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Modeling the Volatility of Exchange Rate and Macroeconomic Indicators in Sudan: Application of Multivariate GARCH Models

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Keywords

adequacy
conditional correlation,
MGARCH ,
shock transmission

Abstract

This paper aims to analyze shock transmission and subsequently the conditional correlation between real effective exchange rate with its determinants, i.e. economic growth proxied by per capita income, inflation rate, and the trade balance ratio to GDP employing annual data from Sudan economy covering the period 1960 - 2014. Long-run relationship was found among these variable. Vector Conditional Heteroskedasticity (VECH) and Baba, Engle, Kraft and Kroner (BEKK) estimation methods gave significant results, and the adequacy of the models has been achieved. The impact of own shocks via VECH is greater than those from BEKK. Shocks come from other variables, are strongest between real exchange rate and inflation rate, while that from inflation to per capita income is the weakest. Per capita income has strong persistence to shocks.

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INTRODUCTION

Multivariate GARCH models have become standard tools for estimating volatility of financial instruments, but to some extent consider GDP, inflation or other variables accounting for an economy's fundamentals (Hafner and Franses 2003, Amando and Terasvirta 2011, Baroian 2014, Innocent and Mung'atu (2016)). The consequences of exchange rate volatility on trade and real economic activity has been studied extensively e.g. (Isaac 2015, Yasmina 2012, Supaat 2003, Thapa 2002). Exchange rate usually takes four forms, nominal, nominal effective, real, and real effective. A rise in real exchange rate (RER) in a country means its goods are becoming more expensive relative to its competitors, and its people can get more foreign goods for an equivalent amount of domestic goods. The nominal effective exchange rate (NEER) is is an indicator of a country's international competitiveness in terms of the foreign exchange market (Investopedia 2016). The effective real exchange rate is NEER adjusted by relative prices. It is an indicator international competitiveness and shows what can actually be bought. It gives an overall performance of a currency. If the overall effective exchange rate increases it suggests that the currency is becoming stronger.

The nominal exchange rate of the Sudanese pound was fixed to 2.83 USD for the period 1960-1977, then devaluated for the first time by 43 per cent in September 1978, followed by a series of minor devaluations up to February 1992 where an unprecedented devaluation of more than 700 per cent was done (Annex 4). The nominal and real effective exchange rates were largely affected by these devaluations showing an upward trend during 1960-1977, shifted to downward trend during 1978-1991, and becoming flat for the period 1992-2014.

The aim of this paper is to estimate conditional variances, covariances, and correlations of real effective exchange rate and related economic variables. The motivation to tackle this issue is that real effective exchange rate as an indicator of international competitiveness responds to the movement of the exchange rate and related economic variables. To my knowledge no attempt has been done to model the conditional variance-covariance and correlation between exchange rate and related economic variables of the Sudan economy.

This paper is organized as follows: section two reviews literatures relevant to this research, section three give brief theoretical background, section four is devoted to methodology and data, results and discussions will be presented in section five, and finally we conclude the paper.

2. Literature Review

A plethora of empirical studies that link real exchange rate with stock market instruments and macroeconomic variables (fundamentals) have been done through vector error correction mechanism (VECM), ordinary least squares (OLS), Granger Causality (GC), and ARCH/GARCH models.

Modeling the effects of macroeconomic indicators' fluctuation and subsequently conditional correlation on stock market, exchange rate, and output volatility via MGARCH models have been emphasized by many researchers such as Alagidede, and Ibrahim (2016) on Ghanaian real exchange, Baroian (2014) on the stock markets of Czech Republic, Croatia, Poland, Romania and Hungary, Innocent and Mung'atu (2016) on US Dollars and Kenyan Shillings/Rwandan Francs, Lotfalipour and Bazargan (2014) on real effective exchange rate, Kebalo (2014) on the gold price's volatility on South African exchange, Hegerty (2014) on the output of Mexico and Brazil, Hartman and Sedlak (2013) on daily closing price of the spot prices on exchange rates of EUR/SEK and USD/SEK, Tuysuz (2013) on conditional correlation between the returns of S&P 500, Karunanayake, Valadkhani, and O'Brien (2012) on output volatility for Australia, Canada, the UK and the US, Mahmood, Ehsanullah, and Ahmed (2011) on exchange rate in Pakistan, Hakim and Poghosyana, and Kočendab, (2008) on foreign exchange market, Mohamed et al

