Modeling Price Volatility in Petroleum Products in Ghana*

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Abstract

The main purpose of this paper is to analyse and model the price volatility in petroleum products in Ghana. A historical data on monthly petroleum products (kerosene, gas oil, LPG and premium gasoline) spanning from August,2007 to February, 2016 were used in this study. The methods used were the trend analysis and Generalized Auto-Regression Conditional Heteroscedasticity (GARCH. The results of the analysis revealed that, there was an upward trend existing in all the petroleum products. This implies that the prices of petroleum products increase with time. Seven competing GARCH models were fitted to the returns of the petroleum products. Two models, GARCH (1, 1) and GARCH (1, 2), were considered as the best models by the information criteria. Based on predictive performance, GARCH (1, 2) model was considered as the best model for all the petroleum products. Also, the extent of volatility in the petroleum products, as measured by the coefficients of GARCH (1, 2), indicates volatility persistence (explosive process) and hence the model is adequate. The impacts of news on the petroleum products were tested and it was observed that there were no news impacts in the markets of the petroleum products.

Keywords: Price Volatility, GARCH, Explosive Process

1 Introduction

Energy usage pattern determines the foundation of the whole global economy. Any kind of physical production and transportation is completely impossible without energy. Even non-physical production (services) is unlikely to be performed without energy. Remarkably, engineers, physicists and historians often consider energy to be the primary factor to industrial and economic development. Since the start of the Industrial Revolution, economic growth has been largely synonymous with increasing energy use, generally at declining real prices (Noreng, 2007). The importance of energy is obvious but our understanding of its being volatile is not good enough.

Globally, consumption of petroleum products exceeds $500 billion and it is roughly 10% of the United States Gross Domestic Products (USGDP) (Roger, 1998). The subject of petroleum products prices has always been a contentious one. Ghana is not exempted from the problems of prices of petroleum products that is acceptable to the population and would not cripple the economy. This notion has influenced all pricing regimes for petroleum products and hence causing fluctuations in the pricing of petroleum products. Ghana suffers in decision making due to political crises and at a deficit in the balance of trade account which tends to weaken its currency. In 2015, the average price for Gasoline was about GH¢ 199.45 per barrel (Anon., 2015). This fluctuation in price also occurs in other products such as kerosene and Liquified Petroleum Gas (LPG). The trends in the fluctuations of petroleum products need to be addressed and urgent attentions should be drawn to cause stability of the economy of Ghana.

Fortunately, volatility measures the variability of the price series around its central mean. The main purpose of this paper is to analysis and model the volatility of petroleum products' prices (Kerosene, LPG, Gas Oil and Premium Gasoline) in Ghana.

2 Resources and Methods Used

2.1 Trend Analysis

Trend analysis is the process of comparing data over time to identify any consistent results or trends. It is also a statistical technique that uses historical results to predict future outcomes. It is based on the idea that what has happened in the past gives an idea of what is likely to happen in the future.

2.1.1Trend Equation

A simple trend line equation is given by:

$$y = \beta_0 + \beta_1 t \tag{1}$$

where β_0 is the y-intercept and β_1 is the slope with time.

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2.2 The GARCH Model

The GARCH Model is a Generalized Autoregressive Conditional Heteroscedasticity (GARCH) (Bollerslev, 1986) model used when considering the conditional variance. In that case the GARCH (p, q) model where q is the order of the GARCH terms σ^2 and p is the order of the ARCH terms ε^2 is given by:

$$\sigma_{\epsilon}^2 = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 \qquad (2)$$

where α_i -measures the extents to which volatility shocks today feeds through into next period volatility, $\alpha_i + \beta_j$ - measures the rate at which this effect dies over , ω -represent ambient volatility, and $\varepsilon_{t-i}^2 - \sigma_{t-j}^2$, the volatility shock.

3 Results and Discussion

3.1 Descriptive Statistics

A historical data on monthly petroleum products (kerosene, gas oil, LPG and premium gasoline) spanning from 2007 to 2015 were collected from Ghana National Petroleum Authority website (Anon.,2015). The prices of these petroleum products were transformed into returns in order to apply the methods stated, by taking the log difference of the previous price (p_{t-1}) from the current price (p_t).

