FIW – Working Paper

FIW Working Paper N° 71
September 2011

Exploring oil price – exchange rate nexus for Nigeria

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JEL: F31, E44
Keywords: Exchange rate, oil price, Nigeria, GARCH/EGARCH

The authors

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1. Introduction

Since the first oil price shock of 1973, a large volume of literature has extensively documented the relationship between oil price and the macroeconomy. Hamilton (1983) influential seminal first identified a relationship between oil price changes and variations in macroeconomic variables. Since then other researchers have used different data sets and estimation procedure to examine the oil price macroeconomy relationship. Krugman (1983) and Golub (1983) first developed theoretical models which noted the potential importance of oil prices for exchange rate movements. There are now several empirical efforts geared towards discerning the influence of oil prices on exchange rate movements. The largest part of this literature has however concentrated on understanding the sources of real exchange rate fluctuations in developed countries and evidence on the behaviour of less developed economies is limited (Coleman et al, 2011).

The Nigerian economy is also highly vulnerable to oil price fluctuations. According to Energy Information administration (2010), Nigeria has an estimated 37.2 billion barrels of proven oil reserves and depends on the oil sector for over 95 percent of export and foreign exchange earnings and about 65 percent of government revenues. Nigeria is affected by both oil price declines and oil price increases. Being a net oil exporter, high oil prices constitute an opportunity for Nigeria to earn more oil revenue and achieve high growth rate although there is the risk of exchange rate appreciation. Nigeria's oil and gas wealth has been linked with the increasing volatility in its exchange rate as well as Nigeria's chronic tendency towards exchange rate over valuation (Rosemary et al, 2006)

Over the past five decades, exchange rate arrangements in Nigeria has experienced different regimes, from a fixed regime at independence in 1960 to a pegged arrangement in the 1970s and early 1980s and to various variants of the floating regimes[2] since the IMF inspired structural adjustment programme of 1986 when the determination of the Naira- the Nigerian currency- was made to reflect market forces (Sanusi, 2004; Mordi, 2006 and CBN). Nigeria operates a floating exchange rate regime since the market was liberalised in 2002[3] with the reintroduction of the Dutch Auction System (DAS). In 2006, DAS was replaced with the Whole sale Dutch auction system (WDAS) which has enhanced professionalism in dealings, narrowing premium and has succeeded in conserving foreign reserves[4].

A significant number of studies have looked at the relationship between oil price and selected macro economic variables (including exchange rates) in Nigeria (see e.g Olomola and Adejumo, 2006; Akpan,2009; Aliyu, 2009;Aliyu,2011;Mahmoud,2009 and Chukwu, 2011). However there are limited studies that have looked exclusively at the oil price exchange rate nexus .Olomola and Adejumo (2006) observed that oil price shocks have led to appreciation of the exchange rate in Nigeria. Of recent, Iwayemi

[2] Autonomous foreign exchange market (AFEM) in 1995 and Interbank Foreign exchange market(IFEM) IFEM in 1999

[3] In an attempt to narrow the gap between the official and parallel market rates and evolve a realistic exchange rate thereby conserving foreign exchange the Dutch Auction System (DAS) which was discontinued in 1990 and was reintroduced in 2002

[4] See Sanni(2006) and Akanni (2006)

and Fawowe (2010) established that while oil price shocks did not have a major impact on real exchange rate, negative oil price shocks significantly affects real exchange rate. Adeniyi (2011) carries out similar work[5] but our study depart from his work and we consider a larger time frame and also employ the GARCH/EGARCH-in-mean for our estimations.

There are different types of empirical methods that have been employed to examine the oil price exchange rate dynamics in the literature i.e Vector autoregressive models, cointegration and Causality[6] and the generalised autoregressive conditional heteroscedasticity (GARCH) and exponential GARCH (EGARCH) framework[7].

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[5] This study differs from the previous studies on the Nigerian economy in terms of approach by employing GARCH class models. Adeniyi (2011) used daily observations from January 2, 2009 to September 28, 2010 to investigate the oil price exchange rate dynamics in Nigeria. The author found that doubling oil prices resulted in exchange rate depreciation in both the GARCH and EGARCH models. His study did not cover the oil price fluctuations that occurred in 2008 when oil price rose to an all time high of $148 per barrel in July of 2008 before collapsing as low $31 per barrel by December of the same year.