(2010) on the nominal exchange rate and stock market in Egypt, Morocco, and Turkey McAleer (2008) on daily closing price index of stock, bond and foreign exchange rates from Australia and New Zealand, Manera, McAleer, and Grasso, (2004) on Tapis oil spot returns conditional correlations, Supaat et al (2003) on Singapore dollar (log of the first difference) nominal effective exchange rate (SGD NEER),

Ordinary least Squares, vector error correction, and Granger Causality have been used by Yasmina (2012) on Algerian REER and trade balance, Erjavec, , Cota, , and Jakšić, (2012) on the sources of exchange rate fluctuations in Croatia, Tarawalie (2010) on real effective exchange rate and economic growth, Manzan and Zerom (2009) on some of the macro indicators, such as unemployment rate and housing starts, provide effects on future core inflation, Edwards (2006 inflation targeting, and nominal or real exchange rate volatility, Mamta (1999) on the determinants of real exchange rate of Papua New Guinea as net capital inflow, foreign aid, trade restrictions, and expansionary macroeconomic policies.

3. Theoretical Background.

The relation between exchange rate and the trade balance has been explained by three approaches i.e. elasticities (Marshal-Lerner), absorption, and monetary approach. If the sum of demand elasticities of export and imports exceeds 1, depreciation of the real exchange rate improves the trade balance (Alan 2015). The demand for imports depends negatively on real exchange rate, depreciation of the later raises relative cost of imports and a lowers in the demand for imports contrary to the foreign demand for export. Net effects of depreciation on the balance of payment depend on elasticities, change in income, and absorption (Bouchet, Clark and Groslambert, 2003). The monetary approach centers on the satisfaction of excess demand for money by inflows of money from abroad to improve the trade balance, and the elimination of the excess supply of money by outflows of money to other countries, worsening the trade balance, (Appleyard and Field, 2014).

Changes in exchange rates tend to be highly correlated, but they are not perfectly correlated. As a result, different exchange rates suggest different pictures of the change in the domestic currency's value due to differing inflation rates (Alan 2015).

Aggregate demand and aggregate supply relates real exchange rate to GDP where the depreciation of real effective exchange rate affects competitiveness positively leading to increase in net export and hence increases GDP. The rise of the production cost due to the depreciation of the real exchange rate reduces GDP and redistributes income in favour of the rich as postulated by aggregate supply channel (Thapa 2002). Therefore an increase in the real exchange rate will tend to increase net imports. Foreigners will buy our less expensive exports. It now becomes more attractive to buy imports. This can cause a widening of the current account deficit and lower domestic AD. It will also help reduce inflation. Similarly a fall in the real exchange rate should increase net exports as domestic goods are more competitive. Movements of exchange rate influence general economic equilibrium due to the links between foreign exchange market, money market, and capital markets. An increase the GDP increases it decrease the home currency depreciation. So the gross domestic product is influencing the exchange rate fluctuation. High volatility of output causes random shocks makes the economy contract and can trigger recession (Simon 2001)

4. Methodology

The conditional correlation and covariance are important in hedging, risk management, portfolio selection, and asset allocation (Amado and Terasvirta 2011). They are the expectation and covariance given previous information. A number of multivariate GARCH models have been developed.

Bollerslev (1990) introduced the constant conditional correlation as:

$$y_t = Cx_t + \varepsilon_t;\ \ \varepsilon_t = H_t^{1/2} v_t;$$

$$H_t = D_t R_t D_t \rightarrow h_{ij,t} = \rho_{ij,t}\sigma_{it}\sigma_{jt};$$

Where y_t is $n \times 1$ vector of endogenous variable; C is $m \times k$ parameter matrix; x_t is $k \times 1$ vector of exogenous variables; H is $k \times k$ time-varying diagonal matrix from univariate GARCH, the conditional correlation is given by: $R = |\rho_{ij}|$.

Baba, Engle, Kraft and Kroner proposed the BEKK model restricting CCC to be:

$$H_t = CC' + A(r_{t-1}r'_{t-1})A' + BH_{t-1}B'$$

The A and B matrices are simply a scalar or diagonal rather than a whole matrix still ensure positive definiteness (Tsay 2006).

