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Volatility and asymmetry of the USD/GHS exchange rate: Monetary policy implications in Ghana

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Abstract

The paper examined the uncertainty and asymmetric effect of the dollar/cedi exchange rate using GARCH family models and the monetary policy implications of such uncertainties. The empirical results revealed that asymmetric and leverage effects were existent and persistent in the USD/GHS exchange rate such that negative news tends to exert a larger destabilizing effect on the volatility of exchange rate than positive news of the same magnitude. There is also a greater tendency for the volatility in domestic exchange rate to rise, largely driven by the continuous exchange rate depreciation. This study established that exchange rate volatility was remarkably restrained during the adoption of Heavily Indebted Poor Countries' Initiatives (HIPC) but has subsequently increased, following the adoption of inflation targeting (IT) in Ghana. The empirical results confirmed the effectiveness of interest rate (especially the interbank rate) in dampening the pass through of exchange rate volatility to inflation, albeit sluggishly, with a three-month policy transmission lag. The study therefore supports policy measures that rein in the rapid depreciation of domestic currency to help mitigate the upward bias in the volatility of USD/GHS exchange rate.

Keywords: *Exchange Rate Volatility, Asymmetric Effect, GARCH, TGARCH, EGARCH, Impulse Response.*

1. Introduction

Global trade and improvements in communications, payment systems and technology is such that no single country lives in isolation in this globalized world. The price of foreign currency (especially the US dollar, Ghana's major trade payments and intervention currency) in terms of domestic currency has critical implications on economic growth and development. Indeed, exchange rate volatility has long been a concern for academics and policy-makers, driven largely by the effect of the volatility on trade and growth (e.g, Aghion et al, 2006). In the same vein, it has been

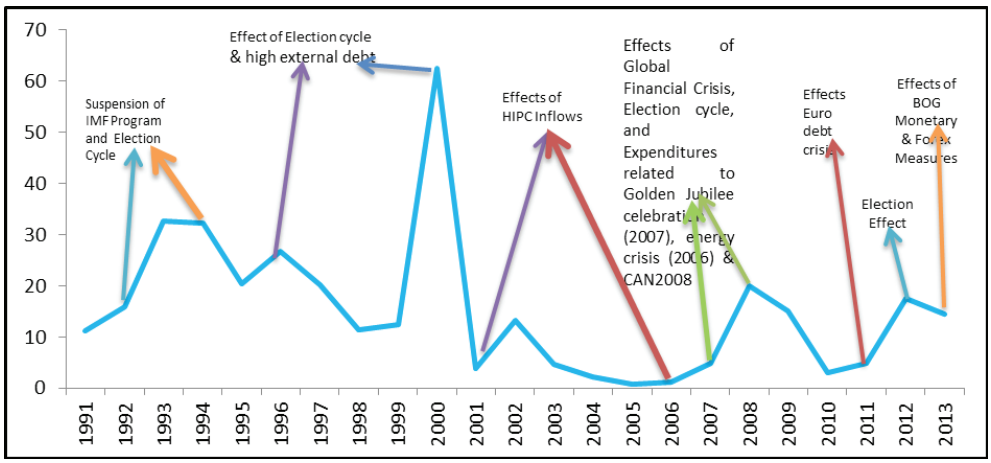
argued that uncertainty in the exchange rate always reflects the inconsistent behaviour of macroeconomic fundamentals (see, Yoon and Lee, 2008). Accordingly, Yoon et al (2008) articulated that the amplitude of exchange rate volatility generally shows the extent to which economic agents fail to discern the direction of actual or future volatility of the exchange rate, that is, the more forecast errors are made by economic agents, the higher the trends in the volatility of the exchange rate. Consequently, various economies have pursued different trade policies alongside institutional arrangements to ensure better stability in the foreign exchange rate in order to guarantee sustained economic growth and development. Even so, most policy-makers are enthusiastic in controlling the volatility in their exchange rate. This is evident from the International Monetary Fund's (IMF) de facto classification of exchange rate regimes which indicated that only 21% (40) of the 188 economies surveyed as at April 2008 allowed their exchange rate to independently float.

Among the reasons for the anxiety to control exchange rate volatility, Frankel (2005) shows that finance ministers are more likely to lose their jobs after excessive depreciation. Klein and Shambaugh (2008) also report that free floating regimes have significantly higher volatility than other regimes (see, Hasan and Wallace, 1996). However, findings of Rose (2007) reveal that countries with inflation targeting regimes tend to have lower exchange rate volatility than those that do not. Moreover, Bravo-Ortega and di Giovanni (2008) found higher exchange rate volatility for economies with lower openness to trade and lower per capita income.

The aversion to high exchange rate volatility is particularly evident in African economies as only two countries (namely Congo and Zambia) had independently floating exchange rate regimes while 17 countries (including Ghana) had managed floating regimes without a predetermined path for the exchange rate, according to the IMF's de facto classification of exchange rate regimes as at April 2008. In Ghana, the period preceding the adoption to Economic Recovery Programme (ERP) in 1983 was widely documented as characterized by widespread policy failures that resulted in massively overvalued exchange rate, among others, on the back of administrative controls of exchange rate alongside closed capital accounts. With the implementation of ERP in 1983, the government moved away from economic controls towards more liberal market-oriented policies that fundamentally turned the fortunes of the economy around. The approach to reform of the exchange rate system in Ghana was gradual, with an initial correction of the overvaluation through a series of large, discrete exchange rate adjustments (1983-86), accompanied by fiscal tightening. Afterwards, a foreign exchange auction market was established to allow the exchange rate to be market determined (in 1986). This was followed by licensing of foreign exchange bureaux (February 1988) and the establishment of a unified exchange rate system in 1987. Alongside these were other reforms that saw a gradual liberalization of the current and capital accounts. Although these reforms transformed the econo-

my remarkably, a key phenomenon of the Ghanaian economy was one of persistent exchange rate depreciation, which peaked at approximately 60% in 2000 amid high external debt (see Figure 1).

