360 (0.0000)	266354.2 (0.0000)	266377.2 (0.0000)	449821.4 (0.0000)	2.47E+08 (0.0000)
PANEL B: Post-Crisis Period						
	AOK	**BWP**	**MWK**	**SCR**	**TZS**	**ZMK**
C	1.31E-05 (0.3657)	4.23E-05 (0.0789)	0.000837 (0.0472)	0.000938 (0.0245)	0.000158 (0.0000)	1.18E-06 (0.0000)
ε_{t-q}^{2}	0.027115 (0.4195)	-0.003142 (0.8611)	-0.004062 (0.0001)	0.043843 (0.4616)	0.227686 (0.1164)	-0.023043 (0.0000)
σ_{t}^{2}	0.671073 (0.0515)	0.363590 (0.3335)	0.545851 (0.0124)	0.545510 (0.0046)	0.461077 (0.0000)	1.005357 (0.0000)
ZAR-EURO	0.000359 (0.1690)	0.000758 (0.0000)	-0.034137 (0.0000)	-0.038342 (0.0000)	-0.005998 (0.0000)	-0.000434 (0.0000)
$Wald\ \chi^{2}$ **/IGARCH**	8645.540 (0.0000)	36707.02 (0.0000)	1.18E+10 (0.0000)	5.41E+08 (0.00000	12913037 (0.0000)	56538.02 (0.0000)

Notes: The estimation method is Quasi-Maximum Likelihood, computing Bollerslev-Wooldridge robust standard errors. The P-values are in parentheses.

6. Conclusion

This paper has provided the empirical investigation on the presence and nature of exchange-rate volatility on selected SADC exchange-rate markets. It also provided the results on exchange-rate volatility contagion/spill-over from the South African currency market to other selected SADC currency markets. This has been accomplished by employing the GARCH and the EGARCH models for the crisis and the post-crisis periods.

The preliminary volatility returns' analysis is conducted by using the standard deviation. The results show that the volatility was high under a flexible exchange-rate regime, when compared with those in rigid exchange-rate regimes. The results also show that the volatility was high for all sample currencies during the crisis-period. The graphical/tabulated results show a high and significant correlation among the exchange-rate returns of Angola and Malawi, Angola and Tanzania, and Malawi and Tanzania when compared with other sample countries' exchange rates and return relations. This means that these currency returns are highly influenced by one another; or they are influenced by a common factor – possibly the U.S. Dollar returns.

The regressions show that the GARCH (1, 1) model performs well; since in both sub-sample periods, the lagged-squared residuals and the lagged variance coefficients are positive in all countries, and significantly different from zero in most countries in the sample. EGARCH, on the other hand, provided information on the size effect, the sign effect and the persistence effect on the exchange-rate volatility. The EGARCH estimation provided the evidence of the leverage effect for most currency markets in both the crisis and the post-crisis periods. There is also an evidence of exchange-rate volatility shocks' persistence in both GARCH and EGARCH estimations.

To finalize the volatility contagion/spill-over effect, an analysis in the study investigated the volatility transmission from the South African Rand market to other currency markets in the region. The results were generated with the aid of the GARCH (1, 1) extension model. The results provided the evidence of the exchange-rate volatility contagion during the crisis period from the South African Rand market to the Malawian Kwacha, the Seychelles Rupee and the Tanzania Shilling markets. The evidence of the spill-over effect is also found in the tranquil period from the South African Rand market to the Botswanan Pula, the Malawian Kwacha, the Seychelles Rupee, the Tanzanian Shilling, and the Zambian Kwacha markets.

The results clarify that currency exchange shocks in one country can cause a persistent rise in the volatility of other countries' foreign exchange markets. These results show that the Central Banks in SADC countries will need to take policy actions following a large exchange rate shock. Therefore, the results on the exchange-rate volatility and its contagion/spillover effect are useful for policy makers to formulate and implement appropriate policies in the event an adverse shock is observed in SADC exchange markets where contagion/spillover effect is empirically manifested.