The vector conditional heteroskedasticity (VECH) model was also specified by Bollerslev (Engle 2002) as:

$$c(H_t) = vec(\Omega) + Avec(r_t r'_t) + BvecH_{t-1};$$

$$vec(\Omega) = (1 - A - B)vec\left(S = \frac{1}{T}(r_t r'_t)\right)$$

4.1 Data

The sample period starts in 1960 and ends in 2014. When dealing with time series it is desirable to have a stationary data set primarily because the characteristics of a stationary data set allow one to assume models that are independent of a particular starting point, which may be difficult to obtain in practice (Horvath and Johnston 2008). Attaining stationarity is reached through differencing, taking natural logarithms, square roots, and growth rates. Nominal exchange rate (X), inflation rate (INF), and per capita GDP (Q) were gathered from the Central Bureau of Statistic (CBS), Nominal exchange rate, and real exchange rate supplied by

REER_database_ver19Jan2015, finally trade balance obtained from the Central Bank of Sudan and CBS.

5.1 Results

Nominal exchange rate has been devaluated many times since September 1978. The sample period has been divided into three sub-periods according to the two major devaluations i.e. before the first devaluation, between the first and second devaluation, and after the second devaluation. The second sub-period is the worst in terms of rising inflation, appreciation of real effective exchange rate, and decline in per capita income, while the third sub-period was the worst in terms of the depreciation and variability of nominal exchange rate, and net trade balance ratio to GDP. According to the coefficient of variation (CV), NEER exhibited highest overall variability followed by inflation, nominal exchange rate, trade balance, REER, and per capita income. The appreciation of the nominal effective exchange rate in the first period has been followed by depreciation in the next two periods contrary to the real effective exchange rate this can be attributed mainly to the local prices which in turn raised the relative prices.

Table (1) Descriptive Statistics

Period	1960-1977		1978-1991		1992-2014		55 Years
Item	Mean	Std Dev.	Mean	Std Dev.	Mean	Std Dev.	CV
Nominal/$ %change	0.4 0.0	0.0 0.0	3.2 40.8	3.8 65.8	2690.4 61.3	2057.8 168.3	1.04
NEER %change	177424.2 2.5	21472.2 3.6	79297.9 -18.9	54592.7 26.0	216.1 -16.6	344.9 24.3	1.67
REER %change	117.3 2.1	11.0 6.2	164.1 8.4	56.6 25.8	83.0 1.3	23.9 21.6	0.40
INF	7.5	8.6	43.1	27.7	35.7	41.0	1.18
Q %change	452.9 -0.4	45.4 5.4	354.5 -0.1	26.3 6.9	552.9 3.9	150.2 5.2	0.27
TBR	-2%	0.032	-5%	0.032	-6%	0.056	-1.01

Unit root tests present contradicting results, real effective exchange rate is stationary according to ADF & PP and integrated of order one I(1) by KPSS; inflation rate is stationary by PP&KPSS, has one unit root I(1) by ADF; per capita income is stationary by ADF & KPSS and has one unit root by PP; trade balance ratio to GDP is stationary by ADF & PP and I(1) by KPSS (Annex 1).

Cointegration results indicated two cointegrated equation among REER, INF, Q, and TBR (Annex (2)). Data were transformed to stationarity by the performing the first difference a procedure followed by many e.g. Kebalo (2014) and Poghosyan & Kočenda (2008).

Table (2) below emphasizes the validity of the model by the residual Portmanteau tests for autocorrelation where the null hypothesis of no residual autocorrelations up to lag h has been accepted at 5% significance level, thus capture all the persistence in the variances.

Table (2) Residual Portmanteau Tests for Autocorrelations (VEC & BEKK)

System Residual Portmanteau Tests for Autocorrelations					
Null Hypothesis: no residual autocorrelations up to lag h					
Orthogonalization: Cholesky (Lutkepohl)					
Date: 08/11/16 Time: 05:21					
Sample: 1960 2014					
Included observations: 55					
Lags	Q-Stat	Prob.	Adjusted Q-Stat	Prob.	Df
1	13.68048	0.6225	13.93382	0.6036	16
2	31.01303	0.5163	31.92043	0.4707	32
3	45.15617	0.5901	46.87952	0.5188	48
4	51.89934	0.8612	54.15157	0.8051	64
5	61.54174	0.9377	64.7582	0.8921	80
6	78.77918	0.8992	84.10635	0.8018	96
7	87.43219	0.9586	94.02126	0.8901	112
8	95.90592	0.9846	103.9373	0.9415	128
9	109.7524	0.9848	120.4929	0.9235	144
10	121.5457	0.9896	134.9069	0.9259	160
11	135.6072	0.9895	152.4838	0.8994	176
12	148.5722	0.9912	169.0669	0.8822	192

The standard GARCH (1,1) VECH and BEKK models have been estimated using 55 observations, they achieved convergence after 122 iterations. Bollerslev-Wooldridge robust standard errors & covariance was chosen to allow for inference when the conditional distribution of the residuals is non-normal (Innocent and Mung'atu 2016).