Figure 1: Year-on-year changes in nominal exchange rate (%, GHS/USD)

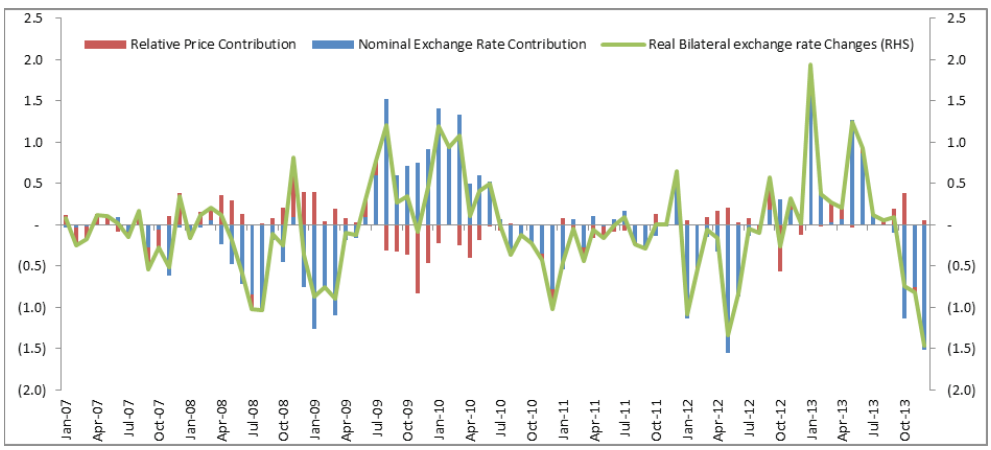


Source: *Research Department, Bank of Ghana (2014)*

Following the acute exchange rate depreciation exacerbated by rising external debt burden and an election cycle in 2000, Ghana shifted towards the implementation of a more liberalized foreign exchange and fully opened capital account regime, accompanied by the adoption of the Heavily Indebted Poor Countries' (HIPC) initiative in 2001. The multilateral debt relief and increased foreign exchange inflows that followed the adoption of HIPC together with the execution of prudent fiscal and monetary measures helped to stabilize the domestic currency between 2001 and 2006 (figure 1). During the period, monetary policy implementation shifted from monetary targeting to inflation targeting in 2002 with official announcement of the adoption of the latter in 2007. This set of policy mix placed Ghana among the few countries that permitted a more flexible exchange rate regime. However, this regime change has concomitantly been associated with rapid depreciation of the nominal exchange rate. The much expected appreciation of the domestic currency and the accompanying Dutch Disease (i.e. loss of international competitiveness of Ghanaian exports and the shifting of economic resources away from the other economic sectors into the oil sector) following the production and export of crude oil in 2011, did not happen. Instead, the currency has continued to depreciate against the US dollar (and the other major trading currencies), while the contribution of nominal currency depreciation to changes in real exchange rate has continued to outstrip[19] that of the relative price (see figure 2).

Like many developing economies, Ghana relies principally on a few primary export commodities (including cocoa, gold, timber and now oil) which are subject to the vagaries of international developments. The economy also depends strongly on high quality imports (capital and intermediate goods) to boost economic growth which has led the Ghanaian economy into persistent trade and current account deficits. In addition, capital flows in the economy are significantly influenced by development in the US economy. Indeed, some gains have been recorded following a slowdown in the US (or global) economy in terms of improved portfolio inflows, driven largely by the higher interest rate margin between Ghana and the US. However, this has, more often than not, been associated with weak international commodity demand and prices which adversely affects Ghana's foreign exchange receipts to finance the needed imports for economic growth, and hence, exacerbating pressures on the domestic currency.

Figure 2: Relative contribution to changes in real bilateral exchange rate (%)



Source: *Research Department, Bank of Ghana (2014)*

In particular, the global effect of developments in the US economy was evident following the recent tapering announcement (December 2013) of the Federal Reserve's stimulus package which sent shock waves across emerging and transition economies, including Ghana, in early 2014. By end-February 2014, the cedi had depreciated cumulatively by 12.8% against the US dollar compared with the depreciation of 0.3% during the same period in 2013 (Bank of Ghana, March 2014).

[19] *The depreciation has been linked to government expenditure especially during election cycles, changing import trade pattern towards the Far East (especially China) which is purely cash-based instead of letters of credit, seasonal factors that increased demand for foreign exchange (especially during the last quarter of the year), unexpected withdrawal of foreign investors by speculators, excess liquidity, among others.*

This culminated in the introduction of a number of macro-prudential measures by the central bank including 200 basis points increase in monetary policy rate (MPR) to 18% in February 2014. To address the demand pressures on the foreign exchange market, the central bank also re-introduced foreign exchange regulatory measures (see, Press Release of Bank of Ghana, February and June 2014). Furthermore, in a bid to address the liquidity overhang and supply of foreign exchange in the market, the central bank reduced the aggregate net open position limits of the commercial banks from 20% to 10% and increased the primary reserve requirement from 9% to 11% respectively in April 2014 (Reports of the 59th and 60th Monetary Policy Committee Meetings).

Notwithstanding these policy mixes, the cedi cumulatively depreciated by 29.5% from an average interbank rate of GH¢2.10 per US$1 as at end-December 2013 to GH¢2.98 per US$1 as at end-June 2014. This compares with a cumulative depreciation of 3.40% during the corresponding period of 2013 (see, Bank of Ghana website, June 2014). The pinnacle of the macroeconomic instability on the back of the rapid rate of depreciation in the domestic currency reflected government's upward revisions of targeted budget deficit from 8.5% to 8.8% of GDP and inflation target from 9±2% to 13.0±2% alongside a downward revision of projected real GDP growth from 8.0% to 7.1% for 2014 (Minister of Finance, Mid-Year Budget Review, July 2014). Not only has this resulted in considerable academic, political and international discourses, but has also culminated in a series of labour unrests, alluding to reasons including untold economic hardships emanating from the rapid depreciation of the domestic currency, rising inflation, among others. A survey conducted by the Association of Ghana Industries (AGI) shows an unprecedented loss of business confidence in the economy during the second quarter of 2014 (The Business and Financial Times, issued on August 6th-7th, 2014). According to the AGI survey, the business barometer which measures the level of confidence in the business environment worsened significantly from 90.13 in the first quarter of 2014 to an all time low of 22.42 at the end of second quarter of 2014. This decline in business confidence was largely attributed to the rapid depreciation in the domestic currency against the US dollar, while the recent Bank of Ghana's exchange rate measure was also cited among the top-five challenges faced by businesses (The Business and Financial Times, issued on August 6th-7th, 2014). In terms of the international landscape, Ghana's sovereign rating was downgraded in June 27th, 2014 by the rating agencies (including Moody's, Fitch and Standard & Poor) from B1 to B2 with a negative outlook, driven largely by deteriorating fiscal strength, increased vulnerability to both domestic and external shocks, and strong pressures on the Ghanaian cedi. Against this background, the government decided to seek assistance from the IMF in August, 2014 to restore macroeconomic stability (Bloomberg, August, 7th 2014 at www.bloomberg.com).