Future work may consider the application of other asymmetric GARCH models, such as the Threshold ARCH (TARCH), as well as regime-switching of GARCH models to model the currency-volatility contagion and the spill-over effect.

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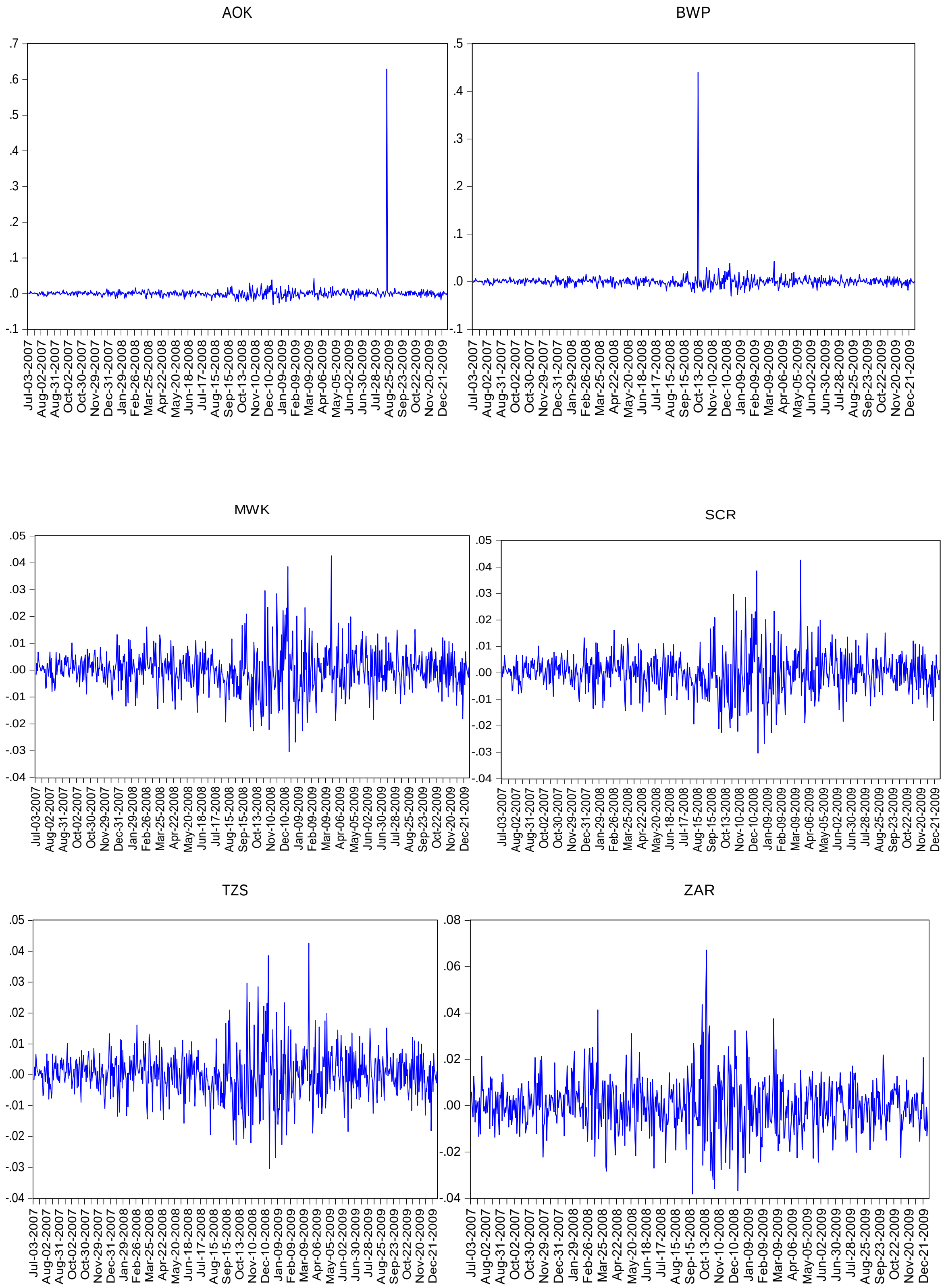
Figure 1: Daily spot exchange-rate returns against EURO in the crisis period recorded from 03 July to 31 December 2009