[6] Extensive work can be seen in Korhonen and Juurikkala (2009), Chen and Chen (2007), Chaudhuri and Daniel (1998), Aleisa and Dibooglu (2002), Nikbakht (2010), Huang and Guo (2007) and Coleman (2011),

[7] Prominent work can be seen in Narayan et al (2008), Ghosh (2010) and Adeniyi (2011)

Killian and Vigfusson (2009) demonstrated that that widely used asymmetric vector autoregressive models of the transmission of energy price shocks are misspecified, resulting in inconsistent parameter estimates. They noted that the Vector autoregressive (VAR) models which have shaped discussions of the effects of oil price on macroeconomic aggregates have exaggerated the quantitative importance of energy price shocks as the implied impulse responses have been routinely computed incorrectly. The largest part of the literature quantifying the asymmetric effects of oil price shocks are based on the "censored oil price VAR methodology" that has been proved to be invalid (Killian and Vigfusson, 2011)

We aim to contribute to the literature on the Nigerian economy by examining the symmetric and asymmetric effects of oil price shocks on nominal exchange rates in Nigeria. Despite the significant number of studies on the Nigerian economy. There are still analytical and methodological gaps that exist in the literature on the Nigerian economy. In order to investigate the potential linkages between recent oil price changes and exchange rate in Nigeria, we estimate the generalised autoregressive conditional heteroscedasticity (GARCH) and exponential GARCH (EGARCH) models using daily data for the time span January 2, 2007 – December 31, 2010.

The rest of the paper is organized as follows. Section 2 describes the econometric methodology employed and also provides the data analysis. The statistical results are presented and evaluated in section 3 and section 4 provides the conclusion.

2. Methodology, Data and their Properties

The Generalised Autoregressive Conditional Heteroscedasticity (GARCH) and Exponential GARCH (EGARCH) models are used to estimate the relationship between recent oil price changes and exchange rates. Bolerslev (1986) introduced the GARCH model by extending Engles(1982) framework and have been popular since the early 1990s .Daily nominal return on exchange rate is denoted $grex_t$, while the daily nominal returns on oil price is denoted $groilt_t$.

The Daily returns were computed as follows:

$$grex_t = \log(er_t/er_{t-1}) \quad (1)$$

$$groil_t = \log(brent_t/brent_{t-1}) \quad (2)$$

Where $grex_t$ are the daily returns on exchange rate, er_t represents naira-dollar exchange rate for period's t and er_{t-1} is the lag of naira-dollar exchange rate. For the nominal oil returns, $groil_t$, represents the daily returns on oil price, $brent_t$ is the daily spot price for brent crude for the periods t and $brent_{t-1}$ is the lag of the daily spot price for brent crude.

The specification of the GARCH (1, 1) takes the form:

$$grex_t = a + \zeta\, groil_t + \upsilon_t, \quad \upsilon_t \sim N(0,\delta^2) \quad (3)$$

$$h_t = \alpha_0 + \alpha_1 \upsilon^2_{t-1} + \beta\, h_{t-1}$$

The mean equation is a function of a constant, one regressor and an error term. Where υ_t is white noise $(0, \delta^2_t)$. The variance equation for GARCH (1, 1) is written as a function of a constant term, the ARCH term which captures news about volatility from the previous period measured as the lag of squared residuals from the mean equation and the last period forecast period. The coefficients a_1 and β are positive to ensure the conditional variance h_t is always positive(Roman, 2010). The non- negativity restrictions are needed to guarantee that $h_t > 0$ in all periods and the upper bound $\alpha+\beta<1$ is needed inorder to make the h_t stationary and therefore the unconditional variance finite(Soderlind,2011). Due to persistent volatility of many financial time series the condition $\alpha + \beta <1$ may not be met but a unity sum of both α_i and β_j leading to the integrated GARCH (IGARCH). However even if a GARCH is not covariance stationary, Nelson (1990), Bougerol and Picard (1992) and Lumsdaine (1991) in Wang (2003) observed that standard asymptotically based inference procedures are generally valid.