Table (3) Estimated Parameters of the Mean and Variance-Covariance Equations

Conditional Mean Equation		
	VEC	BEKK
u_0	3.678815***	3.678815***
u_1	3.852488***	3.852488***
u_2	16.14357***	16.14357***
u_3	-0.00821***	-0.00821***
u_4	3.678815**	3.678815**
Conditional Variance-Covariance		
	VEC	BEKK
a_{11}	2.136819***	1.461786***
a_{12}	2.779335***	
a_{13}	-0.2492*	
a_{14}	0.859164***	
a_{22}	3.615049***	1.901328***
a_{23}	-0.32413*	

a_{24}	1.117504***	
a_{33}	0.029061	-0.17047*
a_{34}	-0.1002*	
a_{44}	0.345449***	0.587749***
b_{11}	0.467366***	0.683642***
b_{12}	0.366515***	
b_{13}	0.68788***	
b_{14}	0.490927***	
b_{22}	0.287426***	0.536121***
b_{23}	0.539444***	
b_{24}	0.384991***	
b_{33}	1.012437***	1.006199***
b_{34}	0.722557***	
b_{44}	0.515675***	0.718105***

Notes: *** indicates statistical significance at the 1 per cent level, ** indicates statistical significance at the 5 per cent level and * indicates statistical significance at the 10 per cent level.

Model variables respond to their own shocks and shocks from other variables. ARCH effects are captured by matrix A(m,n) indicating the importance of variable's own shocks Matrix B(m,n) explains the rate of shocks decay (Karunanayake, Valadkhani, and O'Brien, 2012). VECH estimates of own-shocks (spillovers) of real effective exchange rate, inflation and trade balance ratio to GDP are significantly different from zero except per capita income while all own-shocks given by BEKK are statistically different from zero.

The estimated coefficients through VECH and BEKK are the same in magnitudes, signs, and significance. The own-mean spillovers in both models are significant at 1 per cent level expect TBR which is significant at 5 per cent level, indicating an evidence of strong impact of own lagged values on the current ones. Inflation rate lagged values have the greatest influence on its current rates. The weakest lagged influence is for per capita income.

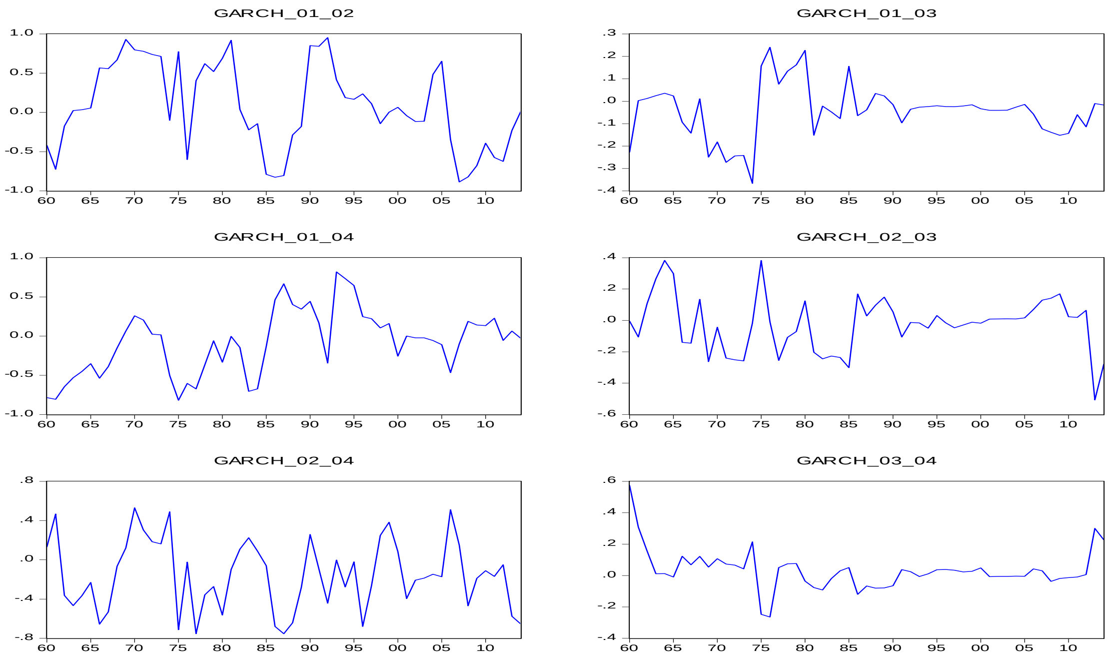
Results from VECH model show that cross-volatility coefficients, $a_{ij}(i \neq j)$ in all four variables are significantly different from zero, and the degree of cross-volatility shocks pair-wise is the strongest between real effective exchange rate and inflation rate (2.7793) and the weakest between per capita income and the trade balance ratio to GDP (-0.1002). The own-volatility coefficients $b_{ij}(i = j)$ for the lagged conditional variance of all four variables are positive and statistically significant. These own-volatility spillovers effects vary from its lowest magnitude on the INF (0.287426) to the highest on Q (1.012437). Persistence to own shocks is greater by BEKK than VEC except for per capita income. Persistence to shocks from per capita income is ranked first, followed by shocks from inflation to per capita income.

