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ARE THE RESPONSES OF OIL PRODUCTS PRICES ASYMMETRICAL TO GLOBAL CRUDE OIL PRICE SHOCKS? EVIDENCE FROM INDIA

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Abstract

The paper examines the existence of asymmetry and nonlinearity in the influence of global crude oil price shocks on oil product prices in India for the time period April 2000 to March 2022. For the purpose, novel assessments of symmetry and linearity, namely slope and impulse response tests, have been utilized. The findings of the slope tests indicate that there is absence of nonlinearity in the reaction of the majority of oil product prices to global crude oil price shocks. In contrast, the results obtained from the impulse response test indicate that with the exception of liquid petroleum gas, all oil product prices exhibit asymmetric responses to positive and negative crude oil shocks of varying magnitudes. The findings are in line with prior research on the transmission of oil prices to oil product prices and provide evidence for the existence of a rockets-and-feathers phenomenon in the Indian oil products market. From a policy standpoint, the results suggest the government to consider reducing taxes on petroleum products. This measure would help to ensure a symmetric response of oil product prices to global fluctuations in crude oil prices and expected to mitigate the welfare loss experienced by consumers due to the presence of asymmetry.

Keywords: *Oil shocks, Oil products prices, Asymmetry, Non-linearity, Slope test, Impulse response test, India.*

JEL Codes: *C3, C22, D4*

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INTRODUCTION

The impact of global crude oil prices on the pricing of oil products, including petrol, diesel, and other related commodities, has been the subject of extensive research in macroeconomic literature. The utilization of crude oil as the principal feedstock in the production of diverse petroleum derivatives, including but not limited to diesel, liquefied petroleum gas and petrol, is a widely recognized practice. Prior research has posited that the propagation of global crude oil price fluctuations to the retail or wholesale prices of oil products exhibits asymmetry. This assertion is supported by various studies, including those conducted by Borenstein *et. al.* (1997), Peltzman (2000), Borenstein & Shepard (2002), Alom & Ritson (2012), Driffield *et. al.* (2003), and Chua (2017). Specifically, these studies observed that the rate of increase in oil product prices is comparatively higher during periods of rising crude oil prices, whereas the rate of decrease in oil product prices is relatively slower during periods of falling crude oil prices. The phenomenon of nonlinear and asymmetric oil price reactions is widely recognized as the "rockets and feathers" effect. This effect is characterized by a rapid increase in oil product prices in response to a rise in crude oil prices, while a reduction in crude oil prices leads to a slow decrease in oil product prices. This nomenclature was first introduced by Bacon (1991).

Numerous factors have been posited in scholarly literature as potential origins of the aforementioned asymmetrical reactions. In their seminal study, Borenstein *et. al.* (1997) identified two primary sources of asymmetry, namely adjustment delays in production or inventory lags, and seller market power. Borenstein and Shepard (2002) demonstrated that firms possessing monopolistic power exhibit a comparatively sluggish adjustment of petrol prices in contrast to their counterparts operating in a competitive market. Kaufmann and Laskowski (2005) have suggested that asymmetry may be influenced by refinery utilization rates and inventory modifications. According to the findings of Brown and Yucel (2000), it is improbable that market power is the underlying cause of asymmetry.

Instead, they suggested that asymmetry may be attributed to factors such as search costs and locational advantages. According to Peltzman's (2000) research, there was no observed correlation between the level of asymmetry and various market power indicators. The author also observed the absence of a correlation between the extent of asymmetry and inventory costs or asymmetric menu costs. The aetiologies of asymmetry that have been cited are not necessarily ubiquitous and may exhibit heterogeneity across nations.

A multitude of empirical investigations have been conducted to explore the asymmetric response of oil product prices to crude oil price shocks, utilizing a variety of nonlinear time-series models. The findings exhibit a heterogeneous pattern, with substantial variations across investigations contingent on the country of focus and the employed methodologies. Numerous studies, including those conducted by Borenstein *et. al.* (1997), Godby *et. al.* (2000), Driffield *et. al.* (2003), Berument *et. al.* (2004), Grasso and Manera (2007), Liu *et. al.* (2010), Alom and Ritson (2012), Bumpass *et. al.* (2015), Boroumand *et. al.* (2016), Chua (2017), Rahman (2018), and Valadkhani and Smyth (2018), have demonstrated that the prices of oil products tend to increase at a more rapid pace in response to increases in crude oil prices, while they tend to decrease at a slower rate or may not respond at all to decreases in crude oil prices. Several studies have reported no evidence of asymmetry in the response of oil product prices to fluctuations in crude oil prices. These studies include Bettendorf *et. al.* (2003), Bachmeier and Gryphon (2003), Adilov and Samavati (2009), Rao and Rao (2008), and Karagiannis *et. al.* (2015). Table 1 presents a comprehensive summary of the aforementioned study.

