Unlocking India's Natural Gas Potential: Challenges and Opportunities in a Price-Sensitive Market

Rajani Kant Awasthi

Abstract: ***The Indian gas market is expected to be one of the fastest growing in the world over the next two decades: the IEA forecasts gas demand to increase at 5.4% per annum over 2007-30 (IEA, 2009) reaching 132 bcm by 2030. Indian primary energy supply is currently dominated by coal (37%), biomass and waste (27%) and oil (26%) while the share of natural gas is only 6%. The potential for growth of the natural gas market in India is tremendous; however, this is a very price sensitive market as the ability of customers to pay differs between sectors. The power generation and fertiliser sectors are the main consumers. Fertiliser producers are subsidised by the government and have limited ability to absorb higher prices. In the power generation sector, gas has to compete against coal for base-load generation. Any change in the power sector or in coal markets will have a huge impact on whether gas is used as a base-load option or for peak purposes, and therefore on future gas demand in the power sector. City gas and industrial users show greater price flexibility, but they are still emerging markets. Historically, gas had been allocated in priority to fertiliser and power plants, while city gas, compressed natural gas (CNG) and industrial had the remainder. The gas price increase will hit the fertiliser sector's profitability by increasing working-capital requirements, which is also facing higher import costs due to rising crude oil prices. Auto gas fuel prices may be increased but should remain competitive against liquid fuels, albeit with a reduced differential as liquid auto fuel prices also rise with increasing crude oil prices. The cost of power generated by gas-based power plants will increase, further affecting their utilisation.***

Keywords: Gas Prices, VAR (Vector Auto Regression), ARIMA-GARCH (Auto Regressive Integrated Moving Average-Generalized Autoregressive Conditional Heteroscedasticity), ARCH GARCH Volatility for Gas prices, Forecasting

1.Introduction

The potential for growth of the natural gas market in India is tremendous; however, this is a very price sensitive market as the ability of customers to pay differs between sectors. The power generation and fertiliser sectors are the main consumers. Fertiliser producers are subsidised by the government and have limited ability to absorb higher prices. In the power generation sector, gas has to compete against coal for base-load generation. Any change in the power sector or in coal markets will have a huge impact on whether gas is used as a base-load option or for peak purposes, and therefore on future gas demand in the power sector. City gas and industrial users show greater price flexibility, but they are still emerging markets. Historically, gas had been allocated in priority to fertiliser and power plants, while city gas, compressed natural gas (CNG) and industrial had the remainder. Furthermore, fertiliser producers and power generators were allocated gas at low Administrative Price Mechanism (APM) prices determined by the government. But the recent pricing reforms that took place mid2010 mean the end of low APM prices, and that new gas supplies are likely to be more expensive.

The Indian gas sector, like the whole energy sector, is dominated by state-owned companies. Oil and Natural Gas Corporation (ONGC) and Oil India Ltd (OIL) have dominant upstream positions, while until 2006, GAIL (India) Ltd. alone had been responsible for pipeline gas transport. The state has also a very important role in the regulatory framework and gas policy, in particular the allocation and pricing of gas. Recent reforms have brought more private investors in the upstream and downstream sectors, but a more transparent regulatory framework will be critical to incentivise future private investments.

India has a rather unusual dual gas pricing and supply policy, with APM gas produced by state-owned companies and non-APM gas from private companies and joint ventures (JVs). Until May 2010, prices differed widely from around USD 2/MBtu for APM gas to almost USD 6/MBtu for the most expensive non-APM gas. Such a gap was pushing towards changes. Increasing private supply of gas has been indeed a major policy challenge for the government as the pooling of gas prices was limited by the declining availability of APM gas. Moreover, any effort to keep domestic gas prices low would act as a disincentive for more upstream investment. Two major changes took place in May 2010. APM prices were increased from USD 1.8/MBtu to USD 4.2 MBtu, and ONGC and OIL were allowed to market gas discovered in new fields allocated to them at market prices. This decision will have consequences for producers, and is an important step forward in order to encourage further investments in the upstream sector. Furthermore, if India wants to attract additional LNG in the long term, it would have increasingly to compete on global gas markets at prices potentially higher than the current ones. Meanwhile, the Supreme Court announced its verdict on the five-year battle between Reliance Industry (RIL) and Reliance Natural Resources (RNRL) regarding the price at which RIL was to sell its KG-D6 gas to RNRL: the Court decided that only the government had the right to fix the price in the Production Sharing Contract (PSC) (fixed at USD 4.2/MBtu) when an arm-lengths price is impossible to find. It remains to be seen whether or not such a decision could deter private or foreign upstream investment. Pricing is also key for the demand side due to some sectors' limited ability to absorb high prices: gas-fired plants compete with coal-fired plants while fertiliser producers depend on international urea price and government subsidies. A market approach based on comparison with alternative fuels should be taken.

In the above backdrop and keeping in view the high demand of petroleum products in India with high volatility of prices and India's import bill, this study states about the future trend of international gas prices in preparing India to formulate the best strategy to cope up with any eventuality.

Using ML in Eviews12.0, internationally, the trend of gas prices until 2024M12 has been assessed with the help of two models (1) VAR (Vector Auto Regression) (2) ARIMA-GARCH (Auto Regressive Integrated Moving Average-Generalized Autoregressive Conditional Heteroscedasticity) (3) ARCH GARCH Volatality for Gas prices.

(1) VAR (Vector Auto Regression)

First, what is Vector Autoregression (VAR) and when to use it?

Vector Autoregression (VAR) is a multivariate forecasting algorithm that is used when two or more time series influence each other.

That means, the basic requirements in order to use VAR are:

1)We need at least two time series (variables)
2)The time series should influence each other

It is called 'Autoregressive' because It is considered as an Autoregressive model as, each variable (Time Series) is modeled as a function of the past values that is the predictors are nothing but the lags (time delayed value) of the series.

Now, how is VAR different from other Autoregressive models like AR, ARMA or ARIMA?

The primary difference is those models are uni-directional, where, the predictors influence the Y and not vice-versa. Whereas, Vector Auto Regression (VAR) is bi-directional. That is, the variables influence each other.

A typical AR (p) model equation looks something like this:

$Yt = \alpha + \beta1Yt\text{-}1 + \beta2Yt\text{-}2 + \text{----------------------------} + \beta pYt\text{-}p + €t$

Where α is the intercept, a constant and $\beta1$, $\beta2$ till βp are the coefficients of the lags of Y till order p.

Order 'p' means, up to p-lags of Y is used and they are the predictors in the equation. The $\varepsilon\_\{t\}$ is the error, which is considered as white noise.

Alright. So, how does a VAR model's formula look like?

In the VAR model, each variable is modeled as a linear combination of past values of itself and the past values of other variables in the system. Since you have multiple time series that influence each other, it is modeled as a system of equations with one equation per variable (time series).

That is, if you have 5 time series that influence each other, we will have a system of 5 equations.

Therefore, the equation is exactly framed as below:

Let's suppose, you have two variables (Time series) Y1 and Y2, and you need to forecast the values of these variables at time (t).

To calculate Y1 (t), VAR will use the past values of both Y1 as well as Y2. Likewise, to compute Y2 (t), the past values of both Y1 and Y2 be used.

For example, the system of equations for a VAR (1) model with two time series (variables `Y1` and `Y2`) is as follows:

$Y1, t = \alpha1 + \beta11, 1Y1, t\text{-}1 + \beta12, 1Y2, t\text{-}1 + €1, t$
$Y2, t = \alpha2 + \beta21, 1Y1, t\text{-}1 + \beta22, 1Y2, t\text{-}1 + €2, t$

Where, Y{1, t-1} and Y{2, t-1} are the first lag of time series Y1 and Y2 respectively.

The above equation is referred to as a VAR (1) model, because, each equation is of order 1, that is, it contains up to one lag of each of the predictors (Y1 and Y2).

Paper ID: SR23906152103 DOI: 10.21275/SR23906152103

Since the Y terms in the equations are interrelated, the Y's are considered as endogenous variables, rather than as exogenous predictors.

Likewise, the second order VAR (2) model for two variables would include up to two lags for each variable (Y1 and Y2).

Y1, t = α1 + β11, 1Y1, t-1 + β12, 1Y2, t-1 + β11, 2Y1, t-2 + β12, 2Y2, t-2 + €1, t
Y2, t = α2 + β21, 1Y1, t-1 + β22, 1Y2, t-1 + β21, 2Y1, t-2 + β22, 2Y2, t-2 + €2, t

Can you imagine what a second order VAR (2) model with three variables (Y1, Y2 and Y3) would look like?

Y1, t = α1 + β11, 1Y1, t-1 + β12, 1Y2, t-1 + β13, 1Y3, t-1 + β11, 2Y1, t-2 + β12, 2Y2, t-2 + β13, 2Y3, t-2 +€1, t
Y2, t = α2 + β21, 1Y1, t-1 + β22, 1Y2, t-1 + β23, 1Y3, t-1 + β21, 2Y1, t-2 + β22, 2Y2, t-2 + β23, 2Y3, t-2 +€2, t
Y3, t = α3 + β31, 1Y1, t-1 + β32, 1Y2, t-1 + β33, 1Y3, t-1 + β31, 2Y1, t-2 + β32, 2Y2, t-2 + β33, 2Y3, t-2 +€3, t

As we increase the number of time series (variables) in the model the system of equations becomes larger Application:

Exogenous Variable: Gas rice
Endogenous Variable: Crude Oil Prices, Exchange Rates and coal prices
Sample Data Set: 2003M01 2023M04
Source of Data Collection: Federal Reserve Bank of St. Louis and World Bank Open Data

Vector Auto regression Estimates
Date: 08/24/23 Time: 13:38
Sample (adjusted): 2003M04 2021M12
Included observations: 225 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	GASPRICE	EXR1	LNCOAL_PRICE	CRUDEOILPRICE
GASPRICE(-1)	0.779046	-0.001136	0.000105	0.001772
	(0.07013)	(0.00138)	(0.00013)	(0.00831)
	[11.1079]	[-0.82187]	[0.83158]	[0.21320]
GASPRICE(-2)	0.061829	0.000568	-0.000173	-0.001472
	(0.07016)	(0.00138)	(0.00013)	(0.00831)
	[0.88124]	[0.41069]	[-1.37548]	[-0.17708]
EXR1(-1)	2.644511	0.247249	-0.001674	-0.172996
	(3.50174)	(0.06901)	(0.00629)	(0.41489)
	[0.75520]	[3.58301]	[-0.26611]	[-0.41697]
EXR1(-2)	-1.647936	-0.104156	-0.000191	-0.090355
	(3.42285)	(0.06745)	(0.00615)	(0.40555)
	[-0.48145]	[-1.54416]	[-0.03105]	[-0.22280]
LNCOAL_PRICE(-1)	8.058531	0.026480	0.944605	1.555764
	(38.0679)	(0.75017)	(0.06837)	(4.51036)
	[0.21169]	[0.03530]	[13.8157]	[0.34493]
LNCOAL_PRICE(-2)	-25.43942	0.013017	-0.000153	0.743693
	(37.6187)	(0.74132)	(0.06756)	(4.45714)
	[-0.67624]	[0.01756]	[-0.00227]	[0.16685]
CRUDEOILPRICE(-1)	0.439232	-0.004469	0.000569	1.340158
	(0.54786)	(0.01080)	(0.00098)	(0.06491)
	[0.80172]	[-0.41397]	[0.57798]	[20.6459]
CRUDEOILPRICE(-2)	-0.117122	0.012097	-7.31E-05	-0.413572
	(0.55354)	(0.01091)	(0.00099)	(0.06558)
	[-0.21159]	[1.10894]	[-0.07353]	[-6.30590]
C	98.18853	-0.457860	0.254019	-6.065621
	(46.2214)	(0.91085)	(0.08302)	(5.47640)
	[2.12431]	[-0.50267]	[3.05988]	[-1.10759]
R-squared	0.746837	0.114713	0.957275	0.946550
Adj. R-squared	0.737460	0.081924	0.955693	0.944570
Sum sq. resids	461535.8	179.2304	1.488817	6479.029
S.E. equation	46.22488	0.910917	0.083022	5.476815
F-statistic	79.65058	3.498575	604.9538	478.1410
Log likelihood	-1177.210	-293.6755	245.2772	-697.2865
Akaike AIC	10.54409	2.690449	-2.100242	6.278103
Schwarz SC	10.68074	2.827093	-1.963598	6.414747
Mean dependent	229.2108	0.123192	4.793054	66.74631