In view of the above deliberations, the fundamental issues that arise are:

- Whether asymmetric and leverage effects are existent in the volatility of the cedi/dollar exchange rate,
- If yes, which information (negative or positive) exerts the larger effect on exchange rate volatility in the case of Ghana?
- Has volatility of the exchange rate increased after the official adoption of an inflation targeting regime?
- Have monetary policy tools been effective in restraining the rate of depreciation in the domestic currency?

Against this background, the overall objective of this paper is to examine the dynamic behaviour of the domestic exchange rate against the US dollar and its monetary policy implications. In particular, the paper seeks to:

- Ascertain the existence of asymmetric and leverage effects in the volatility of exchange rate.
- Identify the relative impact of positive and negative developments in the US economy on the volatility of USD/GHS exchange rate.
- Identify the appropriate GARCH model that captures the dynamic behaviour of the exchange rate volatility.
- Investigate the effect of an inflation targeting regime on exchange rate volatility.
- Empirically examine the effectiveness of monetary policy in moderating the pass through effect of exchange rate volatility on inflation.

As a net importer with a persistent trade deficit, the study expects asymmetric information (or leverage effect) in the volatility of exchange rate to be existent in the case of Ghana. In particular, international events that cause depreciation in the domestic currency are expected to increase the volatility in the domestic exchange rate than a similar magnitude of events that appreciate the domestic currency.

Although the post-Bretton Woods' literature is replete with studies on volatility of exchange rates, it has focused more on developed countries. Studies on exchange rate volatility in less developed economies, especially sub-Saharan Africa (including Ghana), remain inadequate, despite the findings by Bleaney et al. (2007) that volatility in real effective exchange rates are particularly high in Sub-Saharan Africa. Some studies (such as Todani et al., 2005; Sekantsi, 2011; Olayungbo et al., 2011; Ekanayake et al., 2012; Mpofu, 2013; Chipili, 2013; Mlambo, 2013; Umaru et al. 2013; Mambo et al., 2013; etc.) on SSA economies have focused on macroeconomic implications of real exchange rate volatility, while others (such as Arezki et al. 2012; Mengesha et al., 2013; etc.) have examined the determinants of exchange rate volatility. Likewise, the Ghanaian literature has largely focused on either the

determinants of exchange rate volatility (such as Kyereboah-Coleman et al., 2008[20]; Yemidi, 2010)[21] or the effect of exchange rate volatility on other macroeconomic variables (including Mensah et al., 2013)[22]. However, Appiah et al. (2011) forecast monthly exchange rate between Ghana cedi and US dollar using an ARIMA (1, 1, 1) model for the period January 1994 to December 2010. They found that the predicted rates were consistent with the depreciating trends of the observed series. Of significant exception is the study by Okyere et al. (2013) which modeled volatility of the daily cedi/dollar exchange rate from January 18th 2010 to February 25th 2012 using a GARCH model. They found weakly positive asymmetric effects and the volatility to be persistent.

Like Okyere et al (2013), this paper applies a number of GARCH family models to capture the uncertainty in the exchange rate. The rationale for a GARCH model is that past information of the exchange rate is able to impact on the future exchange rate movements. Besides, exchange rate is often considered to show a phenomenon of volatility cluster. In finance, as noted by Mandelbrot (1963), volatility clustering refers to the observation that large changes tend to be followed by large changes, of either sign, while small changes tend to be followed by small changes. The more appropriate technique to capture this dynamic behaviour of exchange rate volatility is the generalized autoregressive conditional heteroskedasticity (GARCH) model, espoused by Bollerslev (1986) and extended by Glosten, Jagannathan and Runke (1993) and Nelson (1991) to incorporate asymmetric effects in the volatility of exchange rate. However, this study differs from earlier works as it models the dynamic behaviour of exchange rate volatility using a more extensive dataset, spanning over 14 years alongside a robust econometric technique that utilizes all the assumptions to identify the model that best fits the Ghanaian dataset. Unlike other studies, the paper also expands the Ghanaian literature by empirically examining the effect of an inflation targeting regime on exchange rate volatility and the effectiveness of monetary policy in restraining the pass through of exchange rate volatility to inflation.

The study is structured as follows: the next section provides data characteristics and model specification, followed by the presentation of empirical results in section 3, while the final section provides the conclusion.

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[20] *Kyereboah-Coleman et al (2008) found exchange rate volatility to negatively affect foreign direct investment in Ghana.*

[21] *Yemidi (2010) examined the determinants of exchange rate behaviour in Ghana and found fluctuations in exchange rate to be driven largely by government expenditure.*

[22] *Mensah et al. (2013) found exchange volatility to adversely affect employment growth in the manufacturing sector in Ghana.*

2. Data and methodology

2.1. Data characteristics and preliminary results

The study mainly focuses on the volatility and asymmetry of the nominal Cedi exchange rate against the US dollar (units of US$ per one GH¢). By this conversion, an increase (positive) in the exchange rate implies an appreciation, while a decrease (negative) would connote depreciation in the domestic currency. The study used the monthly exchange rate dataset from the Bank of Ghana, spanning the period January 2000 - March 2014. To examine the stationarity of the time series prior to the econometric estimation, logarithm was first applied to the level variables and then both Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests for unit root were conducted.

Table 1 displays the results the unit roots from both ADF and PP tests. Both techniques fail to reject the null hypothesis that unit root is existent for the level variable of exchange rate. However, the first difference of the exchange rate series exhibits a stationary process as the null hypothesis is rejected at 1% significant level.

Table 1: Unit root tests for monthly dollar/cedi exchange rate

	ADF Test		Phillips-Perron Test	
	Level	First Difference	Level	First Difference
Monthly Cedi/Dollar Exchange Rate	-1.0155	-4.2101*	-1.2213	-4.0905*

Note: * denotes 1% significant level; the level variable included constant and trend but the difference variable included only the constant when carrying out the test.

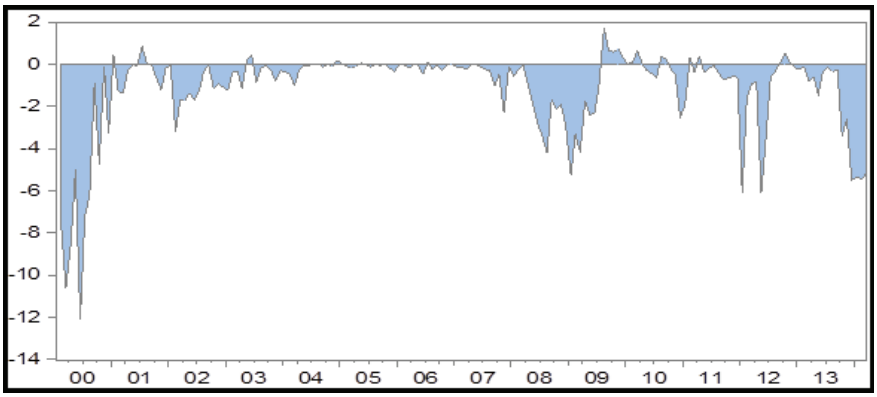
As a result, the paper defines returns on nominal exchange rate as the first order log difference as follows;

$$r_t = log\left(\frac{e_t}{e_{t-1}}\right) * 100$$

where is the unit of US dollar per one Ghana Cedi (that is, $e = USD/GHS$) .