3.1.1 Price and Return

Let p_t denote the current price of a stock and p_{t-1} denote the previous stock price. Then the return of "buying yesterday and selling today" (assuming no dividend) is given by:

$$r_t = \frac{p_t - p_{t-1}}{p_{t-1}} \approx \log(p_t) - \log(p_{t-1}) \qquad (3)$$

The approximation works well when r_t is close to zero.

Fig. 1 shows the change in price of petroleum products as time varies. Sometimes it was quite stable, sometimes it was intense, and large fluctuations are followed by large fluctuations indicating variation in variance.

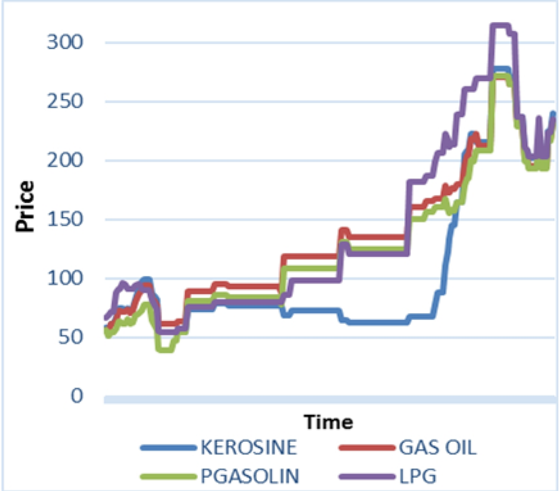


Fig. 1 Time Series Plot of Price of Petroleum Products

3.2 Test of Stationarity

In testing for stationarity in petroleum products, the Augmented Dickey-Fuller (ADF) and Phillips & Perron (PP) tests were used at 5% significance level. The null hypothesis states that all the returns of the petroleum products at all levels were not stationary against the alternate hypothesis. It was observed that all the returns of the petroleum products at all levels, were not stationary, hence the null hypothesis is accepted at levels. However, at first difference, all the returns have p-value of 0.00, which is less than 0.05, as shown in Table 1. Hence the null hypothesis of non-stationary is rejected. Therefore, the returns of the petroleum products are stationary after first difference.

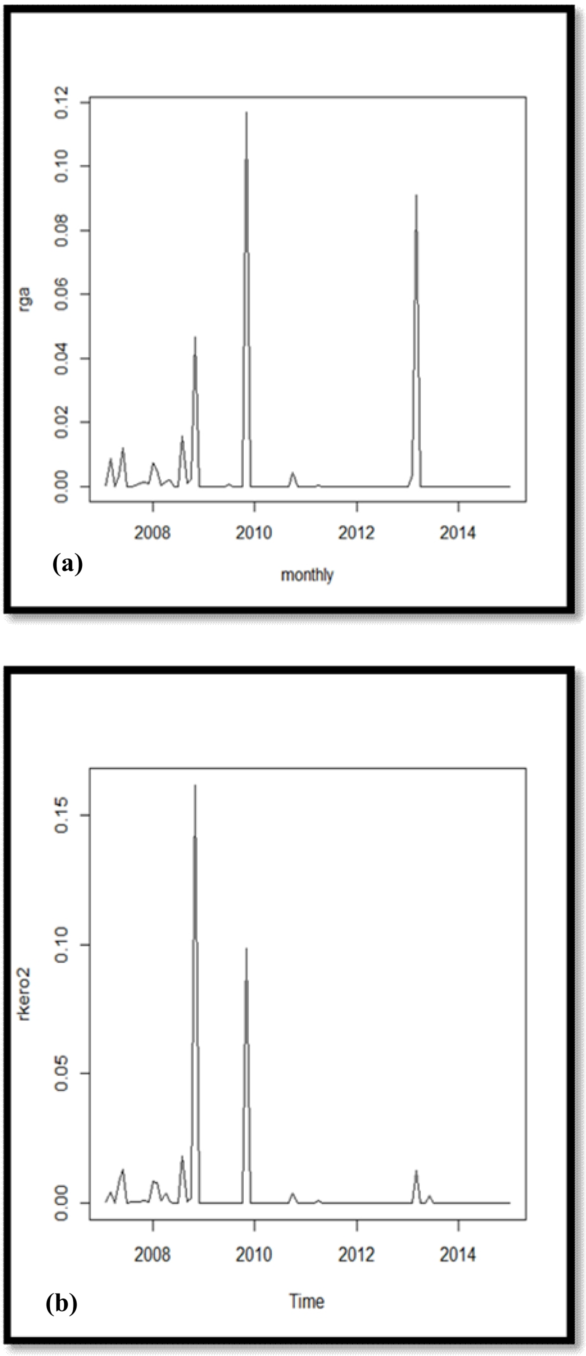
Table 1 ADF and PP Test for Stationarity