S.D. dependent	90.21493	0.950692	0.394419	23.26245
Determinant resid covariance (dof adj.)		329.7105		
Determinant resid covariance		280.0385		
Log likelihood		-1910.974		
Akaike information criterion		17.30644		
Schwarz criterion		17.85301		
Number of coefficients		36		

VAR Residual Serial Correlation LM Tests						
Date: 08/24/23 Time: 13:39						
Sample: 2003M01 2024M12						
Included observations: 225						
Null hypothesis: No serial correlation at lag h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	10.76648	16	0.8237	0.671191	(16, 639.1)	0.8237
2	13.86835	16	0.6085	0.866649	(16, 639.1)	0.6086
3	12.56803	16	0.7040	0.784598	(16, 639.1)	0.7041
Null hypothesis: No serial correlation at lags 1 to h						
Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	10.76648	16	0.8237	0.671191	(16, 639.1)	0.8237
2	25.32152	32	0.7928	0.788790	(32, 757.6)	0.7929
3	38.68309	48	0.8293	0.801957	(48, 776.3)	0.8296
*Edgeworth expansion corrected likelihood ratio statistic.						

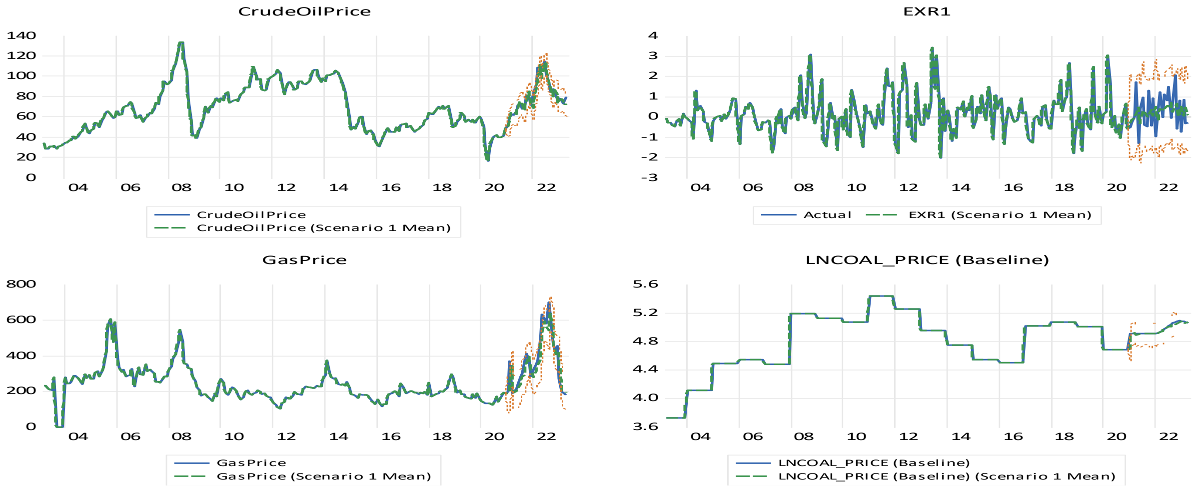
VAR Residual Heteroscedasticity Tests (Levels and Squares)					
Date: 08/24/23 Time: 13:39					
Sample: 2003M01 2024M12					
Included observations: 225					
Joint test:					
Chi-sq	df	Prob.			
288.8750	160	0.0000			
Individual components:					
Dependent	R-squared	F(16,208)	Prob.	Chi-sq(16)	Prob.
res1*res1	0.219520	3.656425	0.0000	49.39209	0.0000
res2*res2	0.127544	1.900470	0.0219	28.69746	0.0261
res3*res3	0.048965	0.669311	0.8223	11.01702	0.8084
res4*res4	0.122677	1.817804	0.0306	27.60233	0.0353
res2*res1	0.161598	2.505686	0.0016	36.35952	0.0026
res3*res1	0.198892	3.227520	0.0001	44.75064	0.0002
res3*res2	0.044145	0.600393	0.8816	9.932689	0.8701
res4*res1	0.200813	3.266530	0.0000	45.18291	0.0001
res4*res2	0.097393	1.402728	0.1426	21.91348	0.1460
res4*res3	0.044839	0.610264	0.8739	10.08867	0.8620

The above diagnostic tests (LM Test) indicate that model is free from serial correlation as Null Hypothesis is not rejected at 5% confidence level

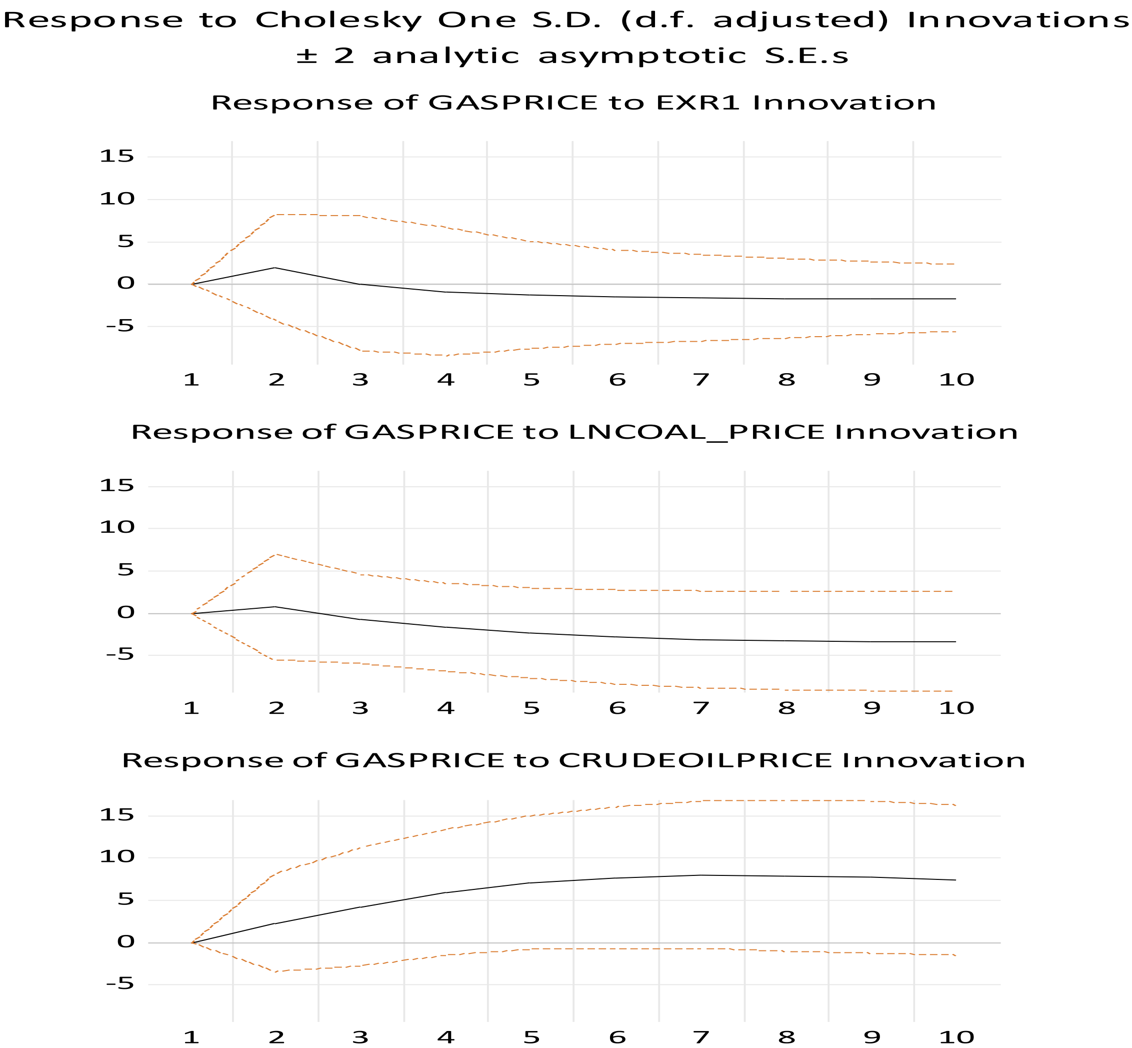
Similarly, above diagnostic test (Residual Heteroscedasticity Tests) indicates that model is free from Heteroscedasticity as Null Hypothesis is rejected at 5% confidence level.

Testing of Models with Data Set (2003M01 2023M04):

Model testing suggests that all the results lie under 95% confidence band, meaning thereby the adopted model hold good for forecasting purpose.