The conditional standard deviations of the series are used to distinguish between periods of low and high volatility regimes (Supaat et al 2003). The standard deviation of REER and inflation, and TBR are dynamic reach the peak in 1993, 1998, and 2001 respectively while per capita income standard deviations shows upward trend.

Figure (1) reveals that all conditional correlations between pair of variables are dynamic and sometimes positive and sometimes negative. The means of the conditional correlations reported in Annex (3) are very low and fluctuating. The unconditional correlation between REER and INF is 15% and not significant, the conditional correlation is dynamic oscillating between -0.88 and 0.95; that is the most volatile.

There is insignificant negative correlation between REER and Q -22%, the conditional correlation was oscillating between -0.36 and 0.24; i.e. the least volatile showing downward trend for the first 15 years, then upward for the next five years, and flat for rest of the period. The unconditional correlation between REER and TBR is low and insignificant 19% while the conditional correlation is oscillating between -0.82 and 0.82; the second highly volatile, and showing upward trend. The unconditional correlation between INF and Q is -34% and significant, the conditional correlation was oscillating between -0.51 and 0.38; the third least volatile. The unconditional correlation between INF and TBR is -56% and significant, the conditional correlation was oscillating between -0.75 and 0.53; the third highly volatile. The unconditional correlation between Q and TBR is 23% and significant, the conditional correlation was oscillating between -0.26 and 0.57; the second least volatile.

Figure (1) Conditional Correlations



5.2 Discussion

The evolution of the nominal exchange rate has the biggest effects on the movement real, effective nominal and effective real exchange rates. Concerning the real effective exchange rate, the other two components i.e. trade weights and relative prices have fewer effects on its movement. Since the exports are mainly raw material and primary products, the Sudan has little power to impose its terms and set the appropriate prices, the change in foreign trade composition due to economic policies reduced the growth of domestic production, in addition to the adverse effects of economic sanctions. Imports on the other hand satisfy the growing demand for consumer goods and raw material for manufacturing sector. The main trade partners are Europe, Arab countries and China. Europe has the highest difference in means according to the quality and political matters they impose (Arabi 2011), The Heckscher-Ohlin theory explains inter-industry, instead of intra-industry, highlighting competitiveness rather than complementarity between Sudan and Arab countries (Arabi and Ibrahim (2012). China imports raw materials from Sudan with low prices and exports finished goods with higher prices the trade balance is in favour of china. The third component is the relative prices, where domestic inflation has upward trend. Thus the conditional correlation is of great importance. The impact of own shocks is greater than shocks come from other variables suggesting stronger influence on its future volatility than those from other three variables. Depreciating the nominal exchange accompanied with restraining wage, and formulating appropriate fiscal and monetary policies fosters economic growth recommended by Eichengreen (2007), bearing in mind that J-curve hypothesis has not been proven in Sudan economy so the government should seek formulating an appropriate economic policies.

6. Conclusion

The purpose of this paper is to analyze shock transmission and subsequently the conditional correlation between four economic variables that is real effective exchange rate, inflation rate, per capita income, and ratio of trade balance to GDP bases on multivariate GARCH model. Mean equation and variance-covariance coefficients are statistically different from zero. Variance-covariance results emphasize the role of own shocks. The standard deviations of real effective exchange rate and inflation, and trade balance ratio to GDP are dynamic reach the peak in 1993, 1998, and 2001 respectively while per capita income standard deviations shows upward trend. Results reveal that own-shocks i.e. lagged values have strong influence on future volatility, per capita income showed the strongest persistence to shock decay; finally conditional correlations are low and fluctuating.