Returns	**ADF**	**PP Test**
Gas Oil	(-3.280) *0.0764	(-2.741) *0.2661
Premium Gasoline	(-3.214) *0.0875	-2.7291 *0.2712
LPG	(-2.601) *0.3249	-2.0026 *0.5751
Kerosene	-1.7458 *0.6283	-1.2251 *0.9001
First Difference		
Gas Oil	(-5.693) *0.0000	-13.5171 *0.0000
Premium Gasoline	(-5.184) *0.0000	-13.6410 *0.0000
LPG	(-5.188) *0.0000	-13.425 *0.0000
Kerosene	-4.6200 *0.0000	-12.0623 *0.0000

Statistic ( ) , p-value *

3.3 Measuring the Presence of Volatility

In measuring the presence of volatility in the petroleum products, the returns of the petroleum products against time were plotted. Fig. 2 indicates the presence of volatility in these petroleum products. Volatility clustering implies time varying conditional variance, showing that there are ARCH effects. This feature of time series with ARCH errors, the unconditional distribution of r_t being non-normal, is consistent with what was observed in the shock return series.



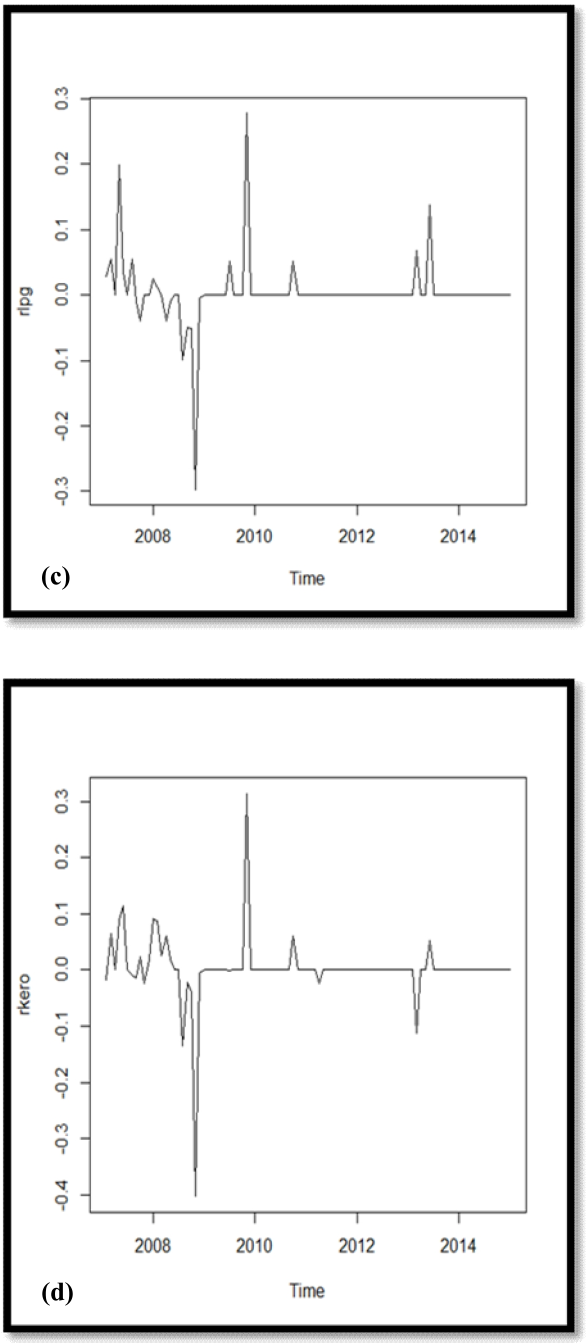


Fig. 2 Plot of Returns on Time/month for Petroleum Products

3.4 Test for the Presence of ARCH Effect

The hypothesis states that there is no ARCH effect (null) and there is an ARCH effect (alternative). The rejection of the null hypothesis of no ARCH effect indicates that the variance of the series varies over time. In Table 2 the test for the presence of ARCH effect confirms the presence of ARCH in all the petroleum products. This is because the p-values associated with the Lagrange Multiplier (LM) test are small, therefore the null hypothesis of no ARCH effect is rejected. The confirmation of the presence of ARCH effects in each case indicates that volatility in the prices of these petroleum products is time varying and hence the GARCH model can be applied.

Table 2 ARCH-LM Test Results

Petroleum Products	LM Test	P –Values
Gas Oil	3.3534	0.0000
LPG	2.7534	0.0000
Kerosene	4.0213	0.0000
Premium Gasoline	1.8724	0.0200

3.5 Model Selection