In Figure 3, the returns in cedi/dollar exchange rate also illustrate a phenomenon of volatility clustering. In particular, the uncertainty in the domestic exchange rate reduced significantly amid inflows from the HIPC and the multilateral debt relief, but has increased remarkably following the official adoption of an inflation targeting regime in 2007, with its accompanying freely floating exchange rate regime.

Figure 3: Monthly returns of USD/GHS exchange rate



As a prerequisite, this paper performed normality tests to assess the suitability of fitting the data series with normal distribution assumption associated with GARCH models. The histogram (in figure 4) clearly demonstrates both patterns of leptokurtosis (highly peaked) and asymmetry (skewed to the left). This indicates a violation of normally distributed assumption of the returns, and hence, models that assume a normal distribution may not be appropriate to capture the dynamics of the cedi/dollar exchange rate. More importantly, the asymmetry to the left also connotes a higher tendency for the domestic currency to depreciate against the US dollar. In addition, the result from the analysis of variance in table 2 shows the presence of heteroskedasticity (non-constant variance) in the USD/GHS returns as the joint probability of the variance ratio test is statistically significant at 5% alpha level.

Figure 4: Histogram of monthly exchange rate returns (2000:01 -2014:03)

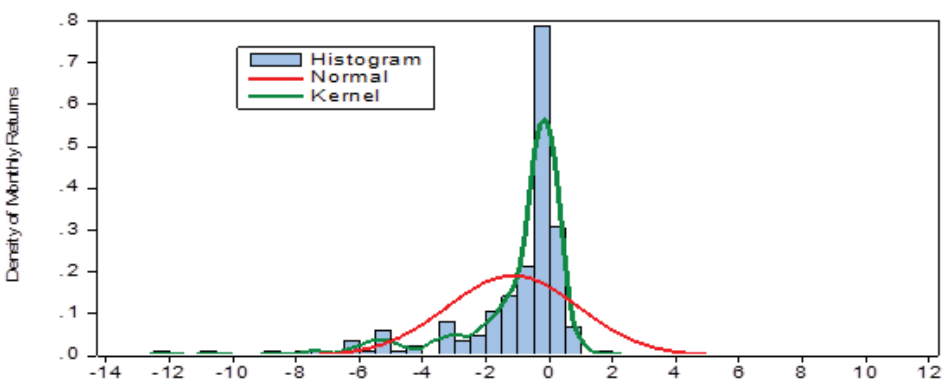


Table 2: Variance ratio test on USD/GHS returns

Null Hypothesis: Returns from USD/GHS are martingale				
Joint Tests		Value	df	Probability
Max |z| (at period 2)		2.82	169	0.02
Individual Tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.54	0.16	-2.82	0.01
4	0.36	0.29	-2.23	0.03
8	0.31	0.44	-1.58	0.06
16	0.20	0.57	-1.41	0.04

2.2. Volatility framework

In view of the episodes of heteroskedastic pattern of the datasets, the study mainly focuses on modelling the conditional variance of Ghana's nominal exchange rate using a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model developed by Bollerslev (1986). Like most financial and economic time series, the exchange rate exhibits periods of unusually high volatility followed by more tranquil periods of low volatility (see figure 3). In such case, it is clear that the assumption of constant variance (homoskedasticity) is very limiting but the more preferable approach is to examine the conditional variance which allows the variance to depend upon its history. In addition, the choice of a GARCH model was mainly due to the fact that it overcomes the need for long lag to improve the goodness of fit when the autoregressive conditional heteroskedasticity (ARCH) model is adopted. The GARCH model considers conditional variance to be a linear combination of past values of shocks captured by the lagged squared residual term and lagged values of conditional variance. However, this study also allows the condition mean to either depend on the conditional variance or not. Hence, by the parsimony principle, the study employed both the GARCH (1, 1) and GARCH-in-Mean (1, 1) which is summarized as follow:

$$y_t = \alpha + \beta' X_t + \mu_t \tag{1}$$

Or

$$y_t = \alpha + \beta' X_t + \tau\sqrt{\varphi_t^2} + \mu_t$$

$$\mu_t|\Omega_t \sim iid\ N(0, \varphi_t^2) \tag{1a}$$

$$\varphi_t^2 = \vartheta + \gamma\mu_{t-1}^2 + \rho\varphi_{t-1}^2 \tag{2}$$

Equation (1) is GARCH (1,1), while equation (2) is GARCH-in-mean (1,1) model which includes a conditional variance into the conditional mean equation due to the fact that investors are risk averse and therefore require higher premium as a compensation in order to hold a risky asset.

In equation (2), ϑ is a constant term; γ indicates news about volatility from the previous period, measured as the lag of the squared residual from the mean equation (μ_(t-1)^2; the ARCH term); while ρ captures the last period's forecast variance (φ_(t-1)^2; the GARCH term or conditional variance of μ_t). In addition, the GARCH model is stationary if ϑ>0, γ≥0, ρ≥0 (non-negativity assumption) and also the sum of the ARCH coefficient, γ, and the GARCH coefficient, ρ, is less than one and if it comes much closer to one, volatility shock will be much more stationary.

Although the GARCH model is able to capture the volatility clustering phenomenon, it has a major drawback because the conditional variance is only symmetric, that is, what matters in the GARCH model is only the absolute value of the shock and not its sign as the residual term is squared. Therefore, in the GARCH model a big negative shock will have exactly the same effect on the volatility as a big positive shock of the same magnitude. So, ARCH and GARCH models do not reflect leverage effects, a kind of asymmetric information effect that has greater impact on volatility when unexpected negative shock happens than unexpected positive shock of the same magnitude. This is usually noticed in the equities market as 'bad news' (or negative shock) has a larger impact on the volatility than 'goods news' (or positive shock) of the same magnitude. The notion of an asymmetry effect has its origin in the works of Black (1976), French, Schwert and Stambaugh (1987), Nelson (1991) and Schwert (1990).