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Annex

Annex (1) Unit Root Test Results (ADF-GLS)

	ADF		PP		KPSS	
	Constant	Trend and Constant	constant	Trend and Constant	Constant	Trend and Constant
REER	-4.47***	-4.60***	-4.54***	-4.65***	0.21	0.11
Δ(REER)					0.19	0.12*
INF	1.70	1.60	2.33	-10.23***	0.22	0.15*
Δ(INF)	10.53***	10.47***	2.31	-10.18***	0.09	
Q	1.55	-6.55***	1.55	0.79	0.48**	0.25**
Δ(Q)	0.43	-5.50***	-6.56***	-7.21***		
TBR	-4.33***	-4.31***	-4.32***	-4.31***	0.24	0.16
Δ(TBR)					0.50*	0.50***

*, **, *** denote rejection of the Null hypothesis at 10%, 5%, and 1% Significance Level

Annex (2) Cointegration Results

Date: 07/29/16 Time: 16:14				
Sample: 1960 2014				
Included observations: 55				
Trend assumption: Linear deterministic trend				
Series: REER INF Q TBR				
Lags interval (in first differences): 1 to 1				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.59846	87.53375	47.85613	0.0000
At most 1 *	0.39643	37.34909	29.79707	0.0056
At most 2	0.137934	9.579961	15.49471	0.3144
At most 3	0.025429	1.416702	3.841466	0.2339
Trace test indicates 2 cointegrating equation(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Annex (3) Conditional Correlations

	REER_INF	REER_Q	REER_TBR	INF_Q	INF_TBR	Q_TBR
Mean	0.083142	-0.04408	-0.07958	-0.02402	-0.15545	0.03317
Median	0.033353	-0.02678	-0.03019	-0.01114	-0.16874	0.024207
Maximum	0.952797	0.240232	0.81913	0.382253	0.529723	0.5749
Minimum	-0.88723	-0.36648	-0.81841	-0.5066	-0.75415	-0.26413
Std. Dev.	0.547092	0.119067	0.408105	0.174737	0.354214	0.125638
Skewness	-0.0798	-0.08333	0.048789	-0.0594	0.079465	1.453529
Kurtosis	1.89666	3.645599	2.436662	3.337921	2.161277	8.734383
Jarque-Bera	2.84815	1.018815	0.749079	0.294029	1.66997	94.72408
Probability	0.240731	0.600851	0.687606	0.863281	0.433881	0
Sum	4.572814	-2.42416	-4.37715	-1.32133	-8.5498	1.824354
Sum Sq. Dev.	16.16271	0.765558	8.993672	1.648784	6.775246	0.852386
Observations	55	55	55	55	55	55

Annex (4) Nominal Exchange Rate Movements 1978 - 1994

Month/Year	Official	Devaluation rate	Free	Devaluation rate	free/Official	Duration
Sep-78	0.5	43%	0.8	129%	160%	
Mar-83	1.3	160%	1.8	125%	138%	54
Oct-84	1.3 y	0%	2.1	17%	162%	18
Feb-85	2.5	92%	3.03	44%	121%	4
Mar-86	2.5	0%	4.1	35%	164%	12
Oct-87	4.5	80%	12.3	200%	273%	18
Oct-91	15.1	236%	30.3	146%	201%	12
Feb-92	90	496%	90	197%	100%	4
Dec-92	216	140%	333	270%	154%	22
Mar-94	216	0%	404	21%	187%	17