Seven competing Generalized Auto-Regression Conditional Heteroscedasticity (GARCH) models were fitted to the return data for each of the four petroleum products (kerosene, gas oil, premium gasoline and LPG) and four associated information criteria were recorded for each model. Standard practice shows that the model with the minimum information criterion is considered as the best model. Three information criteria (Akaike, Schwarz and Hannan-Quinn) indicated GARCH (1, 2) as the best model in all the returns of the petroleum products (kerosene, gas oil, premium gasoline and LPG) since they recorded the minimum values. However, the Bayesian Information Criterion suggested GARCH (1, 1) as the best model. The information criteria selected GARCH (1, 1) and GARCH (1, 2) as the best models. The data set from 2007-2013 was used to validate the model. It was then used to forecast for the 2017 and beyond. Based on predictive performance GARCH (1, 2) was the best model.

3.5.1 Model Estimation for petroleum products using GARCH (1, 2)

The extent of volatility in the petroleum products as measured by coefficients of the GARCH model in each of the petroleum products indicates persistence (explosive process) volatilities though there was indication of one coefficient being not 'significant. The GARCH model obtained for the petroleum products was adequate in predicting the prices for future returns and volatile.

The GARCH (1, 2) model for volatility in premium gasoline is given as;

$$\sigma_{\epsilon}^2 = 0.01 + 0.20\varepsilon_{t-1}^2 + 0.53\sigma_{t-1}^2 + 0.31\sigma_{t-2}^2 \quad (4)$$

The GARCH (1, 2) model for volatility in kerosene is given as:

$$\sigma_{\epsilon}^2 = 0.02 + 0.18\varepsilon_{t-1}^2 + 0.52\sigma_{t-1}^2 + 0.36\sigma_{t-2}^2 \quad (5)$$

The GARCH (1, 2) model for volatility in Gas Oil is given as;

$$\sigma_{\epsilon}^2 = 0.04 + 0.17\varepsilon_{t-1}^2 + 0.50\sigma_{t-1}^2 + 0.30\sigma_{t-2}^2 \quad (6)$$

The GARCH (1, 2) model for volatility in LPG is given as:

$$\sigma_{\epsilon}^2 = 0.03 + 0.21\varepsilon_{t-1}^2 + 0.60\sigma_{t-1}^2 + 0.36\sigma_{t-2}^2 \quad (7)$$