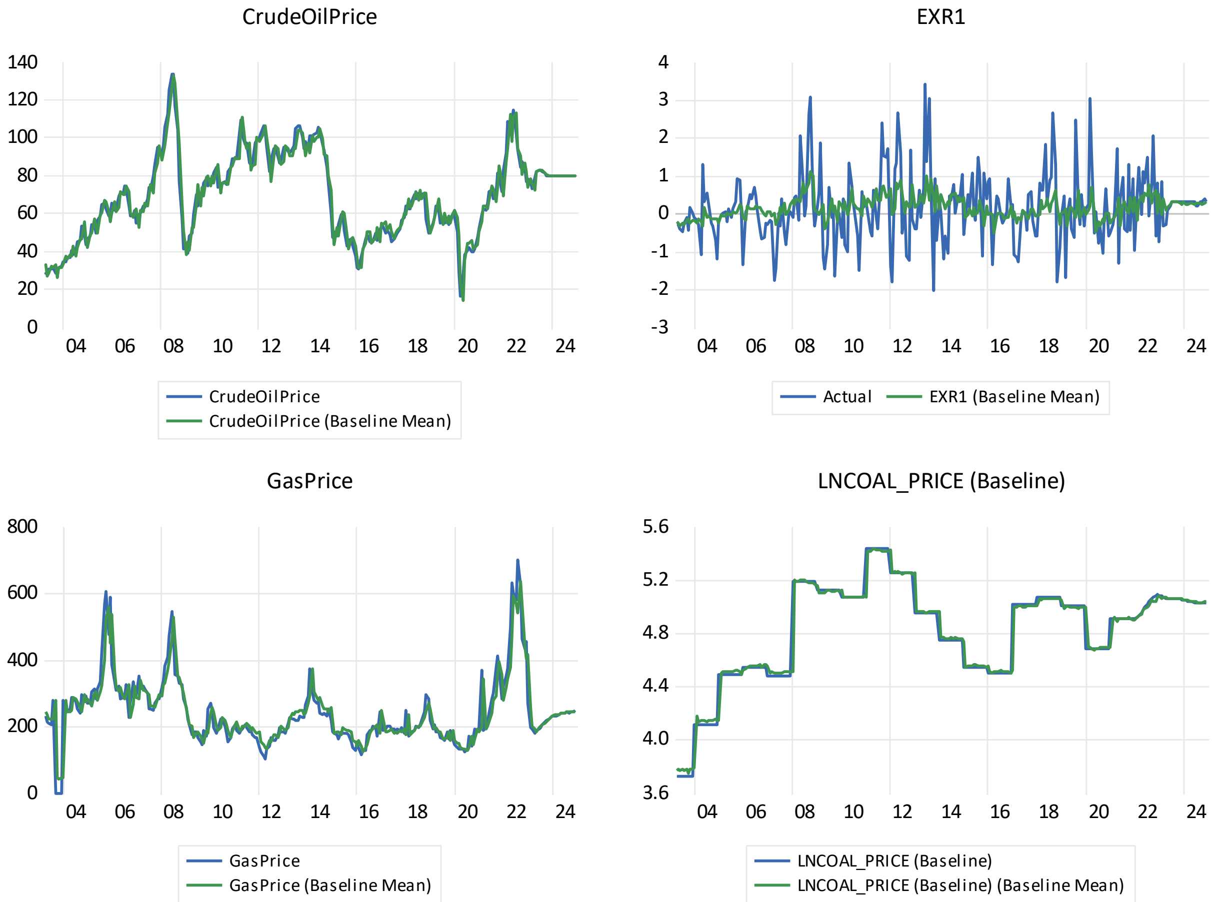


Effects of Crude Oil, Coal Prices and Exchange Rates Innovation:

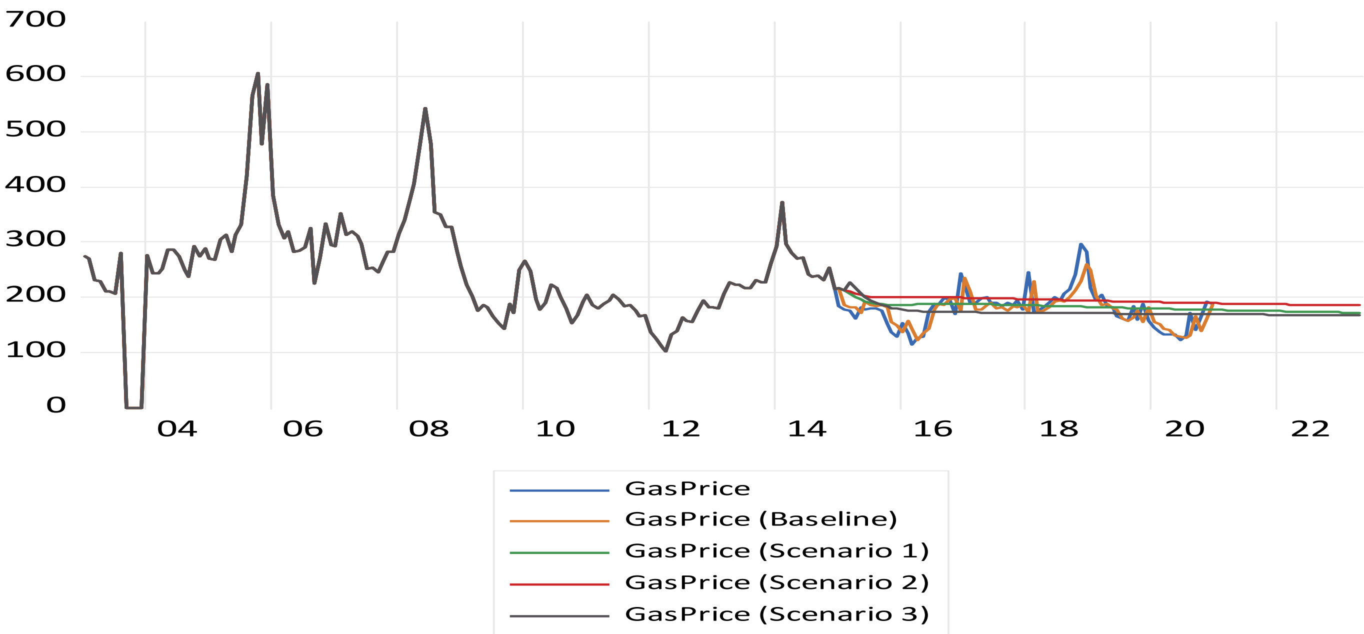


The above graphs indicate that gas prices continuously increase in short run and get stable in long run with the increase in crude oil prices. Similarly with increase in exchange rates and coal prices , the gas prices slightly increase then decrease in short run and get normalised in long run with the trends remaining in negative side only.

Forecasting of International Gas Prices from 2023M05 2024M12:



Effect of Increase in Crude Oil Prices, Coal Prices and Exchange Rates:



A shock of 10% was applied to crude oil prices(scenario1), coal prices(scenario2) and exchange rates (scenario3) during the period 2015M01 2023M04 and results reveal that gas prices get affected more with crude oil prices and less with coal prices and least with the upward variation of exchange rates.

ARIMA-GARCH (Auto Regressive Integrated Moving Average-Generalized Autoregressive Conditional Heteroscedasticity) Model:

The main contributions of this study are as follows :(1)ARIMA model and ARIMA-GARCH combined model have been constructed(2)The future trend of international gas price is predicted, which has certain theoretical value and significance for economic development (3)Comparing with other traditional models, we obtain that the proposed model has higher prediction accuracy

2.Brief Introduction of ARIMA and GARCH Models

General Form of the ARMA Model

In the ARIMA(p, d, q), AR represents autoregressive, p represents the number of autoregressive terms, MA represents average move, q represents the average number of terms of moving, and d represents the difference number. If

$$Y_t = (1 - B)^d X_t, \tag{2}$$

is a sequence of ARMA(p, q), it indicates that $\{X_t\}$ is a sequence of ARMA(p, q)and the model is shown as follows:

$$\phi(B)(1 - B)^d X_t = \theta(B)\varepsilon_t, \quad t \in Z, \tag{3}$$

where B represents the operator, $(1 - B)$ represents finite difference operator, $\{\varepsilon_t\}$ represents a flanoise in zero-mean, and real polynomial $\phi(z) = 1 - \phi_1 z - \cdots - \phi_p z^p$ and $\theta(z) = \theta_0 + \theta_1 z + \cdots + \theta_q z^q$ meet the requirements of stationarity and reversibility, respectively.

The modeling steps of ARIMA(p, d, q) model are as follows:

① The stationarity test is carried out on the original time series. If the series does not meet the stationarity condition, the difference transformation is needed to make the series meet the stationarity condition, so as to obtain the value of d in the model.

② The values of p and q in the model are determined by using ACF and PACF.

③ The unknown parameters of the model were estimated and the significance of the parameters and the applicability of the diagnostic model were tested.

④ Predict the future value of time series.

The structure of the ARMA model is as follows:

$$X_t = \sum_{j=1}^{p} \phi_j X_{t-j} + \sum_{j=0}^{q} \theta_j \varepsilon_{t-j}, \quad t \in Z, \qquad \left\{ \begin{cases} \theta_0 = 1, \\ \phi_p \theta_q \neq 0, \end{cases} \right) \tag{1}$$

where $\{\varepsilon_t\}$ represents a flat noise in zero-mean , real polynomial.

$\phi(z) = 1 - \phi_1 z - \cdots - \phi_p z^p$ and $\theta(z) = \theta_0 + \theta_1 z + \cdots + \theta_q z^q$ meet the requirements of stationarity and reversibility, respectively.

$$\left\{\left\{\begin{array}{l} x_t = f(t, x_{t-1}, x_{t-2}, \ldots) + \varepsilon_t, \\ \varepsilon_t = \sqrt{h_t} e_t, \\ h_t = w + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2, \\ e_t \sim II\ D(0,1), \end{array}\right.\right) \quad (4)$$

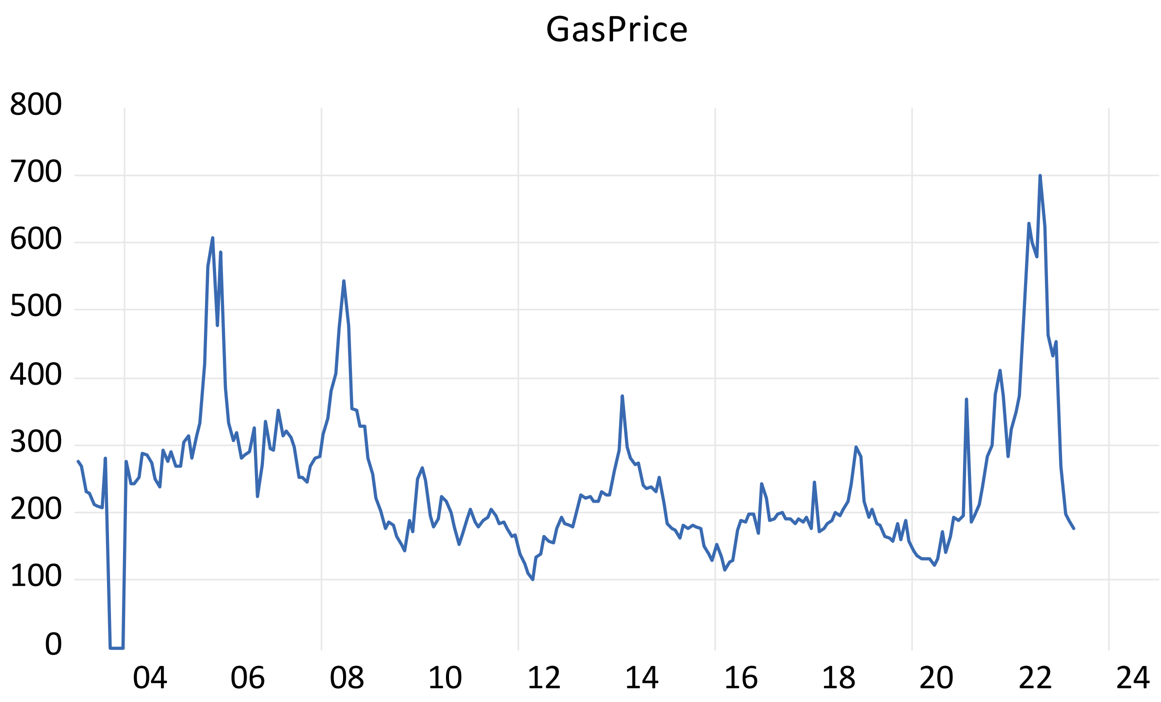
where α_i is nonnegative and $f(t, x_{t-1}, x_{t-2}, \ldots)$ is the deterministic information fitting model of $\{x_t\}$.