As a result, the paper further applies the Threshold ARCH (TARCH) model introduced by Zakonian (1990) and Glosten, Jagannathan and Runkle (1993). The TARCH model (or GJR model) captures the asymmetry in information by simply adding into the variance equation a multiplicative dummy variable. The dummy variable checks whether there is statistically significant difference when shocks are negative. The specification of the conditional variance for a TARCH (1,1) model is given by:

$$\varphi_t^2 = \vartheta + \gamma\mu_{t-1}^2 + \lambda\mu_{t-1}^2 d_{t-1} + \rho\varphi_{t-1}^2 \qquad (3)$$

where $d_t = 1$ when $\mu_t < 0$ and $d_t = 0$ otherwise. That is, negative and positive shocks from abroad have different impacts. In this case, good news (in equation 3) has an impact and bad news has an impact of $\gamma + \lambda$. If $\lambda \neq 0$, (that is if λ is statistically significant), then the impact is asymmetric. Besides, if $\lambda > 0$ then there is a leverage effect such that negative developments (news) from abroad has larger impact on the volatility of exchange rate than positive news. On the contrary, if $\lambda < 0$, then positive developments (news) from abroad has a larger impact than negative developments (news) of the same magnitude. Moreover, the conditional variance is stationary when $\gamma + \rho + (\lambda / 2)$ is less than one.

Although the TARCH model is able to explain the asymmetry of the conditional

variance, it does not restrict the parameters to make variance non-negative (positive). For that reason, the study applies a third model called Exponential GARCH (EGARCH) model espoused by Nelson (1991). The EGARCH model is able to make the conditional variance non-negative regardless of the plus or minus sign of parameter in the model by applying logarithm φ_t^2 to the conditional variance equation. Contrary to the GARCH models, EGARCH model does not have to restrict the parameters to obtain stationary estimation. Like the TARCH model, the conditional variance in the EGARCH model is dependent on the sign and magnitude of the parameters. The specification of the conditional variance in the EGARCH (1,1) model is given by:

$$log(\varphi_t^2) = \vartheta + \gamma \left| \frac{\mu_{t-1}}{\sqrt{\varphi_{t-1}^2}} \right| + \lambda \frac{\mu_{t-1}}{\sqrt{\varphi_{t-1}^2}} + \rho log(\varphi_{t-1}^2) \quad (4)$$

In equation (4), application of logarithm is distinctive as it makes the leverage effect to be exponential instead of quadratic and hence, guarantees the estimates of the conditional variance to be non-negative. In particular, if the absolute value of ρ is less than one, $|\rho| < 1)$, the model is stationary. Also, ρ measures the persistence in conditional volatility irrespective of anything happening in the market. When ρ is relatively large, then volatility takes a long time to die out following a crisis in the market (see, Alexander, 2009). To test for asymmetry and whether it is existent or not, the parameter of importance is λ. If the null hypothesis, $H_0\, \lambda = 0$ is rejected in favour of the alternative hypothesis, H_1: $\lambda \neq 0$, then the model presumes the existence of asymmetry information. In particular, if $\lambda < 0$, then the leverage effect is considered to be existent such that positive shocks (good news) generate less volatility than negative shocks (bad news) of the same magnitude. However, if $\lambda > 0$, then positive shocks (good news) generate a more destabilizing effect on exchange rate than negative shocks (bad news) of the same magnitude.

Since the data series appears to violate the normal distribution assumption, the model framework in this study explored the three main underlying assumptions of normal distribution, student t-distribution and the generalized error distribution to examine the best fit. In addition, the effects of official adoption of inflation targeting regime (in 2007) and the HIPC era on exchange rate volatility were examined by augmenting the GARCH models with dummy variables that capture these two episodes. The periods when these policies occurred are assigned a value of one and zero, otherwise.

2.3. VAR Framework for monetary policy implications

As an inflation targeting central bank, exchange rate volatility remains a major concern to Bank of Ghana due to its potential impact on inflation, if left unattended. Consequently, the bank uses the tools at its disposal (especially the policy interest rate) to defend the set inflation target. This has however yielded mixed results as the

bank, more often than not, has recorded deviations from its inflation target, driving by fiscal and external factors that heightened the volatility of domestic exchange rate. As a result, the study would empirically analyze how volatility in exchange rate affects the effectiveness of monetary policy, and by so doing, investigate the potency of the latter in ensuring stability in the former. This was carried out by analyzing the impulse response and variance decomposition functions from a stationary five-variable VAR framework, using the Choleski ordering:

$$\Gamma = \{\text{XVOL, DMPR DINT, DTBILL, DINF}\} \quad (5)$$

where XVOL denotes conditional exchange rate volatility computed from EGARCH (1, 1) model; DMPR is change in monetary policy rate; DINT is change in interbank rate; DTBILL is change in 91-day interest rate; and DINF is a change in general price level.

In this case, a shock to any one of the variables in the VAR affects not only the variable itself, but is also transmitted to other endogenous variables through a dynamic lag structure of the VAR. In effect, the paper assumes initial exogenous shock to exchange rate volatility which contemporaneously affects other variables in the system. Accordingly, impulse response function was used to specifically trace out the direction of the dynamic responses of variables to these shocks, while variance decomposition technique was used to track the relative importance of each random shock to the endogenous variables in the VAR. Both methods were carried out using Cholesky decomposition and standard errors generated from Monte Carlos simulations with 10,000 iterations for 12 periods.

3. Empirical results

3.1. Asymmetric and leverage effects

Table 3 reports both the likelihood values and various information criteria for the alternative GARCH model and the respective distribution assumption that best fit the volatility of the USD/GHS exchange rate. Consistent with figure 4, the assumption of normal distribution was generally not appropriate for the data series as the log likelihood ratio improved with relatively minimum information loss when alternative assumptions such as student t-distribution and generalized error distribution were applied. Likewise, asymmetric effect appeared to be existent as the likelihood ratios and information criteria were relatively better when TGARCH (1, 1) and EGARCH (1, 1) models were used to fit the data. On the whole, EGARCH (1, 1) model with student t-distribution appropriately fit the distribution of the error terms as both the likelihood value and information criteria were most favourable than that of other models.