3.6 Diagnostic Test for GARCH Model (1,2)

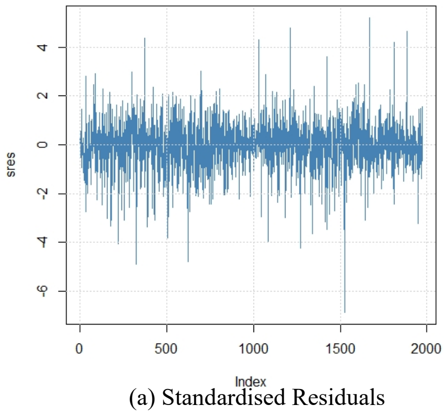
For normality, the Shapiro-Wilk Test at % level of significance was used. The hypothesis states that residuals are normally distributed null) and residuals are not normally distributed alternative). It was observed that the p-values for all the petroleum products were greater than 0.05, hence the null hypothesis is not rejected and therefore, residuals are normally distributed as shown in Table 3. For correlation on the standardized tests, the Ljung-Box Test was used. The hypothesis states that residuals are not correlated (null) and residuals are correlated (alternative). It was deduced that the p-values for all the petroleum products were greater than 0.05, hence the null hypothesis is not rejected and conclude that residuals are not correlated, as shown Table 3. Fig. 3 confirms that residuals are not correlated. This implies that the models are adequate and volatile for the petroleum products. For Leverage Effects on the returns of the petroleum, the Sign –Bias Test at 5% level of significance was used. The hypothesis states that there are no leverage effects on news (null) verses there are leverage effects on news (alternative). Since the p-values for all the petroleum products are greater than the 5% significance level, then we can conclude that, there was no leverage effects on news as shown in Table 4.

Table 3 Testing for Normality and Serial Correlation of Petroleum Products

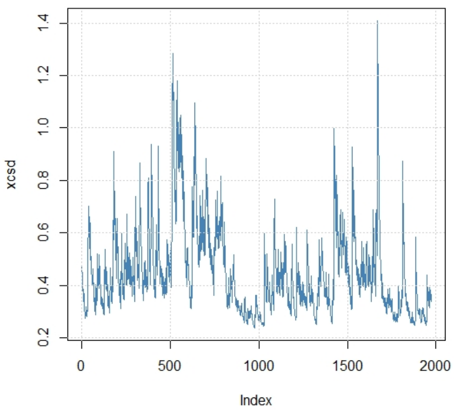
Petroleum Products	Shapiro-Wilk Test	Ljung-Box Test
Gas Oil	(0.962) *0.822	(18.820) *0.531
Kerosene	(0.961) *0.821	(18.810) *0.534
LPG	0.964 *0.824	(18.862) *0.523
Premium Gasoline	0.963 *0.823	(18.831) *0.533

Table 4 Leverage Effects on Petroleum Products (Sign Bias Test)

Sign Bias Test	Petroleum Products	T-Value	Prob. Sign
Sign Bias	Kerosene	0.3800	0.7100
	Gas Oil	0.2600	0.7100
	P. Gasoline	0.4000	0.6900
	LPG	0.6800	0.5000
NSB	Kerosene	0.1500	0.8800
	Gas Oil	1.2000	0.2600
	Premium Gasoline	1.2800	0.2000
	LPG	0.0300	1.0000
PSB	Kerosene	0.1600	0.8700
	Gas Oil	0.2200	0.8200
	Premium Gasoline	0.1800	0.8600
	LPG	0.1400	0.8900



(a) Standardised Residuals



(b) Conditional SD's

Fig.3 Serial Correlation on the Returns of Petroleum Products

4 Conclusions and Recommendation

There was an upward trend existing in all the petroleum products. This implies that as time varies upward the prices of the petroleum products increase. The extent of volatility in the petroleum products, as measured by coefficients of the best GARCH (1, 2) indicates persistence (explosive process) volatilities and hence the model was adequate, though there was one coefficient that was not significant. Also, there were no impacts of news on all the petroleum products from the sign bias test, hence there was no leverage effect in all petroleum products. It is recommended that, the best models obtained in this paper are adopted for policy decisions.

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