GARCH Model

$$\left\{\left\{\begin{array}{l} x_t = f(t, x_{t-1}, x_{t-2}, \ldots) + \varepsilon_t, \\ \varepsilon_t = \sqrt{h_t} e_t, \\ h_t = w + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \gamma_j h_{t-j}, \\ e_t \sim II\ D(0,1), \end{array}\right.\right) \quad (5)$$

where α_i and γ_j are nonnegative and $f(t, x_{t-1}, x_{t-2}, \ldots)$ is the deterministic information fitting model of $\{x_t\}$. It is an extension of the ARCH model and claims that h_t has AR $\sum_{j=1}^{p} \gamma_j h_{t-j}$ and ARCH term is $\sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2$. In general, the GARCH model is easier to identify and estimate, and the GARCH model can capture the flat period and fluctuation period of time series.

3.Results and Discussions



Null Hypothesis: GASPRICE has a unit root				
Exogenous: Constant				
Lag Length: 0 (Automatic - based on SIC, maxlag=14)				
			t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic			-3.754253	0.0039
Test critical values:	1% level		-3.457173	
	5% level		-2.873240	
	10% level		-2.573080	
*MacKinnon (1996) one-sided p-values.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(GASPRICE)				
Method: Least Squares				
Date: 08/30/23 Time: 12:03				
Sample (adjusted): 2003M02 2023M04				
Included observations: 243 after adjustments				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
GASPRICE(-1)	-0.111073	0.029586	-3.754253	0.0002
C	26.57476	7.865715	3.378556	0.0008
R-squared	0.055252	Mean dependent var		-0.402510
Adjusted R-squared	0.051332	S.D. dependent var		51.19960
S.E. of regression	49.86821	Akaike info criterion		10.66484
Sum squared resid	599328.0	Schwarz criterion		10.69359
Log likelihood	-1293.778	Hannan-Quinn criter.		10.67642
F-statistic	14.09442	Durbin-Watson stat		2.000703
Prob(F-statistic)	0.000218			

The above graph shows constant mean and variance over time, it suggests a stationary series, ADF test also indicates stationary at level with 5% as p-value is 0.0039 which is less than 0.05.

Correlogram for ARIMA Model:

<table>
<tr><td colspan="7">Date: 08/28/23 Time: 09:48</td></tr>
<tr><td colspan="7">Sample: 2003M01 2023M04</td></tr>
<tr><td colspan="7">Included observations: 244</td></tr>
<tr><th>Autocorrelation</th><th>Partial Correlation</th><th></th><th>AC</th><th>PAC</th><th>Q-Stat</th><th>Prob</th></tr>
<tr><td>.|*******</td><td>.|*******</td><td>1</td><td>0.907</td><td>0.907</td><td>203.21</td><td>0.000</td></tr>
<tr><td>.|******|</td><td>.|. |</td><td>2</td><td>0.817</td><td>-0.034</td><td>368.66</td><td>0.000</td></tr>
<tr><td>.|***** |</td><td>.|. |</td><td>3</td><td>0.734</td><td>-0.010</td><td>502.66</td><td>0.000</td></tr>
<tr><td>.|***** |</td><td>*|. |</td><td>4</td><td>0.632</td><td>-0.148</td><td>602.70</td><td>0.000</td></tr>
<tr><td>.|**** |</td><td>*|. |</td><td>5</td><td>0.529</td><td>-0.077</td><td>672.99</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>.|* |</td><td>6</td><td>0.466</td><td>0.160</td><td>727.79</td><td>0.000</td></tr>
<tr><td>.|*** |</td><td>.|. |</td><td>7</td><td>0.406</td><td>-0.014</td><td>769.62</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>8</td><td>0.352</td><td>0.002</td><td>801.12</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>9</td><td>0.305</td><td>-0.041</td><td>824.84</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>10</td><td>0.276</td><td>0.054</td><td>844.32</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>.|. |</td><td>11</td><td>0.252</td><td>0.042</td><td>860.65</td><td>0.000</td></tr>
<tr><td>.|** |</td><td>*|. |</td><td>12</td><td>0.218</td><td>-0.076</td><td>873.00</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>13</td><td>0.200</td><td>0.049</td><td>883.36</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>14</td><td>0.190</td><td>0.023</td><td>892.75</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>15</td><td>0.170</td><td>-0.023</td><td>900.35</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>16</td><td>0.145</td><td>-0.047</td><td>905.86</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>17</td><td>0.124</td><td>-0.026</td><td>909.95</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|* |</td><td>18</td><td>0.114</td><td>0.078</td><td>913.40</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>19</td><td>0.095</td><td>-0.035</td><td>915.78</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>*|. |</td><td>20</td><td>0.062</td><td>-0.106</td><td>916.79</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>21</td><td>0.036</td><td>-0.014</td><td>917.15</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|* |</td><td>22</td><td>0.028</td><td>0.096</td><td>917.37</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>23</td><td>0.012</td><td>-0.000</td><td>917.41</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>24</td><td>0.001</td><td>-0.019</td><td>917.41</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>25</td><td>-0.003</td><td>-0.033</td><td>917.41</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>26</td><td>-0.005</td><td>0.027</td><td>917.42</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|* |</td><td>27</td><td>0.002</td><td>0.091</td><td>917.42</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>28</td><td>0.016</td><td>0.012</td><td>917.48</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|. |</td><td>29</td><td>0.034</td><td>0.013</td><td>917.81</td><td>0.000</td></tr>
<tr><td>.|. |</td><td>.|* |</td><td>30</td><td>0.066</td><td>0.099</td><td>919.04</td><td>0.000</td></tr>
<tr><td>.|* |</td><td>.|. |</td><td>31</td><td>0.091</td><td>0.006</td><td>921.36</td><td>0.000</td></tr>
</table>

.|* |	.|. |	32	0.104	-0.057	924.45	0.000
.|* |	*|. |	33	0.109	-0.075	927.85	0.000
.|* |	.|. |	34	0.104	-0.002	930.92	0.000
.|* |	.|. |	35	0.088	0.016	933.15	0.000
.|. |	*|. |	36	0.065	-0.068	934.36	0.000

Based on above correlogram it is observed that ACFremains large for a long time and PAC cuts off at lag1, therefore we start with the simplest model: AR(1), MA(1) and ARIMA(1,1,1) until we get a model with significant coefficients.

Summary of the Derived Models:

Model	Coefficient(s)	White Noise	AIC	SIC
AR(1,1,0)	Significant	-	10.40731	10.45030
MA(0,1,1)	Significant	-	11.30198	11.34498
AR(1,1,1)	AR Significant MA Not Significant	-	10.41432	10.47165
AR(2,1,0)	Significant	-	11.04199	11.04899
MA(0,1,2)	Significant	-	11.47465	11.51764
AR(2,1,2)	AR Significant MA Not Significant	-	11.04024	11.09757
NOTE:-AR(1,1,0) is based suited depending upon AIC and SC values				

ARIMA (1,1,0)

Dependent Variable: GASPRICE				
Method: ARMA Maximum Likelihood (OPG - BHHH)				
Date: 08/30/23 Time: 12:26				
Sample: 2003M01 2023M04				
Included observations: 244				
Convergence achieved after 31 iterations				
Coefficient covariance computed using outer product of gradients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	241.6224	31.29046	7.721918	0.0000
AR(1)	0.885692	0.019368	45.73049	0.0000
SIGMASQ	2457.433	102.7659	23.91292	0.0000
R-squared	0.789267	Mean dependent var		242.6104
Adjusted R-squared	0.787518	S.D. dependent var		108.2096
S.E. of regression	49.88009	Akaike info criterion		10.67563
Sum squared resid	599613.7	Schwarz criterion		10.71863
Log likelihood	-1299.427	Hannan-Quinn criter.		10.69295
F-statistic	451.3125	Durbin-Watson stat		1.993777
Prob(F-statistic)	0.000000			
Inverted AR Roots	.89			

Date: 08/28/23 Time: 14:21						
Sample: 2003M01 2023M04						
Q-statistic probabilities adjusted for 1 ARMA term						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.|. |	.|. |	1	0.035	0.035	0.2989	
.|. |	.|. |	2	0.008	0.007	0.3152	0.574
.|* |	.|* |	3	0.139	0.139	5.1340	0.077
.|. |	.|. |	4	0.068	0.060	6.3020	0.098
*|. |	*|. |	5	-0.187	-0.197	15.124	0.004
.|. |	.|. |	6	0.010	0.002	15.148	0.010
.|. |	.|. |	7	0.009	-0.003	15.167	0.019
.|. |	.|. |	8	-0.015	0.035	15.225	0.033
*|. |	*|. |	9	-0.098	-0.080	17.690	0.024
.|. |	.|. |	10	-0.015	-0.051	17.751	0.038
.|. |	.|. |	11	0.061	0.073	18.711	0.044
*|. |	*|. |	12	-0.085	-0.068	20.568	0.038
.|. |	.|. |	13	-0.054	-0.032	21.335	0.046
.|. |	.|. |	14	0.055	0.015	22.121	0.054
.|. |	.|. |	15	0.034	0.041	22.427	0.070
.|. |	.|. |	16	-0.026	0.018	22.611	0.093
.|. |	*|. |	17	-0.033	-0.078	22.905	0.116
.|. |	.|. |	18	0.054	0.027	23.687	0.128

.|. |	.|* |	19	0.069	0.085	24.964	0.126
.|. |	.|. |	20	-0.048	-0.021	25.593	0.142
*|. |	*|. |	21	-0.091	-0.123	27.809	0.114
.|. |	.|. |	22	0.039	-0.012	28.219	0.134
.|. |	.|. |	23	-0.031	0.015	28.487	0.160
.|. |	.|. |	24	-0.040	0.029	28.921	0.183
.|. |	.|. |	25	-0.010	-0.040	28.949	0.222
.|. |	*|. |	26	-0.021	-0.073	29.070	0.261
.|. |	.|. |	27	-0.062	-0.026	30.133	0.262
.|. |	.|. |	28	-0.025	0.007	30.305	0.301
.|. |	*|. |	29	-0.065	-0.080	31.467	0.297
.|. |	.|. |	30	0.036	0.024	31.834	0.327
.|. |	.|* |	31	0.055	0.090	32.676	0.337
.|. |	.|. |	32	0.050	0.074	33.397	0.352
.|. |	.|. |	33	0.054	-0.004	34.213	0.362
.|. |	.|. |	34	0.059	-0.018	35.194	0.365
.|. |	.|. |	35	0.043	0.061	35.719	0.388
.|. |	.|. |	36	-0.053	-0.043	36.527	0.398

The above correlogram of residuals are mostly small in magnitude, falling inside the 95% confidence interval, suggesting that residuals are independently distributed (no autocorrelation in the residuals), implying the fitted (1, 1, 0) model is adequate. Moreover, the Q-statistics are greater than alpha=0.05, therefore we are certain that the error terms of the selected model are white noise.

We have also tried for over fitting as per above table which that only AR (1, 1, 0) has been found to be the best depending upon coefficients significance and AIC, SIC values. Which should be minimum for best fitted model.