Table 3: Model selection criterion for monthly returns

	GARCH (1, 1)			TGARCH (1, 1)			EGARCH (1, 1)		
	Normality Assumption	Student t-Distribution	Generalised Error Distribution	Normality Assumption	Student t-Distribution	Generalised Error Distribution	Normality Assumption	Student t-Distribution	Generalised Error Distribution
Log likelihood Value	-258.161	*-194.752*	-201.292	-250.933	*-192.440*	-199.947	-229.600	***-188.322***	-191.219
Akaike info criterion	3.114	*2.376*	2.453	3.041	*2.360*	2.449	2.788	***2.311***	2.346
Schwarz criterion	3.207	*2.487*	2.564	3.152	*2.490*	2.579	2.899	***2.441***	2.475
Hannan-Quinn criterion	3.152	*2.421*	2.498	3.086	*2.413*	2.502	2.833	***2.364***	2.398

Consequently, the study reports the empirical results from EGARCH (1, 1) model in table 4. The estimation results revealed that news about volatility from the previous period (γ)and the last period's forecast variance (ρ) can significantly affect the uncertainty of exchange rate. The model satisfied the stationarity condition as the absolute value of is less than one, ($|\rho| < 1$) in all the estimation results. In addition, the relatively large value of the parameter ρ (above 0.8 in the model with student t-distribution assumption) suggests that exchange rate volatility is persistent for the sample period. Essentially, the parameter of interest, λ, assumed a significant negative sign, indicating the existence of asymmetric and leverage effects in exchange rate volatility. That is, uncertainty has grown higher in the case of unexpected negative shocks, such as depreciation, than the same magnitude of positive shocks (such as appreciation) during the sample period.

Table 4: EGARCH (1, 1) Estimates of conditional variance model for returns of USD/GHS exchange rate

	EGARCH (1, 1)								
	2000:01 - 2014:03			2000:01 - 2007:12			2008:01 - 2014:03		
	Normality Assumption	Student t-Distribution	Generalised Error Distribution	Normality Assumption	Student t-Distribution	Generalised Error Distribution	Normality Assumption	Student t-Distribution	Generalised Error Distribution
ϑ	0.1006*	-0.1085	-0.0595	-0.4097*	-0.3499**	-0.4441**	0.8460*	0.3786*	0.4241*
γ	-0.2266*	-0.1080	-0.2167	0.1264	0.2102	0.1925	-1.0899*	-0.7329*	-0.8986*
ρ	0.7932*	0.8989*	0.8748*	0.8611*	0.9292*	0.9050*	0.3673*	0.7983*	0.7845*
λ	-0.6413*	-0.7754*	-0.7845*	-0.6511*	-0.369	-0.489	-1.1638*	-0.9565*	-1.1361*
Log likelihood	***-229.600***	***-188.322***	***-191.219***	***-89.855***	***-73.442***	***-75.076***	***-107.281***	***-97.381***	***-97.698***

*Note: *, ** & *** denote 1%, 5% & 10% significant levels respectively.*

However, controlling for the effects of an inflation targeting regime, the adoption of HIPC and interest rates developments did not change the earlier findings, regarding the asymmetric and the persistent nature of the domestic exchange rate. As exhibited in table 5, the coefficient of the IT dummy is positive and significant, suggesting that the inflation targeting regime has significantly increased volatility in the USD/GHS exchange rate and hence contradicts the assertion by Rose (2007). On the other hand, the results confirmed that inflows from HIPC initiatives significantly dampened the volatility (or depreciation) of the domestic exchange rate.

Table 5: EGARCH (1, 1) estimates showing the influence of monetary and fiscal policies on the volatility of USD/GHS exchange rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ϑ	-0.0784	0.2418*	0.0117	-0.0671	-0.1233	-0.0863	0.0259	-0.2712*	-0.0884	-0.0350	0.0992*
γ	-0.2911	-0.6501*	-0.2440	-0.2423	-0.1080	-0.1170	-0.3059***	0.1142	-0.1674	-0.2115	-0.3864**
ρ	0.8654*	0.9383*	0.8835*	0.8799*	0.8823*	0.8971*	0.8748*	0.8973*	0.8756*	0.8630*	0.8640*
λ	-0.7898*	-0.9293*	-0.6392*	-0.8045*	-0.9385*	-0.6977*	-0.7137*	-0.7231*	-0.7359*	-0.6923*	-0.6992*
Inflation targeting	0.0826***										
HIPC Dummy		-0.1842*								-0.1216*	-0.0987**
MPR			0.3970*				0.5839*		0.6061*	0.5287*	0.5233*
Tbill				-0.0101			-0.0875**	0.13779*		0.0567	-0.0704**
Interbank					-0.0795***			-0.2384*	-0.1787*	-0.2308*	
Inflation						0.0583					
Log likelihood	***-189.04***	***-178.42***	***-183.58***	***-190.65***	***-186.66***	***-186.12***	***-182.04***	***-183.51***	***-179.47***	***-177.21***	***-179.66***

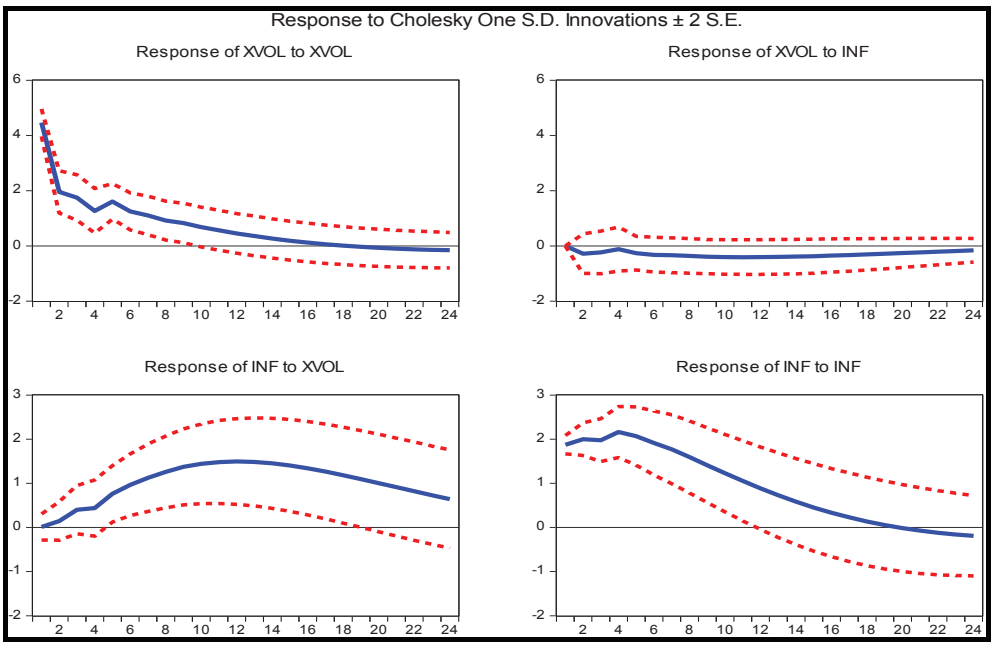
*Note: *, ** & *** denote 1%, 5% & 10% significant levels respectively.*

Furthermore, the increase in monetary policy rate contemporaneously raised the volatility of the domestic exchange rate, while the positive inflation effect on the latter was found to be muted (insignificant). Intuitively, the announcement of monetary policy rate hikes signifies higher inflationary expectation which tends to immediately feed into the asset pricing (exchange rate). On the other hand, the effect of increases in Treasury bill rate (the 91-Day bill) on exchange rate volatility was mixed, while that of interbank rate exhibited stable and a significant dampening (negative) effect on exchange rate volatility in Ghana. The results tend to support the notion that the effectiveness of monetary policy in dampening exchange rate volatility depends primarily on the speed of adjustment of the interbank rate to changes in the monetary policy rate.