Source: Arabi (2012) Volatility of Exchange Rate IJEF

Figure (2) Growth Rates of Nominal, Nominal Effective and Real Exchange Rate

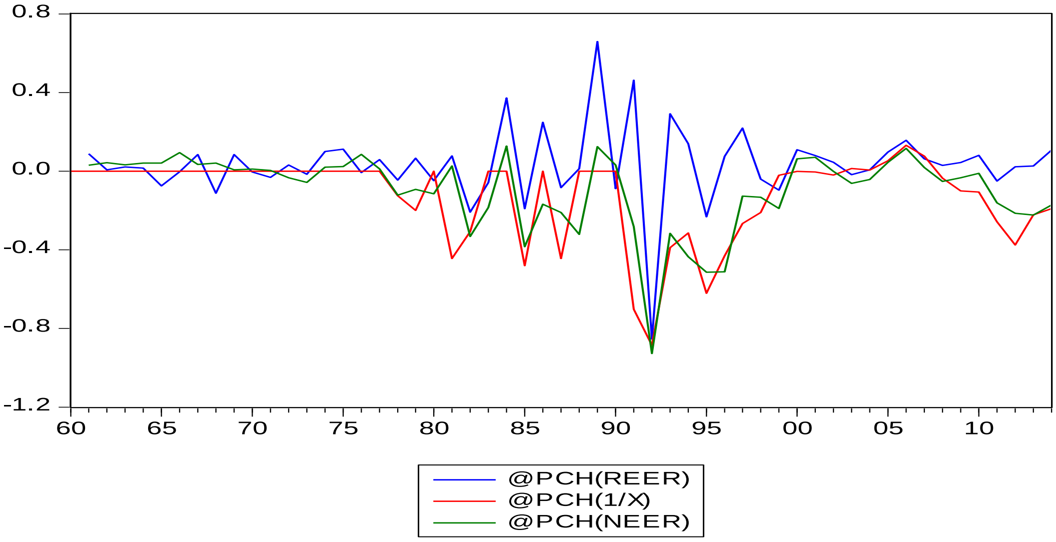

Figure (1) reveals that the real effective exchange rate was the most volatile compared to the nominal and nominal effective exchange rate.

Annex (5)

System: SYS_REER				
Estimation Method: ARCH Maximum Likelihood (Marquardt)				
Covariance specification: Diagonal VECH				
Date: 08/08/16 Time: 16:05				
Sample: 1960 2014				
Included observations: 55				
Total system (balanced) observations 220				
Bollerslev-Wooldridge robust standard errors & covariance				
Presample covariance: backcast (parameter =0.2)				
Convergence achieved after 122 iterations				
	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	3.678815	0.532028	6.9147	0
C(2)	3.852488	0.430961	8.939292	0
C(3)	16.14357	3.324734	4.855599	0
C(4)	-0.00821	0.003292	-2.49495	0.0126
Variance Equation Coefficients				
C(5)	0.000509	0.000274	1.861199	0.0627
C(6)	1.461786	0.291336	5.017533	0.0000
C(7)	1.901328	0.343358	5.537458	0.0000
C(8)	-0.17047	0.091389	-1.86535	0.0621
C(9)	0.587749	0.108654	5.409353	0.0000
C(10)	0.683642	0.018214	37.53333	0.0000
C(11)	0.536121	0.103766	5.166625	0.0000
C(12)	1.006199	0.025088	40.10708	0.0000

C(13)	0.718105	0.084098	8.538862	0.0000
Log likelihood	-661.861	Schwarz criterion		25.01486
Avg. log likelihood	-3.00846	Hannan-Quinn criterion		24.72387
Akaike info criterion	24.5404			
Equation: D(REER) = C(1)				
R-squared	-0.0009	Mean dependent var		2.329091
Adjusted R-squared	-0.0009	S.D. dependent var		45.42385
S.E. of regression	45.44427	Sum squared resid		111519.8
Durbin-Watson stat	2.573721			
Equation: D(INF) = C(2)				
R-squared	-0.02929	Mean dependent var		0.476364
Adjusted R-squared	-0.02929	S.D. dependent var		19.90832
S.E. of regression	20.19779	Sum squared resid		22029.33
Durbin-Watson stat	2.628508			
Equation: D(Q) = C(3)				
R-squared	-0.07954	Mean dependent var		7.68336
Adjusted R-squared	-0.07954	S.D. dependent var		30.27424
S.E. of regression	31.45521	Sum squared resid		53429.23
Durbin-Watson stat	1.651375			
Equation: D(TBR) = C(4)				
R-squared	-0.01371	Mean dependent var		-0.003040
Adjusted R-squared	-0.01371	S.D. dependent var		0.044583
S.E. of regression	0.044888	Sum squared resid		0.108806
Durbin-Watson stat	1.951851			
Covariance specification: Diagonal VECH				
GARCH = M + A1.*RESID(-1)*RESID(-1)' + B1.*GARCH(-1)				
M is a scalar				
A1 is a rank one matrix				
B1 is a rank one matrix				
Transformed Variance Coefficients				
	Coefficient	Std. Error	z-Statistic	Prob.
M	0.000509	0.000274	1.861199	0.0627
A1(1,1)	2.136819	0.851741	2.508767	0.0121
A1(1,2)	2.779335	1.031459	2.694568	0.0070
A1(1,3)	-0.249200	0.137177	-1.8166	0.0693
A1(1,4)	0.859164	0.320615	2.679737	0.0074
A1(2,2)	3.615049	1.305671	2.768729	0.0056
A1(2,3)	-0.324130	0.185767	-1.74479	0.0810
A1(2,4)	1.117504	0.393801	2.83774	0.0045
A1(3,3)	0.029061	0.031159	0.932675	0.3510
A1(3,4)	-0.100200	0.053439	-1.87494	0.0608
A1(4,4)	0.345449	0.127723	2.704676	0.0068