Date: 08/28/23 Time: 11:29						
Sample (adjusted): 2003M02 2023M04						
Included observations: 243 after adjustments						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
.|. |	.|. |	1	0.040	0.040	0.3982	0.528
.|. |	.|. |	2	-0.038	-0.040	0.7630	0.683
.|. |	.|. |	3	-0.022	-0.019	0.8820	0.830
.|. |	.|. |	4	-0.020	-0.020	0.9790	0.913
.|. |	.|. |	5	0.022	0.022	1.1026	0.954
.|. |	.|. |	6	-0.012	-0.015	1.1359	0.980
.|. |	.|. |	7	0.009	0.011	1.1579	0.992
.|. |	.|. |	8	-0.016	-0.017	1.2210	0.996
.|. |	.|. |	9	-0.009	-0.006	1.2414	0.999
.|. |	.|. |	10	0.029	0.028	1.4577	0.999
.|. |	.|. |	11	-0.013	-0.015	1.4979	1.000
.|. |	.|. |	12	-0.025	-0.024	1.6619	1.000
.|. |	.|. |	13	0.016	0.019	1.7293	1.000
.|* |	.|* |	14	0.193	0.191	11.373	0.657
.|. |	.|. |	15	0.030	0.014	11.612	0.708
.|. |	.|. |	16	-0.022	-0.009	11.737	0.762
.|. |	.|. |	17	-0.035	-0.026	12.061	0.796
.|. |	.|* |	18	0.063	0.077	13.100	0.786
.|. |	.|. |	19	-0.020	-0.036	13.205	0.828
.|. |	.|. |	20	0.002	0.009	13.207	0.868
.|. |	.|. |	21	-0.042	-0.048	13.676	0.883
.|. |	.|. |	22	-0.012	0.004	13.716	0.911
.|* |	.|* |	23	0.110	0.111	16.969	0.811
.|. |	.|. |	24	-0.007	-0.027	16.984	0.849
.|. |	.|. |	25	0.028	0.034	17.193	0.875
.|. |	.|. |	26	-0.047	-0.038	17.810	0.883
.|. |	.|. |	27	0.041	0.056	18.267	0.895
.|. |	.|. |	28	0.022	-0.036	18.400	0.916
.|. |	.|. |	29	0.001	0.002	18.400	0.936
.|. |	.|. |	30	-0.024	-0.028	18.558	0.949
.|. |	.|. |	31	-0.020	0.006	18.669	0.960
.|. |	.|. |	32	-0.013	-0.042	18.718	0.970
.|. |	.|. |	33	-0.007	-0.006	18.731	0.978
.|. |	.|. |	34	0.002	0.002	18.733	0.984
.|. |	.|. |	35	-0.021	-0.001	18.859	0.988

.|. |	.|. |	36	0.035	0.039	19.209	0.990
*Probabilities may not be valid for this equation specification.						

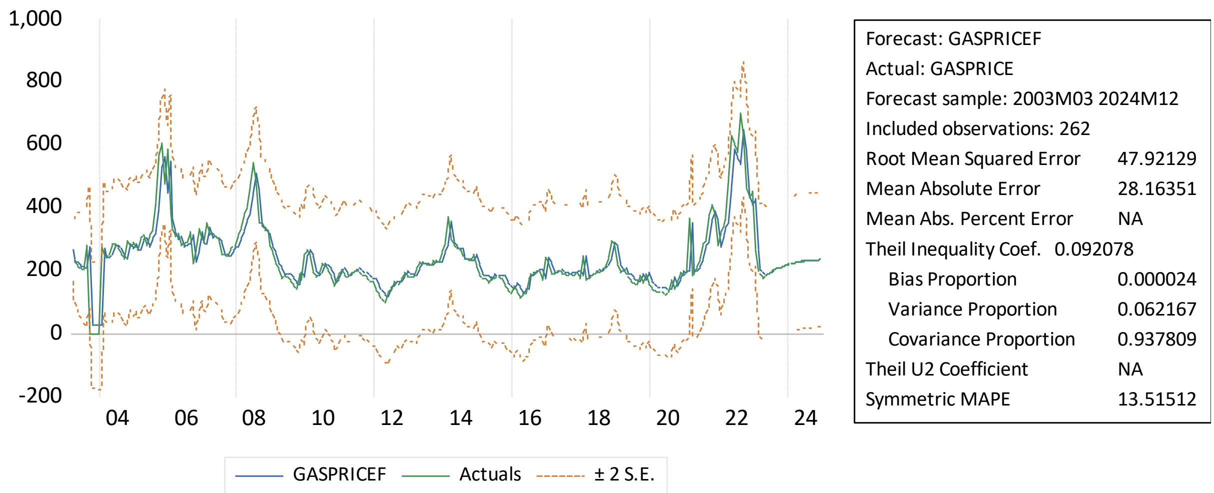
Before fitting GARCH(1,1) into ARIMA(1,0,0)	F-Statistic	30.84307	Prob.F(2,34)	0.0000
	Obs* R-Squared	27.49670	Prob. Chi-square(1)	0.0000
After fitting GARCH(1,1) into ARIMA(1,0,0)	F-Statistic	0.389439	Prob.F(2,34)	0.5332
	Obs* R-Squared	0.392049	Prob. Chi-square(1)	0.5312

The ARCH-LM test is conduced to see whether there is a presence of heteroscedasticity in variance. As can be seen that before fitting GARCH (1, 1) into ARIMA (1, 1, 0) model. The p-values are less than 0.05 (Significance level), therefore we reject null hypothesis indicating that heteroscedasticity is present in residual. Which shows the presence of ARCH effect. After fitting GARCH (1, 1) into ARIMA (1, 1, 0) model, again ARCH-LM test is conducted. This time, the values of p are greater than 0.05 and we failed to reject null hypothesis and conclude that there is no more ARCH effect, implying that the residuals ate now homoscedastic.

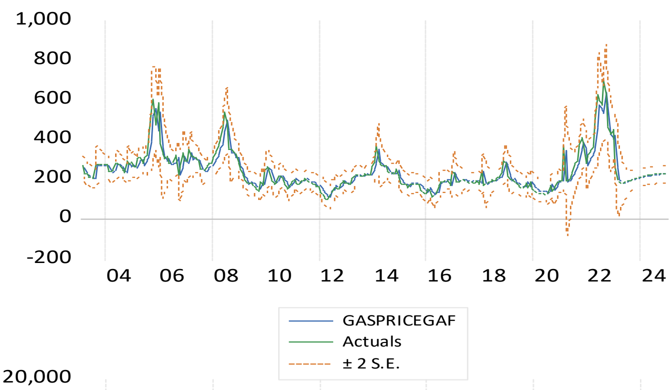
Dependent Variable: GASPRICEF				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Date: 08/27/23 Time: 11:22				
Sample (adjusted): 2003M02 2023M04				
Included observations: 243 after adjustments				
Convergence achieved after 22 iterations				
Coefficient covariance computed using outer product of gradients				
Presample variance: backcast (parameter = 0.7)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	22.75606	7.453498	3.053071	0.0023
GASPRICEF(-1)	0.889300	0.032593	27.28497	0.0000
	Variance Equation			
C	246.6076	67.24706	3.667187	0.0002
RESID(-1)^2	0.332773	0.085672	3.884258	0.0001
GARCH(-1)	0.559690	0.085989	6.508844	0.0000
R-squared	0.822427	Mean dependent var		247.0554
Adjusted R-squared	0.821690	S.D. dependent var		103.8340
S.E. of regression	43.84572	Akaike info criterion		10.04716
Sum squared resid	463309.7	Schwarz criterion		10.11904
Log likelihood	-1215.730	Hannan-Quinn criter.		10.07611
Durbin-Watson stat	1.877211			

The above model ARCH (1, 1, 0)-GARCH (1, 1) is better model with statistically significant coefficients, fulfilled the assumption of NID residuals and AIC, SIC are smaller than that ARIMA (1, 1, 0) model. Therefore, we ensure that the ARIMA (1, 1, 0)-GARCH (1, 1) model is our best model for gas prices.

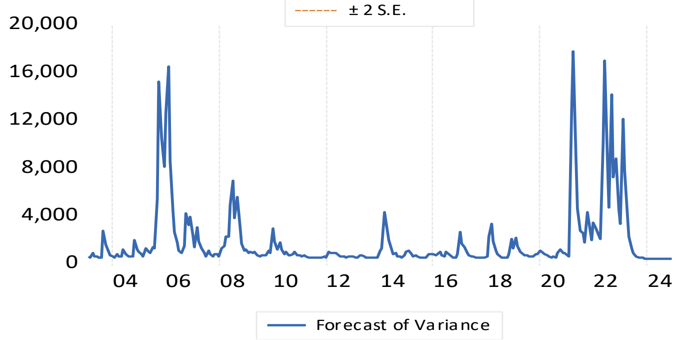
ARIMA (1, 1, 0) model Forecasting



ARCH (1, 1, 0)-GARCH (1, 1) Forecasting



Forecast: GASPRICEGAF	
Actual: GASPRICEGARCH	
Forecast sample: 2003M01 2024M12	
Adjusted sample: 2003M02 2024M12	
Included observations: 263	
Root Mean Squared Error	42.05406
Mean Absolute Error	25.70840
Mean Abs. Percent Error	9.785076
Theil Inequality Coef.	0.080834
Bias Proportion	0.009892
Variance Proportion	0.084645
Covariance Proportion	0.905463
Theil U2 Coefficient	0.990814
Symmetric MAPE	9.716032