Against this background, the paper further verified the robustness of the empirical results using both impulse response (bivariate and multivariate) and variance decom-

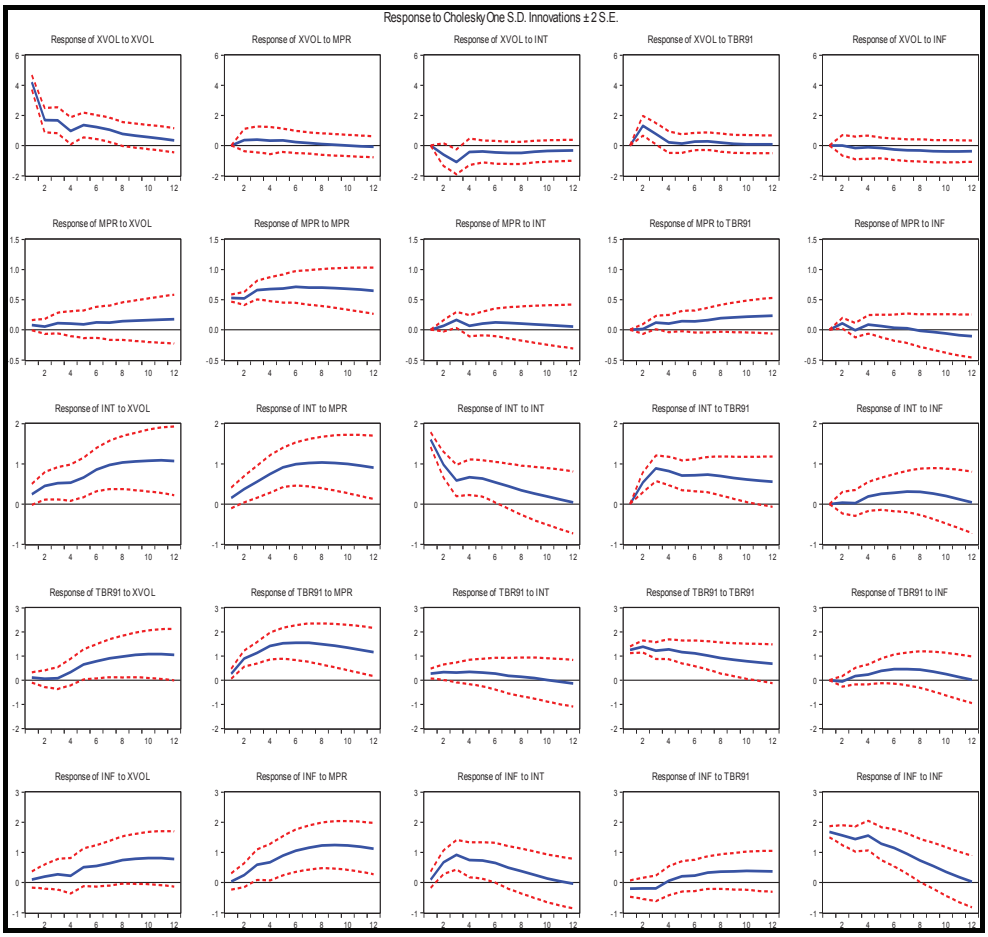
position functions to examine the dynamic link between exchange rate volatility and interest rate/inflation. The bivariate and multivariate impulse response functions are displayed in figures 5 and 6 respectively. Consistent with the earlier results (in table 5), the inflation effect on exchange rate volatility is insignificant, but the opposite effect shows that the impulse from the latter significantly leads to rising inflation after the 5th period and only tapers off after the 19th period (figure 5). This emphasizes the persistent effect of exchange rate volatility on inflation.

Figure 5: Impulse response functions of exchange rate volatility and inflation



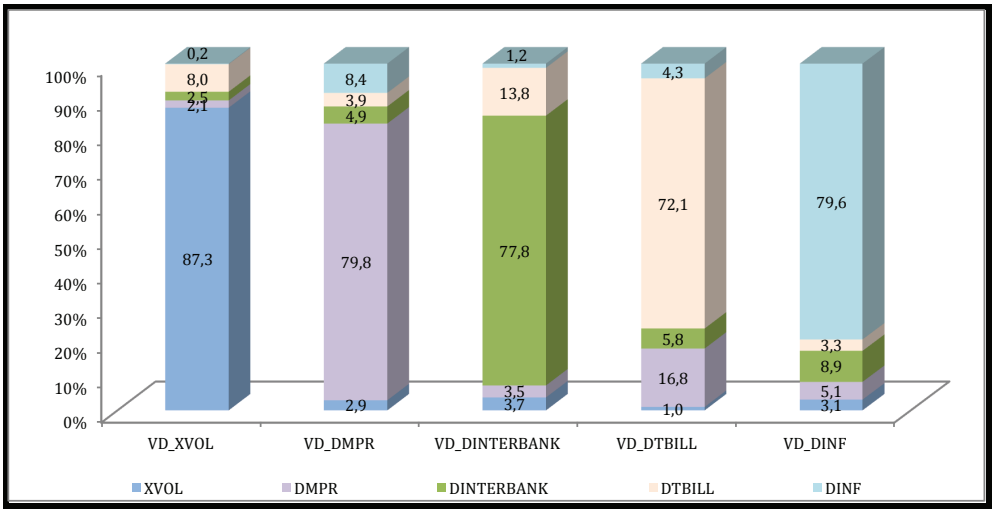
However, as exhibited in figure 6, the pass through effect of exchange rate volatility to inflation appears to be dampened (or insignificant) by the immediate monetary policy responses, especially the hike in policy rate (during the 1st period) and the resultant increase in interbank rate during the 2nd period (see column 1). Also, a noticeable positive response of 91-day Treasury bill to innovations in exchange rate volatility is observed after the 6th period. Consistent with the earlier results (in table 5), innovations from the 91-day Treasury bill increase the volatility in the domestic exchange rate during the first two periods (see row 1, column 4). This may be attributable to the increased government borrowing to meet its impending high expenditures. On the other hand, shocks from interbank rate restrain the volatility in the exchange rate during the 3rd period (see row 1, column 3) which also confirms the result in table 5. This suggests bidirectional causalities between exchange rate volatility and 91-day Treasury bill rate and between exchange rate volatility and interbank rate.