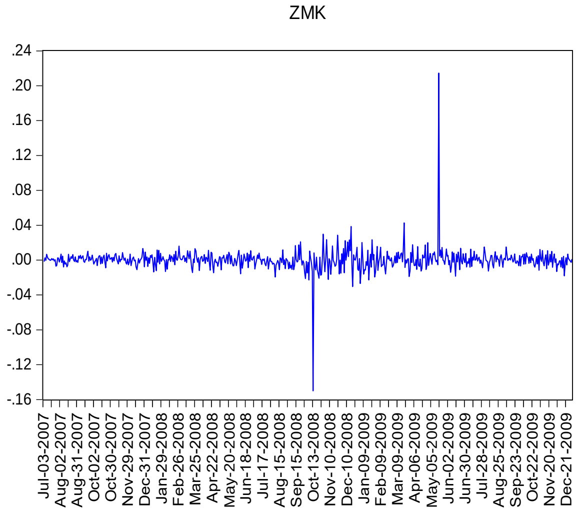
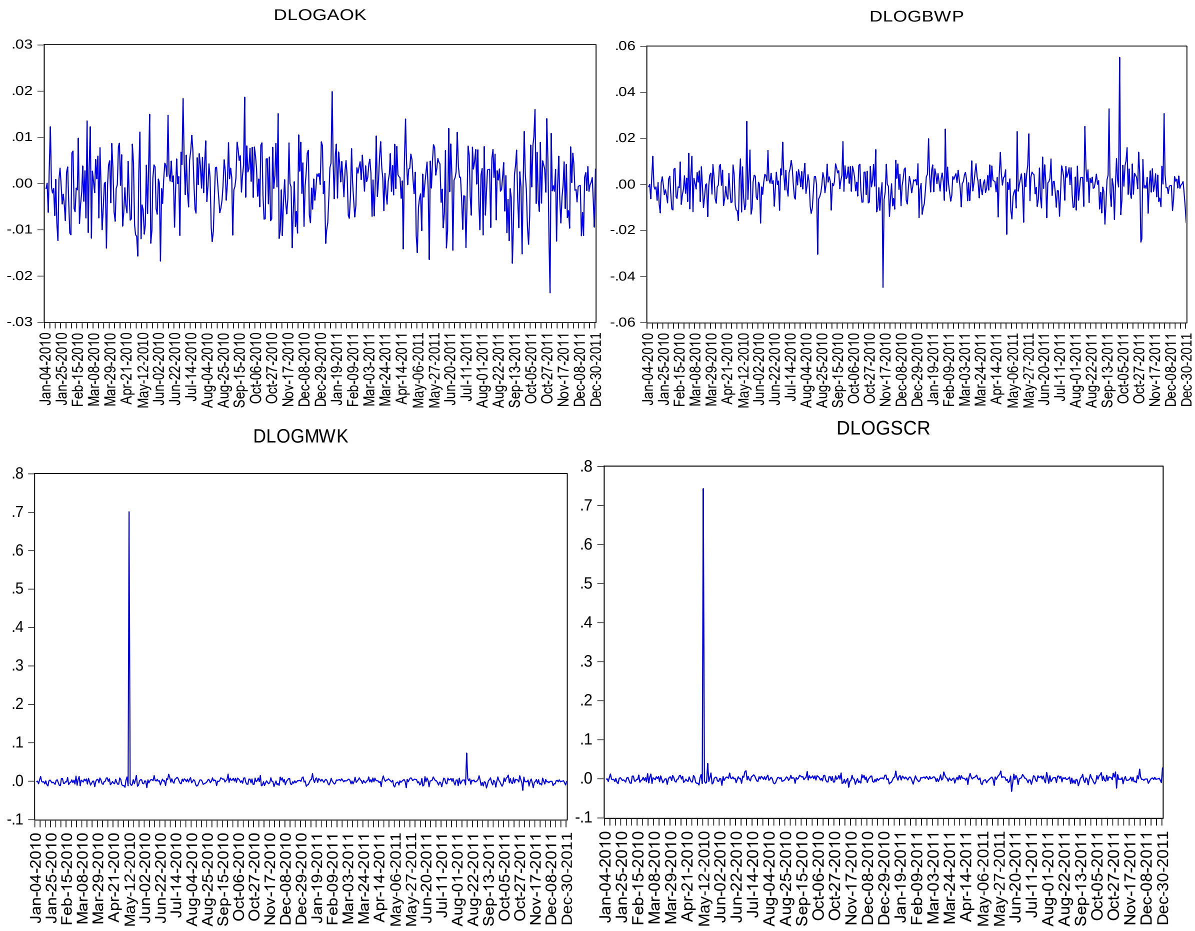
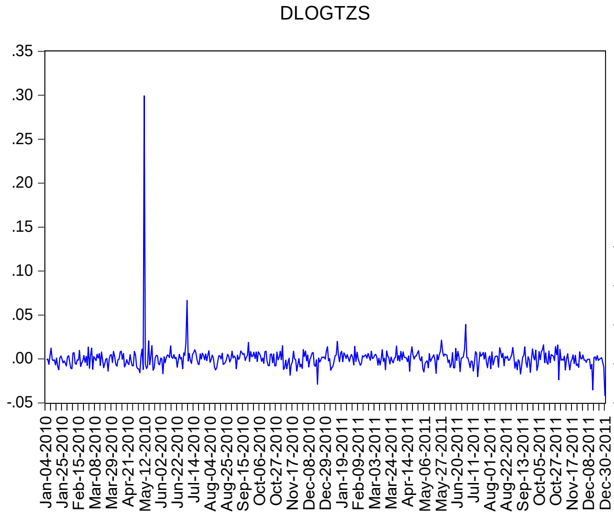
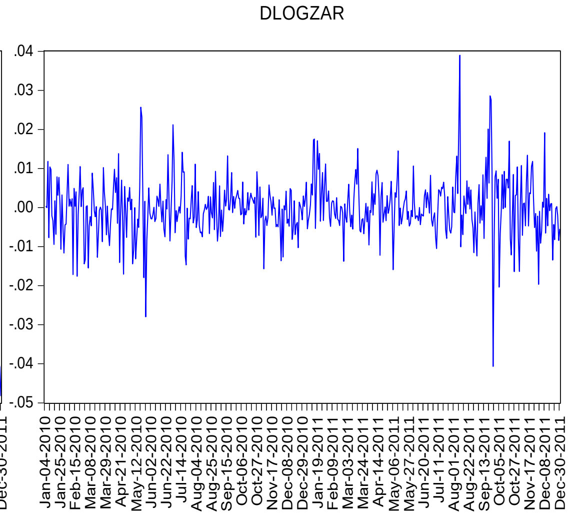
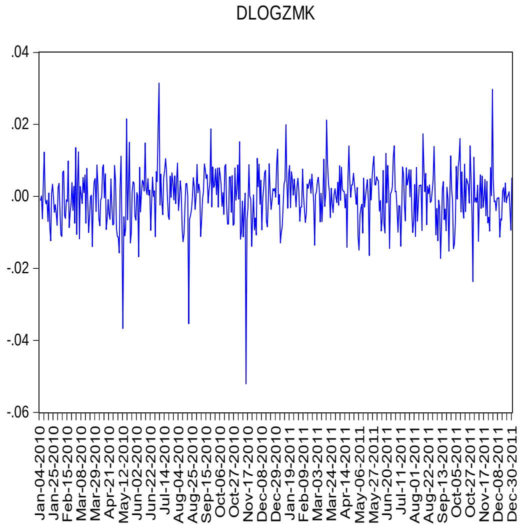


Figure 2: Daily spot-exchange returns against EURO in the post-crisis period recorded from 04 January 2010 to 31 December 2011









Notes:

AOK = Angolan Kwanza

BWP = Botswana Pula

MWK = Malawian Kwanza

SCR = Seychelles Rupee

TZS = Tanzanian Shilling

ZAR = South African Rand

ZMK = Zambian Kwanza