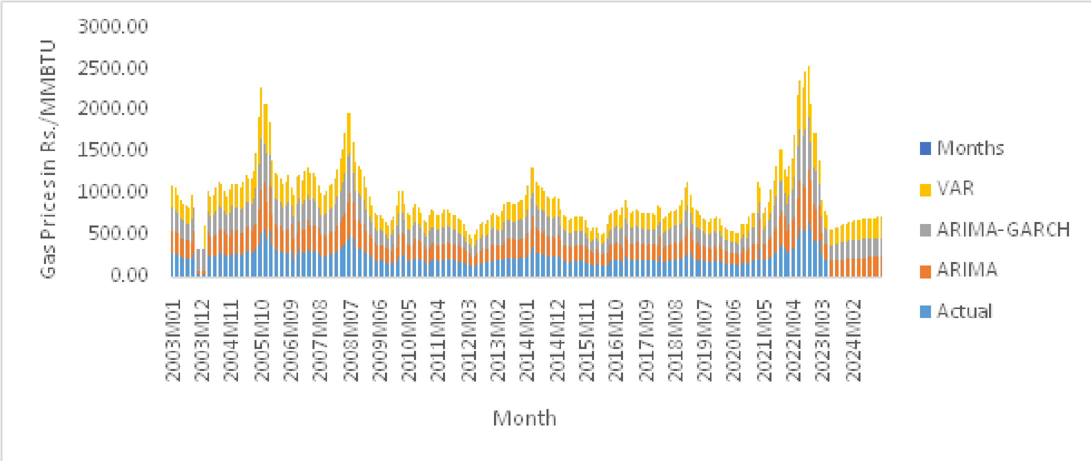
	Actual Gas Prices(INR)		ARIMA(1,1,0) forecasted prices(INR)		ARIMA(1,1,0)-GARCH(1,1) forecasted prices(INR)	VAR forecasted prices(INR)
2003M01	274.97	2003M01	274.97	2003M01	274.97	274.97
2003M02	269.58	2003M02	269.58	2003M02	269.58	269.58
2003M03	266.3861285	2003M03	266.3861285	2003M03	231.64	231.64
2003M04	232.7828323	2003M04	232.7828323	2003M04	228.3	228.3
2003M05	229.8246085	2003M05	229.8246085	2003M05	211.37	211.37
2003M06	214.8297798	2003M06	214.8297798	2003M06	210.61	210.61
2003M07	214.156651	2003M07	214.156651	2003M07	206.21	206.21
2003M08	210.2595898	2003M08	210.2595898	2003M08	279.47	279.47
2003M09	275.1456593	2003M09	275.1456593	2003M09	278.932	0
2003M10	27.62027243	2003M10	27.62027243	2003M10	278.394	0
2003M11	27.62027243	2003M11	27.62027243	2003M11	277.856	0
2003M12	27.62027243	2003M12	27.62027243	2003M12	277.318	0
2004M01	27.62027243	2004M01	27.62027243	2004M01	276.78	276.78
2004M02	272.7631377	2004M02	272.7631377	2004M02	243.56	243.56
2004M03	243.3403255	2004M03	243.3403255	2004M03	243.08	243.08
2004M04	242.9151915	2004M04	242.9151915	2004M04	251.3	251.3
2004M05	250.1956104	2004M05	250.1956104	2004M05	286.83	286.83
2004M06	281.6643799	2004M06	281.6643799	2004M06	285.38	285.38
2004M07	280.3801211	2004M07	280.3801211	2004M07	273.04	273.04
2004M08	269.4506357	2004M08	269.4506357	2004M08	250.25	250.25
2004M09	249.2656299	2004M09	249.2656299	2004M09	236.94	236.94
2004M10	237.4770197	2004M10	237.4770197	2004M10	293.47	293.47
2004M11	287.5453995	2004M11	287.5453995	2004M11	274.73	274.73
2004M12	270.9474615	2004M12	270.9474615	2004M12	289.39	289.39
2005M01	283.931761	2005M01	283.931761	2005M01	269.1	269.1
2005M02	265.9609945	2005M02	265.9609945	2005M02	268.18	268.18
2005M03	265.1461544	2005M03	265.1461544	2005M03	304.52	304.52
2005M04	297.3323374	2005M04	297.3323374	2005M04	312.75	312.75
2005M05	304.6216133	2005M05	304.6216133	2005M05	281.39	281.39
2005M06	276.8461951	2005M06	276.8461951	2005M06	313.38	313.38
2005M07	305.1796016	2005M07	305.1796016	2005M07	332.19	332.19
2005M08	321.8395384	2005M08	321.8395384	2005M08	420.12	420.12
2005M09	399.7187643	2005M09	399.7187643	2005M09	565.64	565.64
2005M10	528.6052075	2005M10	528.6052075	2005M10	606	606
2005M11	564.3518874	2005M11	564.3518874	2005M11	476.92	476.92
2005M12	450.026282	2005M12	450.026282	2005M12	585.79	585.79
2006M01	546.4519766	2006M01	546.4519766	2006M01	384.49	384.49
2006M02	368.1614253	2006M02	368.1614253	2006M02	332.04	332.04
2006M03	321.706684	2006M03	321.706684	2006M03	306.88	306.88
2006M04	299.4225793	2006M04	299.4225793	2006M04	318.69	318.69
2006M05	309.882646	2006M05	309.882646	2006M05	281.54	281.54
2006M06	276.9790494	2006M06	276.9790494	2006M06	285.08	285.08

2006M07	280.1144123	2006M07	280.1144123	2006M07	290.35	290.35
2006M08	284.7820289	2006M08	284.7820289	2006M08	325.77	325.77
2006M09	316.1533718	2006M09	316.1533718	2006M09	224.15	224.15
2006M10	226.1489713	2006M10	226.1489713	2006M10	270.99	270.99
2006M11	267.6349594	2006M11	267.6349594	2006M11	334.18	334.18
2006M12	323.6020729	2006M12	323.6020729	2006M12	293.7	293.7
2007M01	287.7491096	2007M01	287.7491096	2007M01	291.75	291.75
2007M02	286.0220029	2007M02	286.0220029	2007M02	351.97	351.97
2007M03	339.3586	2007M03	339.3586	2007M03	313.46	313.46
2007M04	305.2504573	2007M04	305.2504573	2007M04	319.93	319.93
2007M05	310.9809087	2007M05	310.9809087	2007M05	310.43	310.43
2007M06	302.5667992	2007M06	302.5667992	2007M06	297.56	297.56
2007M07	291.1678951	2007M07	291.1678951	2007M07	251.39	251.39
2007M08	250.2753231	2007M08	250.2753231	2007M08	253.07	253.07
2007M09	251.7632919	2007M09	251.7632919	2007M09	246.07	246.07
2007M10	245.5634217	2007M10	245.5634217	2007M10	268.69	268.69
2007M11	265.5978593	2007M11	265.5978593	2007M11	281.6	281.6
2007M12	277.0321912	2007M12	277.0321912	2007M12	282	282
2008M01	277.3864695	2008M01	277.3864695	2008M01	314.98	314.98
2008M02	306.5967148	2008M02	306.5967148	2008M02	339.69	339.69
2008M03	328.4822564	2008M03	328.4822564	2008M03	379.35	379.35
2008M04	363.6089492	2008M04	363.6089492	2008M04	405.51	405.51
2008M05	386.7787496	2008M05	386.7787496	2008M05	473.07	473.07
2008M06	446.6163534	2008M06	446.6163534	2008M06	542.96	542.96
2008M07	508.5176283	2008M07	508.5176283	2008M07	477.63	477.63
2008M08	450.655126	2008M08	450.655126	2008M08	354.25	354.25
2008M09	341.3779863	2008M09	341.3779863	2008M09	350.39	350.39
2008M10	337.9592007	2008M10	337.9592007	2008M10	327.36	327.36
2008M11	317.561628	2008M11	317.561628	2008M11	326.85	326.85
2008M12	317.1099232	2008M12	317.1099232	2008M12	281.64	281.64
2009M01	277.067619	2009M01	277.067619	2009M01	255.92	255.92
2009M02	254.2875247	2009M02	254.2875247	2009M02	222.48	222.48
2009M03	224.6698594	2009M03	224.6698594	2009M03	202.52	202.52
2009M04	206.9913725	2009M04	206.9913725	2009M04	175.25	175.25
2009M05	182.8384499	2009M05	182.8384499	2009M05	184.91	184.91
2009M06	191.3942706	2009M06	191.3942706	2009M06	181.54	181.54
2009M07	188.409476	2009M07	188.409476	2009M07	164.44	164.44
2009M08	173.264079	2009M08	173.264079	2009M08	152.2	152.2
2009M09	162.4231632	2009M09	162.4231632	2009M09	143.38	143.38
2009M10	154.6113268	2009M10	154.6113268	2009M10	187.82	187.82
2009M11	193.9716452	2009M11	193.9716452	2009M11	171.84	171.84
2009M12	179.8182274	2009M12	179.8182274	2009M12	250.4	250.4
2010M01	249.3984843	2010M01	249.3984843	2010M01	266.84	266.84
2010M02	263.9593221	2010M02	263.9593221	2010M02	247.38	247.38
2010M03	246.7236832	2010M03	246.7236832	2010M03	195.19	195.19
2010M04	200.4992228	2010M04	200.4992228	2010M04	178.44	178.44
2010M05	185.6638192	2010M05	185.6638192	2010M05	190.41	190.41
2010M06	196.2655972	2010M06	196.2655972	2010M06	223.04	223.04
2010M07	225.165849	2010M07	225.165849	2010M07	217.02	217.02
2010M08	219.8339607	2010M08	219.8339607	2010M08	200.7	200.7
2010M09	205.3794063	2010M09	205.3794063	2010M09	179.54	179.54
2010M10	186.6380845	2010M10	186.6380845	2010M10	152.35	152.35
2010M11	162.5560175	2010M11	162.5560175	2010M11	167.39	167.39
2010M12	175.8768814	2010M12	175.8768814	2010M12	191.52	191.52
2011M01	197.2487194	2011M01	197.2487194	2011M01	203.78	203.78
2011M02	208.1073491	2011M02	208.1073491	2011M02	185	185
2011M03	191.4739833	2011M03	191.4739833	2011M03	178.61	178.61
2011M04	185.8143875	2011M04	185.8143875	2011M04	188.2	188.2
2011M05	194.3082096	2011M05	194.3082096	2011M05	193.5	193.5
2011M06	199.002397	2011M06	199.002397	2011M06	204.08	204.08
2011M07	208.3730579	2011M07	208.3730579	2011M07	195.87	195.87
2011M08	201.1014959	2011M08	201.1014959	2011M08	183.38	183.38
2011M09	190.0391562	2011M09	190.0391562	2011M09	186.14	186.14
2011M10	192.4836764	2011M10	192.4836764	2011M10	175.79	175.79
2011M11	183.3167255	2011M11	183.3167255	2011M11	164.24	164.24
2011M12	173.0869398	2011M12	173.0869398	2011M12	166.34	166.34
2012M01	174.9469009	2012M01	174.9469009	2012M01	137.29	137.29
2012M02	149.2174398	2012M02	149.2174398	2012M02	123.89	123.89
2012M03	137.3491169	2012M03	137.3491169	2012M03	109.2	109.2
2012M04	124.3382466	2012M04	124.3382466	2012M04	101.02	101.02
2012M05	117.0932555	2012M05	117.0932555	2012M05	132.58	132.58
2012M06	145.0458129	2012M06	145.0458129	2012M06	137.83	137.83
2012M07	149.6957155	2012M07	149.6957155	2012M07	163.8	163.8
2012M08	172.6972337	2012M08	172.6972337	2012M08	157.79	157.79
2012M09	167.3742023	2012M09	167.3742023	2012M09	154.95	154.95