This study also considers an alternative GARCH equation, the (GARCH-M) GARCH-in-mean by incorporating the conditional variance in to the mean equation and it takes the following form

$$grex_t = \alpha + \zeta \, groil_t + \lambda h_t + \upsilon_t \qquad (5)$$

Higher order GARCH (q,p) can be estimated with the variance equation taking the form:

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} \qquad (6)$$

Nelson (1991) first proposed the Exponential GARCH or EGARCH model due to the percieved problems with standard GARCH (p,q) model. The EGARCH captures asymmetric responses of the time varying variance to shocks[8]. The representation of the EGARCH variance takes the form:

[8] It also ensures that the variance is positive

$$\ln(\sigma_t^2) = \alpha_0 + \phi \ln(\sigma_{t-1}^2) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \chi \left[\frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}} \right] \quad (7)$$

Where α_0, ϕ, γ and χ are the parameters to be estimated. The left hand side is the log of the conditional variance, thus the leverage effect is exponential as opposed to quadratic with the estimates of the conditional variance guaranteed to be non negative[9]. As discussed by Wang etal (2011), the EGARCH benefits from the non negativity constraint which Nelson viewed as too restrictive in linear GARCH model which requires all the explanatory variables in a GARCH to be positive. α_0 denotes the mean of the volatility equation, ϕ represents the size effects which indicate how much volatility increases regardless of the shock direction. The estimate of χ is used to evaluate the perspective of shocks. The absolute value of $\chi < 1$ ensures stationarity and ergodicity for EGARCH (P,Q).

γ is the asymmetric response parameter[10], it is the sign effect which determines whether shocks give rise to higher volatility than negative shock or vice versa. As observed by Soderlind(2011),the EGARCH (exponential GARCH) is an asymmetric model, the $|u_{t-1}|$ term is symmetric(both positive and negative values of μ_{t-1} affect the volatility in the

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9 Being written in terms of log make $h_t > 0$ hold without any restrictions on the parameters

10 Wang(2003) observed that in contrast to standard GARCH model where shocks of the same magnitude(positive or negative) have the same effect on future volatility, in the EGARCH model γ is expected to be positive in most cases such that a negative shock increases volatility and while a positive shock eases uncertainty

same way). The linear term in μ_{t-1} modifies this to make the effect asymmetric. If $\gamma<0$, then the volatility increases more in response to a negative μ_{t-1} than to a positive μ_{t-1}

To estimate generalised autoregressive conditional heteroscedasticity (GARCH) and exponential GARCH (EGARCH) models, we use daily data for the period January 2, 2007 to December 31, 2010. Oil price data are the daily Brent spot price collected from U.S energy departments Energy Information Administration (EIA) website, the daily naira-dollar exchange rate was obtained from DataStream international database. We follow the procedures of Narayan et al (2008) and Ghosh, (2010) and employ nominal data for our analysis as we do not require real values to discern daily behaviour of oil price and exchange rate.

The analysis of the daily series begins with examining the descriptive statistics of the variables as well the integrational properties of our variables. From the table, it is clear that the Jarque-Bera test decisively rejects the null hypothesis of normal distribution at the 1% significance level. The returns on exchange rate indicate positive skewness. Kurtosis indicates that the distribution of both return series is peaked (leptokurtic) relative to normal.

INSERT TABLE 1 HERE

Figure 1 and 2 below present the graphical representation of returns on exchange rate and oil price. We can clearly observe volatility pooling in both series and it seems to be more dominant in the returns to oil price. Figure 3 presents the quantile –quantile plot showing both return series share similar distributions. The higher volatility clustering of the returns on oil price is also indicated in the standard deviations reported in figure 4. We next verify the integrational properties of our variables.

INSERT FIGURE 1 AND 2 HERE

INSERT FIGURE 3 AND 4 HERE

Table 2 presents results on the level of integrations of our variables using the Augmented Dickey Fuller (ADF) and the Phillips Perron (PP) method. We include both (i) an intercept and (ii) an intercept and trend in the estimation. From the table, we can observe that the results indicate that all our variables are stationary at levels and we are able to reject the null hypothesis of unit root in the variables irrespective of whether we use a trend or intercept in the regression.

INSERT TABLE 2 HERE

3. Empirical Results

We start by estimating equation (3) using the ordinary least square (OLS) technique. From table 3, we can observe that coefficient of oil price return ($groil_{t}$) is not statistically significant and there is strong evidence of autoregressive conditional heteroscedasticity (ARCH) in the residuals clearly indicating the need for respecification of the model. We therefore estimate the GARCH class models using maximum likelihood assuming normally distributed errors.