Given this backdrop, the current study aims to investigate the potential nonlinear and asymmetric effects of global crude oil price shocks on Indian oil product prices. India was chosen as the research site for several reasons. India ranks third globally in terms of crude oil consumption. According to Deheri and Ramachandran's (2023), imports account for approximately 80% of the nation's crude oil consumption. India's macroeconomic indicators, specifically crude oil-based product prices, are susceptible to global oil price shocks due to the country's dependence on imported crude oil. Besides, there are few empirical studies have been conducted on the asymmetric and nonlinear impacts of crude oil price shocks on macroeconomic indicators within the Indian economy. The extant literature has predominantly concentrated on Western economies, including but not limited to the United States, the United Kingdom, and Canada, while comparatively less emphasis has been placed on major oil-dependent nations such as India and China.

Numerous investigations carried out in India have utilised censored oil price-macroeconomic vector autoregression (VAR) models, as evidenced by Ghosh and Kanjilal (2014), Gupta and Goyal (2015), and Bhat *et. al.* (2018). The aforementioned studies have employed the analytical techniques of impulse response analysis and the Granger causality test and have arrived at the finding that oil shocks exhibit an asymmetric effect on macroeconomic variables. In their seminal work, Kilian and Vigfusson (2011) have established that the censored-VAR models generally used in the oil price and macroeconomic literature to detect asymmetry and non-linearity are mis-specified. The estimates provided and conclusions drawn from such models exhibit inconsistency and inaccuracy, irrespective of the symmetry or asymmetry of the data-generating process. According to their assertion, the single equation slope test which is again a popular approach used to detect nonlinearity in the impact of oil price by Mork (1989) is insufficient in assessing the magnitude and orientation of asymmetry in the impact of oil price shocks. Following the work of Kilian and Vigfusson's (2011), recently Deheri and Ramachandran (2023) utilised the slope and impulse response tests to ascertain the existence of asymmetry in the reaction of diverse macroeconomic variables (such as industrial production, price level, exchange rate, among others) in India to oil price shocks.

Based on the extant literature, the scholarly works of Chattopadhyay and Mitra (2015) and Pal and Mitra (2016) represent the exclusive endeavours that have scrutinised the asymmetric transmission of fluctuations in crude oil prices to oil product prices in the Indian context. These studies have identified compelling evidence of asymmetry in the influence of crude oil prices on oil product prices using the nonlinear autoregressive distributed lag (ARDL) models. However, these studies have not placed significant emphasis on the extent and orientation of asymmetry within the connection, resulting in perplexing outcomes. The impact of oil prices' asymmetry may be influenced by the size and direction of oil shocks, as suggested by Kilian and Vigfusson (2011) and Herrera *et. al.* (2011). Notwithstanding, extant literature, particularly in the Indian context, has yet to scrutinise this facet. Therefore, a meticulous assessment of the incidence of asymmetry and nonlinearity in the effects of crude oil prices on oil product pricing in India is imperative.

This study exhibits notable distinctions from prior research conducted in India across various dimensions. The present article's contribution can be bifurcated into two distinct parts. First, we examine the potential nonlinearity in the impact of crude oil price shocks on oil product prices. To achieve this objective, the slope tests proposed by Mork (1989) and Kilian and Vigfusson (2011) are employed. Secondly, the present study investigates the potential symmetry of impulsive reactions in oil product prices in response to minor and major positive and negative oil shocks. In other words, we sought to determine if the response of oil product prices is nonlinearly reliant on the magnitude of crude oil price shocks, for which we depend on the impulse response function (IRF) test developed by Kilian and Vigfusson (2011). The empirical results suggest that, regardless of the shock size, most oil products prices in India respond asymmetrically to global crude oil price shocks.