2012M10	164.8588264	2012M10	164.8588264	2012M10	175.82	175.82
2012M11	183.3432964	2012M11	183.3432964	2012M11	193.71	193.71
2012M12	199.1883931	2012M12	199.1883931	2012M12	182.42	182.42
2013M01	189.1888883	2013M01	189.1888883	2013M01	180.86	180.86
2013M02	187.8072029	2013M02	187.8072029	2013M02	178.97	178.97
2013M03	186.133238	2013M03	186.133238	2013M03	207.22	207.22
2013M04	211.1541425	2013M04	211.1541425	2013M04	226.75	226.75
2013M05	228.4517802	2013M05	228.4517802	2013M05	222.33	222.33
2013M06	224.537005	2013M06	224.537005	2013M06	223.4	223.4
2013M07	225.4846995	2013M07	225.4846995	2013M07	216.4	216.4
2013M08	219.2848293	2013M08	219.2848293	2013M08	216.81	216.81
2013M09	219.6479646	2013M09	219.6479646	2013M09	230.55	230.55
2013M10	231.817424	2013M10	231.817424	2013M10	226.19	226.19
2013M11	227.9557906	2013M11	227.9557906	2013M11	227.01	227.01
2013M12	228.6820611	2013M12	228.6820611	2013M12	262.66	262.66
2014M01	260.257114	2014M01	260.257114	2014M01	292.04	292.04
2014M02	286.2788546	2014M02	286.2788546	2014M02	371.84	371.84
2014M03	356.9573742	2014M03	356.9573742	2014M03	297.52	297.52
2014M04	291.1324673	2014M04	291.1324673	2014M04	279.45	279.45
2014M05	275.1279454	2014M05	275.1279454	2014M05	270.6	270.6
2014M06	267.2895381	2014M06	267.2895381	2014M06	272.89	272.89
2014M07	269.3177813	2014M07	269.3177813	2014M07	240.86	240.86
2014M08	240.948947	2014M08	240.948947	2014M08	236.27	236.27
2014M09	236.8836036	2014M09	236.8836036	2014M09	238.66	238.66
2014M10	239.0004164	2014M10	239.0004164	2014M10	231.28	231.28
2014M11	232.4639818	2014M11	232.4639818	2014M11	252.88	252.88
2014M12	251.5950097	2014M12	251.5950097	2014M12	215.1	215.1
2015M01	218.1334249	2015M01	218.1334249	2015M01	184.54	184.54
2015M02	191.0665632	2015M02	191.0665632	2015M02	176.78	176.78
2015M03	184.1935643	2015M03	184.1935643	2015M03	174.86	174.86
2015M04	182.4930285	2015M04	182.4930285	2015M04	161.88	161.88
2015M05	170.9966979	2015M05	170.9966979	2015M05	181.22	181.22
2015M06	188.1260534	2015M06	188.1260534	2015M06	176.89	176.89
2015M07	184.2909909	2015M07	184.2909909	2015M07	180.12	180.12
2015M08	187.1517881	2015M08	187.1517881	2015M08	179.6	179.6
2015M09	186.6912263	2015M09	186.6912263	2015M09	175.47	175.47
2015M10	183.0333029	2015M10	183.0333029	2015M10	150.98	150.98
2015M11	161.3426144	2015M11	161.3426144	2015M11	137.38	137.38
2015M12	149.2971524	2015M12	149.2971524	2015M12	127.86	127.86
2016M01	140.865329	2016M01	140.865329	2016M01	152.76	152.76
2016M02	162.9191528	2016M02	162.9191528	2016M02	133.76	133.76
2016M03	146.0909338	2016M03	146.0909338	2016M03	114	114
2016M04	128.5895861	2016M04	128.5895861	2016M04	126.29	126.29
2016M05	139.4747867	2016M05	139.4747867	2016M05	128.42	128.42
2016M06	141.3613186	2016M06	141.3613186	2016M06	172.91	172.91
2016M07	180.7659218	2016M07	180.7659218	2016M07	187.53	187.53
2016M08	193.7147935	2016M08	193.7147935	2016M08	186.76	186.76
2016M09	193.0328078	2016M09	193.0328078	2016M09	198.22	198.22
2016M10	203.1828809	2016M10	203.1828809	2016M10	196.93	196.93
2016M11	202.0403334	2016M11	202.0403334	2016M11	168.82	168.82
2016M12	177.1434263	2016M12	177.1434263	2016M12	243.08	243.08
2017M01	242.9151915	2017M01	242.9151915	2017M01	222.03	222.03
2017M02	224.2712963	2017M02	224.2712963	2017M02	189.23	189.23
2017M03	195.2204762	2017M03	195.2204762	2017M03	190.5	190.5
2017M04	196.3453098	2017M04	196.3453098	2017M04	198.7	198.7
2017M05	203.6080148	2017M05	203.6080148	2017M05	200.99	200.99
2017M06	205.636258	2017M06	205.636258	2017M06	189.44	189.44
2017M07	195.4064723	2017M07	195.4064723	2017M07	190.74	190.74
2017M08	196.5578768	2017M08	196.5578768	2017M08	184.22	184.22
2017M09	190.7831406	2017M09	190.7831406	2017M09	190.8	190.8
2017M10	196.6110185	2017M10	196.6110185	2017M10	186.15	186.15
2017M11	192.4925334	2017M11	192.4925334	2017M11	193.97	193.97
2017M12	199.418674	2017M12	199.418674	2017M12	177.31	177.31
2018M01	184.6629831	2018M01	184.6629831	2018M01	245.67	245.67
2018M02	245.2091435	2018M02	245.2091435	2018M02	171.88	171.88
2018M03	179.8536552	2018M03	179.8536552	2018M03	175.53	175.53
2018M04	183.0864447	2018M04	183.0864447	2018M04	182.54	182.54
2018M05	189.2951718	2018M05	189.2951718	2018M05	189.12	189.12
2018M06	195.1230497	2018M06	195.1230497	2018M06	199.99	199.99
2018M07	204.7505623	2018M07	204.7505623	2018M07	194.42	194.42
2018M08	199.8172371	2018M08	199.8172371	2018M08	205.82	205.82
2018M09	209.9141684	2018M09	209.9141684	2018M09	215.46	215.46
2018M10	218.4522753	2018M10	218.4522753	2018M10	241.47	241.47
2018M11	241.4892214	2018M11	241.4892214	2018M11	296.63	296.63
2018M12	290.3441981	2018M12	290.3441981	2018M12	281.91	281.91

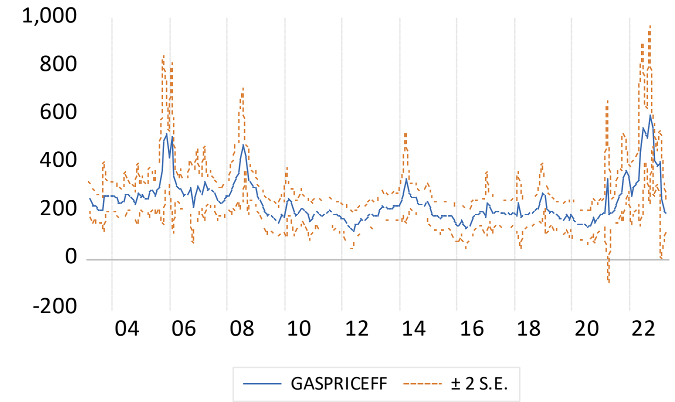
2019M01	277.3067569	2019M01	277.3067569	2019M01	217.2	217.2
2019M02	219.9933859	2019M02	219.9933859	2019M02	192.97	192.97
2019M03	198.5329783	2019M03	198.5329783	2019M03	203.57	203.57
2019M04	207.921353	2019M04	207.921353	2019M04	183.29	183.29
2019M05	189.9594436	2019M05	189.9594436	2019M05	182.15	182.15
2019M06	188.9497504	2019M06	188.9497504	2019M06	165.26	165.26
2019M07	173.9903495	2019M07	173.9903495	2019M07	161.01	161.01
2019M08	170.2261426	2019M08	170.2261426	2019M08	157.94	157.94
2019M09	167.5070567	2019M09	167.5070567	2019M09	183.33	183.33
2019M10	189.9948714	2019M10	189.9948714	2019M10	159.87	159.87
2019M11	169.2164495	2019M11	169.2164495	2019M11	187.86	187.86
2019M12	194.0070731	2019M12	194.0070731	2019M12	156.61	156.61
2020M01	166.3290814	2020M01	166.3290814	2020M01	144.08	144.08
2020M02	155.2313138	2020M02	155.2313138	2020M02	135.75	135.75
2020M03	147.8534683	2020M03	147.8534683	2020M03	132.28	132.28
2020M04	144.7801042	2020M04	144.7801042	2020M04	131.81	131.81
2020M05	144.3638272	2020M05	144.3638272	2020M05	132.4	132.4
2020M06	144.8863876	2020M06	144.8863876	2020M06	122.65	122.65
2020M07	136.2508542	2020M07	136.2508542	2020M07	130.53	130.53
2020M08	143.2301366	2020M08	143.2301366	2020M08	171.75	171.75
2020M09	179.7385148	2020M09	179.7385148	2020M09	141.12	141.12
2020M10	152.6096544	2020M10	152.6096544	2020M10	165.32	165.32
2020M11	174.0434912	2020M11	174.0434912	2020M11	192.35	192.35
2020M12	197.9838469	2020M12	197.9838469	2020M12	187.09	187.09
2021M01	193.3250873	2021M01	193.3250873	2021M01	195.2	195.2
2021M02	200.5080797	2021M02	200.5080797	2021M02	368.92	368.92
2021M03	354.3711427	2021M03	354.3711427	2021M03	186.35	186.35
2021M04	192.6696725	2021M04	192.6696725	2021M04	194.23	194.23
2021M05	199.6489549	2021M05	199.6489549	2021M05	212.01	212.01
2021M06	215.396625	2021M06	215.396625	2021M06	237.59	237.59
2021M07	238.0527219	2021M07	238.0527219	2021M07	283.18	283.18
2021M08	278.4315904	2021M08	278.4315904	2021M08	300.43	300.43
2021M09	293.7098419	2021M09	293.7098419	2021M09	376.17	376.17
2021M10	360.7924368	2021M10	360.7924368	2021M10	410.47	410.47
2021M11	391.1718005	2021M11	391.1718005	2021M11	373.91	373.91
2021M12	358.7907644	2021M12	358.7907644	2021M12	281.76	281.76
2022M01	277.1739025	2022M01	277.1739025	2022M01	322.36	322.36
2022M02	313.1331493	2022M02	313.1331493	2022M02	349.65	349.65
2022M03	337.3037859	2022M03	337.3037859	2022M03	372.07	372.07
2022M04	357.1610843	2022M04	357.1610843	2022M04	497.47	497.47
2022M05	468.2273293	2022M05	468.2273293	2022M05	629.3	629.3
2022M06	584.988598	2022M06	584.988598	2022M06	598.86	598.86
2022M07	558.0280198	2022M07	558.0280198	2022M07	578.04	578.04
2022M08	539.5878346	2022M08	539.5878346	2022M08	699.29	699.29
2022M09	646.9784424	2022M09	646.9784424	2022M09	622.72	622.72
2022M10	579.16072	2022M10	579.16072	2022M10	462.71	462.71
2022M11	437.4405456	2022M11	437.4405456	2022M11	432.05	432.05
2022M12	410.2851144	2022M12	410.2851144	2022M12	452.99	452.99
2023M01	428.8315831	2023M01	428.8315831	2023M01	267.78	267.78
2023M02	264.7918761	2023M02	264.7918761	2023M02	196.6	196.6
2023M03	201.7480538	2023M03	201.7480538	2023M03	189.27	189.27
2023M04	195.255904	2023M04	203.3258165	2023M04	177.16	177.16
2023M05		2023M05	196.969479	2023M05	183	185
2023M06		2023M06	186.468081	2023M06	188	192
2023M07		2023M07	193.2666739	2023M07	193	195
2023M08		2023M08	198.4696787	2023M08	198	203
2023M09		2023M09	203.6726835	2023M09	202	211
2023M10		2023M10	208.0085208	2023M10	206	217
2023M11		2023M11	212.3443581	2023M11	209	222
2023M12		2023M12	215.8130279	2023M12	212	225
2024M01		2024M01	219.2816978	2024M01	215	231
2024M02		2024M02	221.8832002	2024M02	218	231
2024M03		2024M03	224.4847026	2024M03	220	232
2024M04		2024M04	226.2190375	2024M04	222	234
2024M05		2024M05	227.9533724	2024M05	224	238
2024M06		2024M06	229.6877073	2024M06	226	239
2024M07		2024M07	231.4220423	2024M07	228	240
2024M08		2024M08	232.2892097	2024M08	229	242
2024M09		2024M09	233.1563772	2024M09	230	240
2024M10		2024M10	234.0235447	2024M10	231	241
2024M11		2024M11	234.8907121	2024M11	232	245
2024M12		2024M12	235.7578796	2024M12	233	248

The Graphical Representation of Forecasted Gas Prices through Various Models is depicted below:

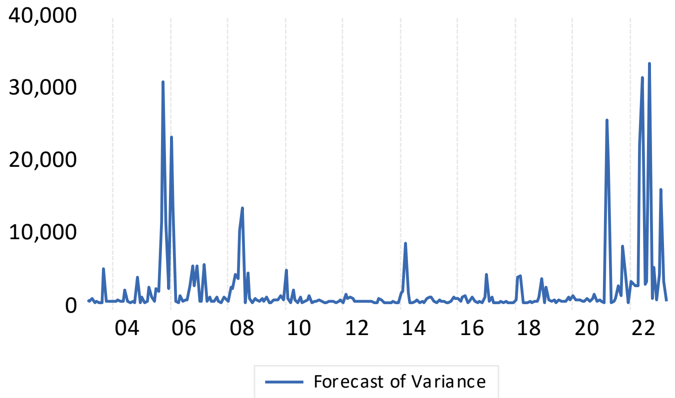


Further, we have also forecasted the ARCH and GARCH volatility.