INSERT TABLE 3 HERE

The results of GARCH (1, 1) model in the third column of table 3 show that the coefficient of the lag conditional variance (β) and the lag squared residual (α_1) are positive and statistically significant. From the mean equation of the GARCH (1, 1) model, it is clear that $groil_t$ is statistically significant at the 1% level. A 10% increase in the oil price return leads to a 0.09% depreciation of the Nigerian currency vis-à-vis the US dollar. The residuals for the GARCH (1,1) model are white noise and there are no serial correlations in the residuals. According to the GARCH (1,1)-M equation in the fourth column of table 3 , the estimated parameter on mean equation has a positive sign but is not statistically significant suggesting that exchange rate volatility has no impact on exchange rate itself. Thus there are no feedbacks from the conditional variance to the conditional mean.

The fifth column from table 3 presents the results of the EGARCH (1,1) model. From the mean equation we can observe that the coefficients $groil_t$ is statistically significant at 1% level and a 10% increase in oil price returns leads to a 0.10% depreciation of the Nigerian currency-vis-à-vis US dollar. From the variance equation, the asymmetry term γ is statistically significant suggesting that Shocks to exchange rate have asymmetric effects with positive shocks giving rise to higher volatility (Narayan et al, 2008).In a nutshell, positive and negative shocks have different effects. χ which measures volatility persistence is positive and statistically significant. The coefficient is also close to 1 suggesting that shocks have permanent effect on exchange rate volatility. The mean equation of the EGARCH (1, 1)-M model in the sixth column of table 3 indicates that an increase in oil price has a negative impact on nominal exchange rate. Note that the variance term (GARCH) in the mean equation is significant. And finally the diagnostic tests, from table 3 we can observe that residuals for EGARCH and EGARCH –M models are free from serial correlations and ARCH effects.

4. Conclusion

This study explored the oil price exchange rate nexus for Nigeria. The study departs from other studies on the Nigerian economy by focusing exclusively on the relationship between the two variables using GARCH class of models. The main finding to come out from the analysis is that an increase in the oil price return led to the depreciation of the Nigerian currency via-a-vis US dollar during the study period. Despite being a net oil exporting economy, Nigeria is vulnerable to fluctuations in the international price of crude oil. This result has important policy implications for the country.

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Table 1: Descriptive statistics

	GREX	GROIL
Maximum	0.048415	0.181297
Minimum	-0.03174	-0.16832
Std. Dev.	0.005408	0.025869
Skewness	2.469465	0.050997
Kurtosis	28.03867	8.811666
Jarque-Bera	27328.65 (0.0)	1417.599(0.0)

Figures in brackets are probability values

Table 2: Unit root test

Augmented Dickey Fuller Test and Phillip perron

Variables	*ADF*		*PP*	
	(i)	*(ii)*	*(i)*	*(ii)*
grex	-34.73*	-34.73*	-34.64*	-34.64*
groil	-31.15*	-31.13*	-31.15*	-31.13*

*Note * indicates significance at the 1% levels*
(i) With an intercept (ii) with an intercept and trend

Table 3: Estimation results

Parameter/Model	OLS	GARCH(1,1)	GARCH(1,1)-M	EGARCH(1,1)	EGARCH(1,1)-M
I. Mean equation					
a	0.0001	-0.0001	-0.0001	-7.18E-05	-0.0001
	[0.98]	[-1.83]	[-1.92]**	[-1.69]***	[2.95]*
□	-0.007	-0.009	-0.009	-0.01	-0.01
	[-1.16]	[13.18]*	[-12.99]*	[-15.18]*	[-14.64]*
□	-	-	3.94	-	10.69
			[0.71]		[2.95]*
II. Variance equation					
a_0	**-**	1.78E-08	1.78 E-07	-0.75	-0.72
		[9.38]*	[9.36]*	[-16.39]*	[-14.36]*
a_1	**-**	0.33	0.32	-	-
		[14.25]*	[14.17]*		
β	**-**	0.73	0.74	-	-
		[60.68]*	[60.54]*		
□	**-**	-	-	0.46	0.46
				[22.37]*	[21.89*]
□	**-**	-	-	0.11	0.11
				[6.62]*	[6.69]*
□	**-**	-	-	0.96	0.96
				[276]*	[255.2]*
III. Diagnostics					
Q-statistics(6)	17.09	6.27	6.21	7.47	8.06
	(0.009)	(0.39)	(0.39)	(0.27)	(0.23)
Q-statistics(24)	52.17	21.76	20.67	15.43	24.32
	(0.00)	(0.59)	(0.65)	(0.21)	(0.44)
Q-statistics(36)	52.17	21.76	37.51	44.42	43.6
	(0.00)	(0.59)	(0.40)	(0.15)	(0.18)
ARCH-LM(6)	34.81	1.31	1.24	0.34	0.21
	(0.00)	(0.24)	(0.27)	(0.91)	(0.97)
ARCH-LM(24)	18.28	0.7	0.68	0.97	0.72
	(0.00)	(0.84)	(0.87)	(0.49)	(0.82)
ARCH-LM(36)	13.34	0.5	0.48	0.74	0.56
	(0.00)	(0.99)	(0.99)	(0.86)	(0.98)