Figure 6: Impulse response functions for exchange rate volatility, interest rate & inflation



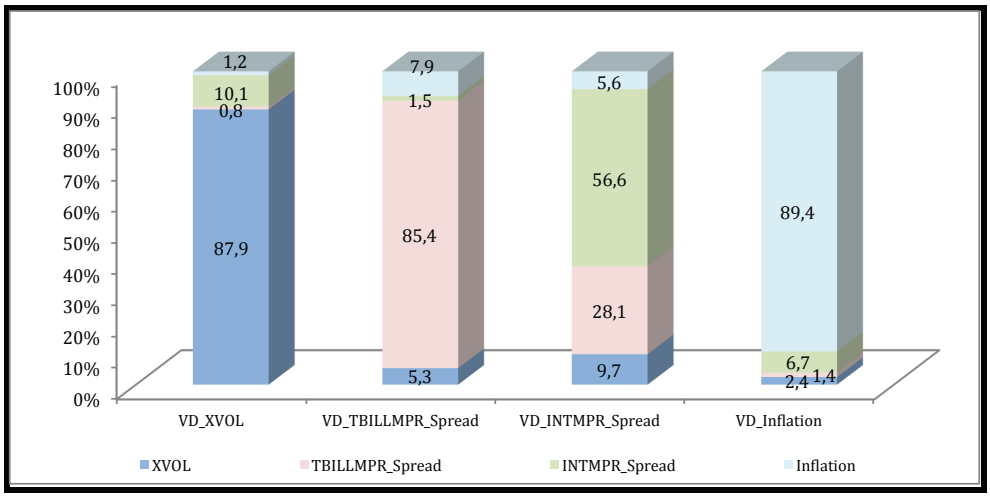
In addition, interbank rate was found to adjust at a relatively slower pace to innovations in the monetary policy rate (after 2nd period), compared to the spontaneous response of the 91-day Treasury bill rate (see row 3, column 2) to changes in the latter. However, the interbank rate tends to respond instantaneously to changes in the Treasury bill rate (see row 3, column 4). The delayed response of the interbank rate amid a more rapid response of the Treasury bill rate to changes in monetary policy rate largely underscores the immediate uptick in exchange rate volatility and the subsequent decline at the 3rd period. The empirical results also suggest that volatility in exchange rate dampens following the adjustment of interbank rate to changes in monetary policy rate, accentuating the crucial role of interbank rate in the monetary policy transmission mechanism.

Figure 7: Average variance decomposition of exchange rate volatility, interest rates and inflation for 12 periods



Besides, the results of the variance decomposition (in figure 7) also indicated that variation in exchange rate volatility is largely explained by itself (87.3%), while 8.0%, 2.5% and 2.1% are explained by changes in treasury bill, interbank and monetary policy rates respectively, with inflation absorbing the remaining 0.2%. While monetary policy rate accounted for 16.8% of the variations in Treasury bill rate, it explained only 3.5% of the changes in interbank rate. This compares with the relatively higher explanation of the Treasury bill rate (13.8%) to the changes in the interbank rate. The result suggests a comparatively higher impact of movements in Treasury bill rate on overnight dealings of commercial banks. Similar results were obtained from the analysis involving interest rate spreads in figure 8. While TBILLMPR_Spread (spread between Treasury bill and monetary policy rate) accounted for 28.1% of the variations in INTMPR_Spread (spread between interbank rate and monetary policy), only 1.5% was explained by the latter to changes in the former. In particular, the significant role of interbank rate in the monetary policy transmission mechanism was also demonstrated by the relatively higher explanation of INTMPR_Spread to the variations in exchange rate volatility and inflation, compared to the explanation from TBILLMPR_Spread. Although not reported here, the impulse response functions also showed a dampening effect of INTMPR_Spread on exchange rate volatility.

Figure 8: Average variance decomposition of exchange rate volatility, interest rate spread and inflation for 12 periods



4. Conclusion

The paper examined cedi/dollar exchange rate volatility and the effectiveness of monetary policy in dampening the pass through effect of the former to inflation using monthly time series from January 2000 to March 2014. The study employed GARCH family models as well as impulse response and variance decomposition functions from a stationary 5-variable VAR framework. The paper identified the following findings: Asymmetric and leverage effects of USD/GHS exchange rate were existent and also persistent for the sample period. Negative news, such as depreciation, tends to exert a much more destabilizing effect on the volatility of domestic exchange rate than positive news (that cause appreciation) of the same magnitude. There is also a greater tendency for the volatility in domestic exchange rate to rise, largely driven by the continuous exchange rate depreciation. Contrary to Rose (2007), exchange rate volatility in Ghana has rather increased, following the adoption of inflation targeting (IT), while the adoption of HIPC significantly moderated the former, as expected. In terms of model specification, EGARCH (1, 1) model with student t-distribution was appropriate for the monthly returns on USD/GHS exchange rate. Among the interest rate variables, the study found interbank rate as the key variable that restrains the volatility in the domestic exchange rate. Unlike the interbank rate which showed a consistent negative and significant effect on exchange rate volatility, the impact of Treasury bill rate was found to be mixed. However, the effectiveness of monetary policy in dampening the effect of exchange rate volatility depends on the speed of adjustment of interbank rates to changes in monetary policy rates. This adjustment is relatively sluggish when compared to that originating from Treasury bill rates, that

is, the efficacy of monetary policy rate in restraining the volatility in exchange rate is hampered by the slow response of the interbank rate to changes in policy rate. On the whole, the study established that monetary policy aimed at dampening exchange rate volatility has a 3-month transmission lag.

The authorities should design policies to mitigate exchange rate volatility, as increasing volatility can cause uncertainty in the domestic and foreign financial markets, and potentially trigger currency crises. In particular, policy direction should revamp the export sector by diversifying the export base through the promotion of new export products and processing of the existing products to add value before export. On the other hand, imports demand should emphasise strategically requisite intermediate and capital goods to facilitate production of manufactured goods for exports, while vigorously pursuing policies to curtail growth in importation of those consumption goods and services that can be produced domestically. These measures would help rake in more foreign exchange to mitigate the upward bias in the volatility of the exchange rate which is exacerbated largely by foreign exchange losses on the back of adverse terms of trade and capital outflows.

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