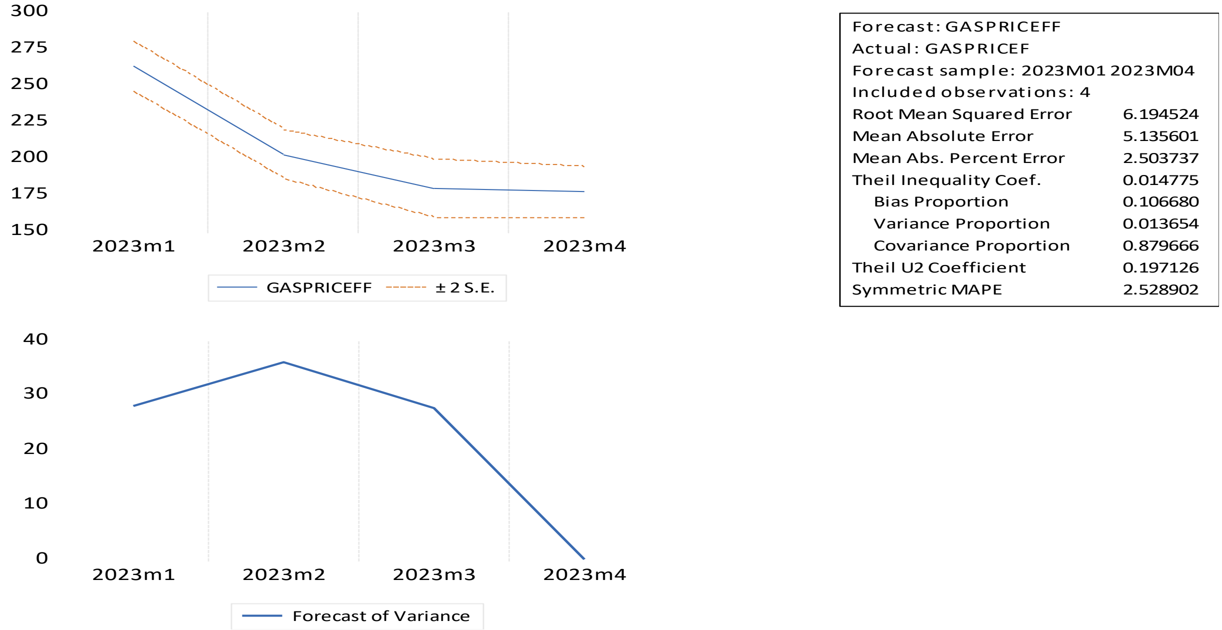
ARCH Volatility



Forecast: GASPRICEFF	
Actual: GASPRICEF	
Forecast sample: 2003M01 2023M04	
Adjusted sample: 2003M02 2023M04	
Included observations: 243	
Root Mean Squared Error	45.63558
Mean Absolute Error	28.86366
Mean Abs. Percent Error	10.82973
Theil Inequality Coef.	0.087665
Bias Proportion	0.033325
Variance Proportion	0.209157
Covariance Proportion	0.757517
Theil U2 Coefficient	1.023196
Symmetric MAPE	10.87945



Paper ID: SR23906152103 DOI: 10.21275/SR23906152103



The above graphs show that there is a stability in return of gas prices, however there is intense volatility, before 2023m1 there was increased volatility which gradually decreased by 2023m4.

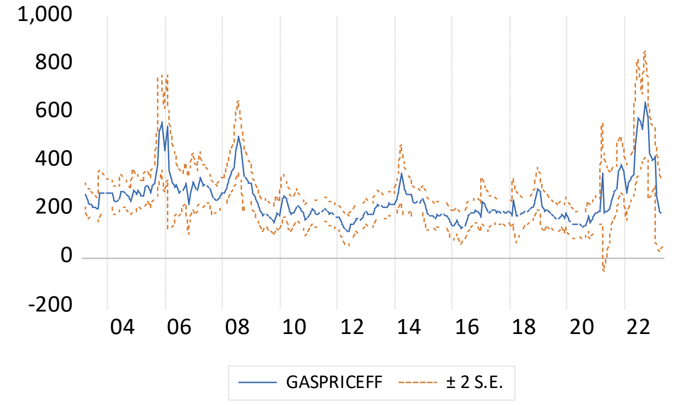
GARCH Volatility:

Dependent Variable: GASPRICEF				
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)				
Date: 08/27/23 Time: 11:22				
Sample (adjusted): 2003M02 2023M04				
Included observations: 243 after adjustments				
Convergence achieved after 22 iterations				
Coefficient covariance computed using outer product of gradients				
Presample variance: backcast (parameter = 0.7)				
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	22.75606	7.453498	3.053071	0.0023
GASPRICEF(-1)	0.889300	0.032593	27.28497	0.0000
	Variance Equation			
C	246.6076	67.24706	3.667187	0.0002
RESID(-1)^2	0.332773	0.085672	3.884258	0.0001
GARCH(-1)	0.559690	0.085989	6.508844	0.0000
R-squared	0.822427	Mean dependent var		247.0554
Adjusted R-squared	0.821690	S.D. dependent var		103.8340
S.E. of regression	43.84572	Akaike info criterion		10.04716
Sum squared resid	463309.7	Schwarz criterion		10.11904
Log likelihood	-1215.730	Hannan-Quinn criter.		10.07611
Durbin-Watson stat	1.877211			

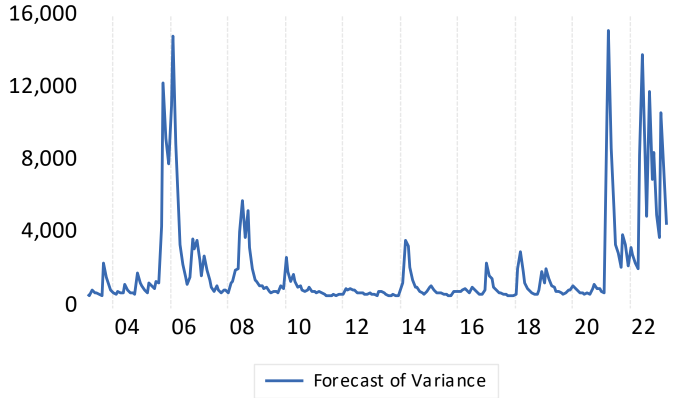
Here, we can write

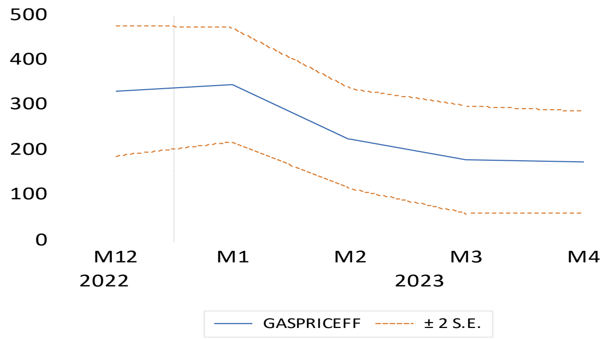
Volatility$\sigma t2$= 246.6067 + 0.332773$\varepsilon 2t$-1 + 0.559690$\sigma 2t$-1

ß1 = 0.332773 and ß2= 0.559690, Here ß1 + ß2=0.892463 <1 and ß2> ß1, meaning thereby there is a persistence volatility in gas prices irrespective of reason and since ß1 + ß2=0.892463 <1 means there is a decaying volatility and the decaying volatility rate would be 0.107537.

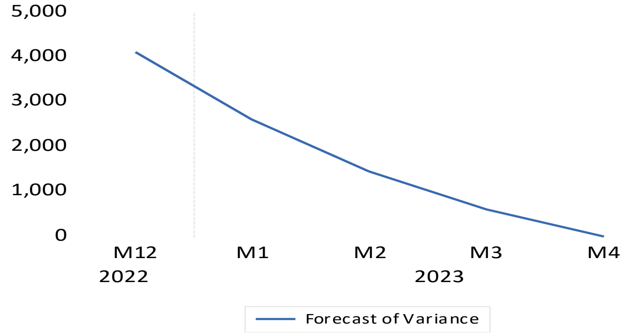


Forecast: GASPRICEFF	
Actual: GASPRICEF	
Forecast sample: 2003M01 2023M04	
Adjusted sample: 2003M02 2023M04	
Included observations: 243	
Root Mean Squared Error	43.66485
Mean Absolute Error	27.46069
Mean Abs. Percent Error	10.40494
Theil Inequality Coef.	0.082762
Bias Proportion	0.009406
Variance Proportion	0.069887
Covariance Proportion	0.920708
Theil U2 Coefficient	0.989582
Symmetric MAPE	10.33666





Forecast: GASPRICEFF	
Actual: GASPRICEF	
Forecast sample: 2022M12 2023M04	
Included observations: 5	
Root Mean Squared Error	65.59373
Mean Absolute Error	47.55247
Mean Abs. Percent Error	15.23471
Theil Inequality Coef.	0.121170
Bias Proportion	0.001574
Variance Proportion	0.199413
Covariance Proportion	0.799013
Theil U2 Coefficient	0.439840
Symmetric MAPE	15.00220



The above graphs show that there is stability in return of gas prices, however there is intense volatility, before 2022m12 there was increased volatility which gradually decreased and became stable by 2023m4.

4.Conclusion

Concluded that due to intense volatility in international gas prices the gas transmission company in India could see an impact of its earnings due to high gas prices as predicted. The company imports gas from the US market, the prices of which are linked to the US gas prices. Thus, higher gas prices in the US will increase the gas sourcing cost for Transmission Company. Along with this, if gas usage declines in India due to higher prices, the same will lead to a lower amount of gas being transmitted through its pipe line, which will eventually lead to lower earning.

India's largest gas importer earns a majority part of its income from gas regasification. Reducing gas imports to the country could hurt regasification income. In the month of July, 2022, total LNG imports in India declined by 10% YoY and 8% MoM, due to a sharp increase in spot LNG prices and also likely due to shortages driven by lower supply on some of the long-term contracts.

City gas distribution companies also stand to market as the blended gas cost increases. Currently, CGD are sourcing 6% of their gas requirement for CNG and household usage from the spot market, while the gas supplied for industrial use is fully sourced through spot market. Owing to rising gas prices in the Asian market, the blended gas cost will also increase for CGSs.

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