Figures in [ ] and ( ) are the t statistics and probabilities respectively

,,*** denotes statistically significant at 1, 5 and 10% respectively*

Figure 1: Return on exchange rate

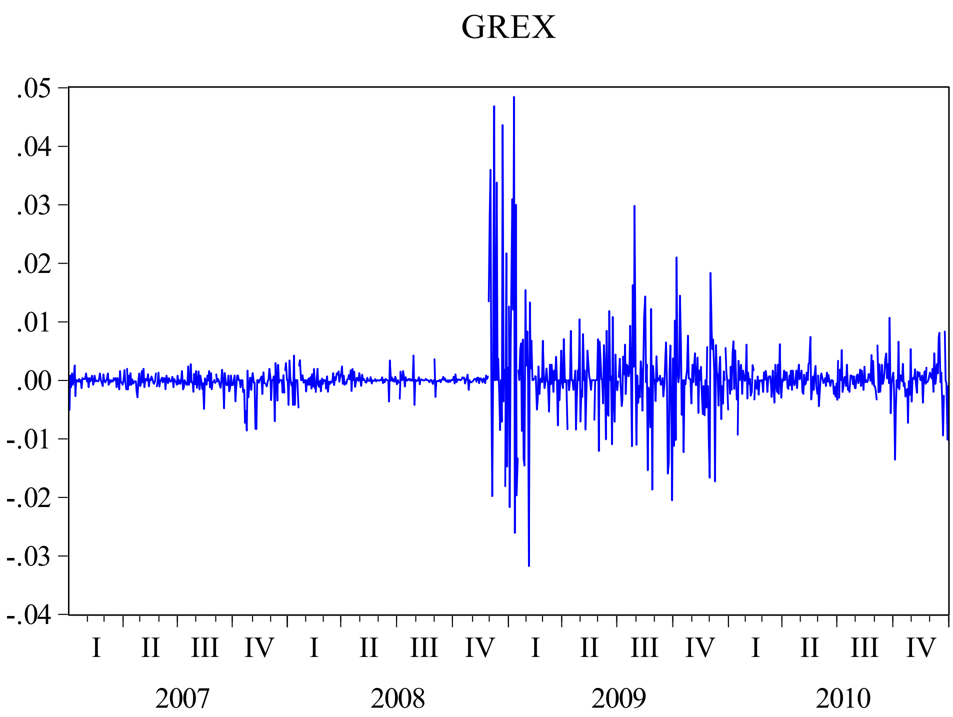


Figure 2: Return on oil price