B1(1,1)	0.467366	0.024904	18.76666	0.0000
B1(1,2)	0.366515	0.066906	5.478025	0.0000
B1(1,3)	0.687880	0.024299	28.30925	0.0000
B1(1,4)	0.490927	0.065187	7.531085	0.0000
B1(2,2)	0.287426	0.111262	2.583313	0.0098
B1(2,3)	0.539444	0.111404	4.842256	0.0000
B1(2,4)	0.384991	0.068883	5.589044	0.0000
B1(3,3)	1.012437	0.050487	20.05354	0.0000
B1(3,4)	0.722557	0.08745	8.262515	0.0000
B1(4,4)	0.515675	0.120783	4.269431	0.0000

Annex (6) Estimation Results

System: SYS_REER				
Estimation Method: ARCH Maximum Likelihood (Marquardt)				
Covariance specification: Diagonal BEKK				
Date: 07/29/16 Time: 12:59				
Sample: 1960 2014				
Included observations: 55				
Total system (balanced) observations 220				
Bollerslev-Wooldridge robust standard errors & covariance				
Presample covariance: backcast (parameter =0.2)				
Convergence achieved after 122 iterations				
	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	3.678815	0.532028	6.9147	0.0000
C(2)	3.852488	0.430961	8.939292	0.0000
C(3)	16.14357	3.324734	4.855599	0.0000
C(4)	-0.00821	0.003292	-2.49495	0.0126
Variance Equation Coefficients				
C(5)	0.000509	0.000274	1.861199	0.0627
C(6)	1.461786	0.291336	5.017533	0.0000
C(7)	1.901328	0.343358	5.537458	0.0000
C(8)	-0.17047	0.091389	-1.86535	0.0621
C(9)	0.587749	0.108654	5.409353	0.0000
C(10)	0.683642	0.018214	37.53333	0.0000
C(11)	0.536121	0.103766	5.166625	0.0000
C(12)	1.006199	0.025088	40.10708	0.0000
C(13)	0.718105	0.084098	8.538862	0.0000
Log likelihood	-661.861	Schwarz criterion		25.01486
Avg. log likelihood	-3.00846	Hannan-Quinn criterion.		24.72387
Akaike info criterion	24.5404			
Equation: D(REER) = C(1)				
R-squared	-0.0009	Mean dependent var		2.329091

Adjusted R-squared	-0.0009	S.D. dependent var		45.42385
S.E. of regression	45.44427	Sum squared resid		111519.8
Durbin-Watson stat	2.573721			
Equation: D(INF) = C(2)				
R-squared	-0.02929	Mean dependent var		0.476364
Adjusted R-squared	-0.02929	S.D. dependent var		19.90832
S.E. of regression	20.19779	Sum squared resid		22029.33
Durbin-Watson stat	2.628508			
Equation: D(Q) = C(3)				
R-squared	-0.07954	Mean dependent var		7.68336
Adjusted R-squared	-0.07954	S.D. dependent var		30.27424
S.E. of regression	31.45521	Sum squared resid		53429.23
Durbin-Watson stat	1.651375			
Equation: D(TBR) = C(4)				
R-squared	-0.01371	Mean dependent var		-0.00304
Adjusted R-squared	-0.01371	S.D. dependent var		0.044583
S.E. of regression	0.044888	Sum squared resid		0.108806
Durbin-Watson stat	1.951851			
Covariance specification: Diagonal BEKK				
GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1				
M is a scalar				
A1 is a diagonal matrix				
B1 is a diagonal matrix				
Transformed Variance Coefficients				
	Coefficient	Std. Error	z-Statistic	Prob.
M	0.000509	0.000274	1.861199	0.0627
A1(1,1)	1.461786	0.291336	5.017533	0.0000
A1(2,2)	1.901328	0.343358	5.537458	0.0000
A1(3,3)	-0.17047	0.091389	-1.86535	0.0621
A1(4,4)	0.587749	0.108654	5.409353	0.0000
B1(1,1)	0.683642	0.018214	37.53333	0.0000
B1(2,2)	0.536121	0.103766	5.166625	0.0000
B1(3,3)	1.006199	0.025088	40.10708	0.0000
B1(4,4)	0.718105	0.084098	8.538862	0.0000