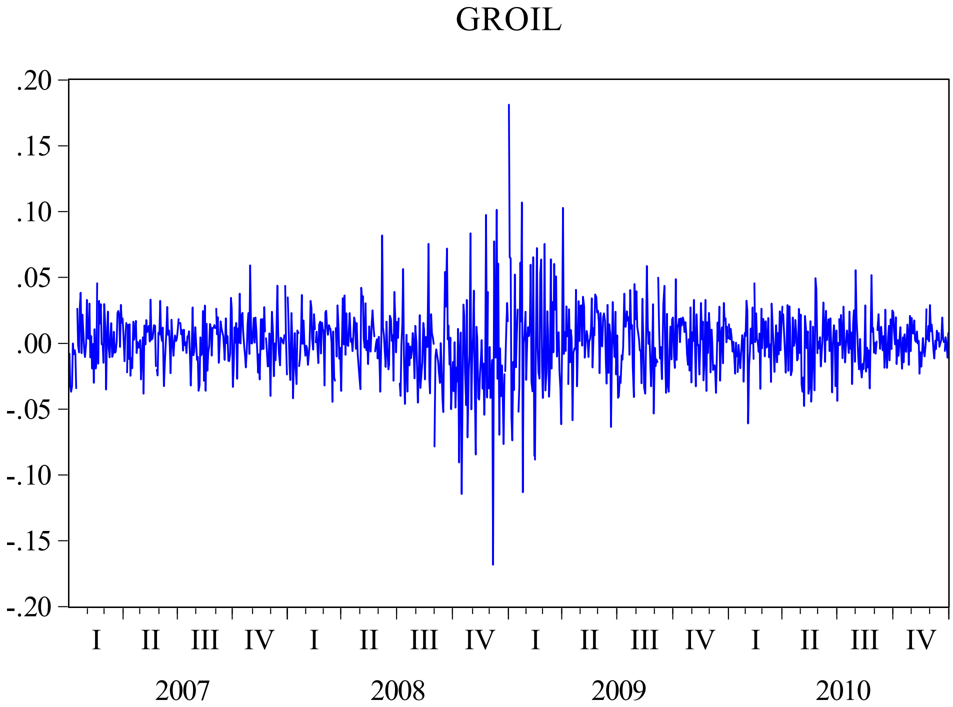


Figure 3: The quantile – quantile plot

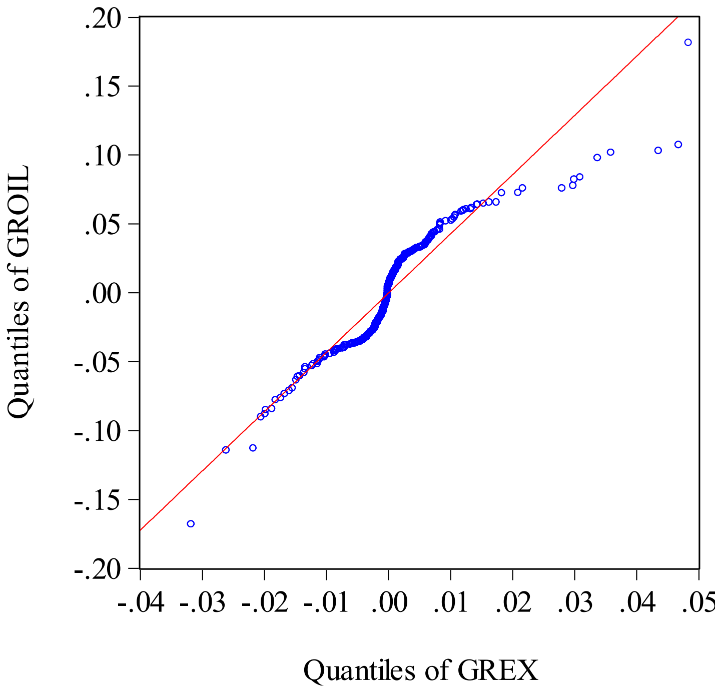
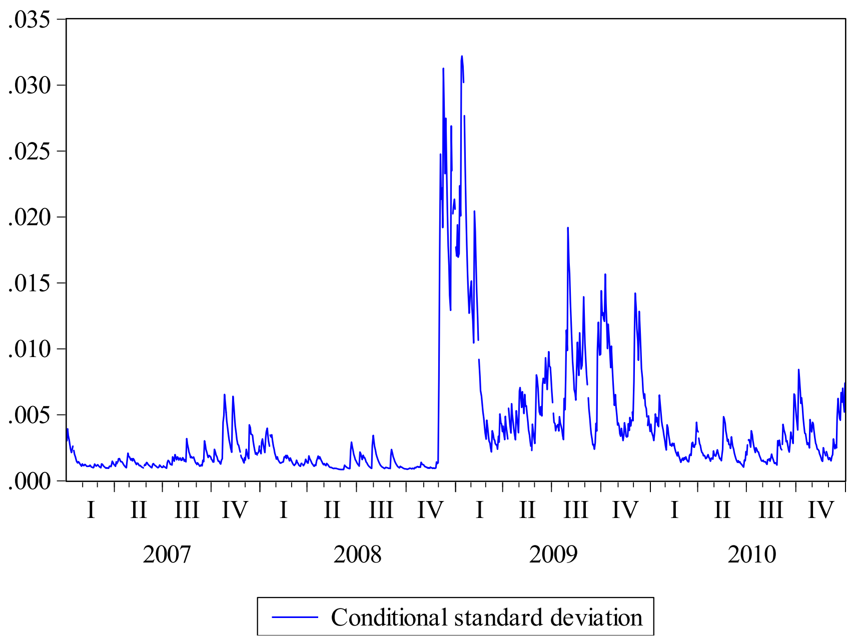


Figure 4: Conditional standard deviation

GARCH(1,1)-M



EGARCH(1,1)-M