Table 1: A Brief Review of the Empirical Literature On The Presence of Asymmetry Between Oil Product Prices And Crude Oil Prices

Study	Period	Country	Methodology	Findings
Borenstein *et. al.* (1997)	1986-1992	United States	Cointegration, Simple Adjustment Lag model	Gasoline price responds more quickly to increases in crude oil prices than to decreases.
Godby *et. al.* (2000)	1990-1996	Canada	Threshold Error Correction model	Retail prices of gasoline respond asymmetrically to crude oil price
Bachmeier and Griffin (2003)	1985-1998	United States	Cointegration and Error Correction model (ECM)	There is no indication of asymmetry in the reaction of wholesale gasoline prices to changes in crude oil prices.
Driffield *et. al.* (2003)	1973-2000	United Kingdom	Cointegration and ECM	Petrol retail prices react asymmetrically to oil shock.
Bettendorf *et. al.* (2003)	1996-2001	Netherland	Asymmetric ECM	The is asymmetry in the relationship between gasoline and crude oil prices is unclear.
Berument *et. al.* (2004)	2005-2012	France, Greece, Italy, Spain and Turkey	Cointegration and asymmetric ECM	Petroleum products in all nations under consideration react asymmetrically to changes in crude oil prices.

Grasso and Manera (2007)	1985–2003	France, Germany, Italy, Spain and the UK	Threshold Cointegration, Symmetric and Asymmetric ECM	There is an asymmetric link between gasoline and crude oil prices.
Rao and Rao (2008)	1978-2004	United States	Cointegration and ECM	Absence of asymmetry in the response of gasoline prices to oil shocks
Adilov and Samavati (2009)	2000-2007	United States	Asymmetric price response model	No evidence of asymmetry in the impact oil shocks on gasoline prices
Liu *et. al.* (2010)	2004-2009	New Zealand	Cointegration and Asymmetric ECM	Petrol prices react symmetrically to changes in crude oil prices, but diesel prices respond asymmetrically.
Alom and Ritson (2012)	2004-2011	New Zealand	Asymmetric cointegration model	Diesel prices react symmetrically to changes in crude oil prices, but petrol prices respond asymmetrically.
Bumpass *et. al.* (2015)	1976-2012	United State Cities	Cointegration and Threshold Autoregressive Model	In the long run, retail gasoline prices react asymmetrically to changes in oil prices.

Table 1: A Brief Review Of The Empirical Literature On The Presence of Asymmetry Between Oil Product Prices and Crude Oil Prices (Cont….)

Karagiannis *et. al.* (2015)	2002-2011	Germany, France, Italy and Spain	Cointegration, Threshold Autoregressive, and ECM	In all four economies, retail gasoline prices react symmetrically to oil shocks.
Boroumand *et. al.* (2016)	1990-2011	France	Markov Switching model	Fuel prices respond asymmetrically to oil price changes
Chua (2017)	2007-2014	Australia	Threshold error correction model	Only four out of twenty-eight retail gas stations have asymmetric pricing adjustment.
Rahman (2018)	1978-2014	United States	Bivariate Generalized Autoregressive Conditional Heteroscedasticity in mean model	Asymmetries in the reaction of gasoline prices to oil shocks were discovered.
Valadkhani and Smyth (2018)	1998-2017	Australia	Asymmetric mixed data sampling model	Found asymmetries in retail petrol prices to daily changes in crude oil prices.

The subsequent sections of this paper are structured in the following manner: The second section of the paper delineates the data and methodology employed in the study. The third section of this study presents the empirical findings and subsequent discussion. The paper is concluded in Section 4, followed by a discussion of potential policy implications.

DATA AND METHODOLOGY

Data

The Indian market for oil products exhibits a wide range of diversity. A wide range of oil-based commodities, such as lubricants, aviation turbine fuel, bitumen, furnace oil, petrol, high-speed diesel, kerosene, liquefied petroleum gas (LPG), and naphtha, are utilized on a daily basis. Prior to 2014, the government regulated the prices of petrol and diesel. However, subsequently, the prices were deregulated and determined by the interplay of market forces of supply and demand. Besides, the government offers subsidies on significant commodities, including LPG and paraffin, as a measure to shield consumers from the impact of escalating global crude oil prices. The prices of the remaining oil products are determined by the market. The retail prices of oil products in India exhibit significant variation both inter-state and intra-state, owing to the presence of diverse transportation costs and intricate tax structures. Because of this reason, we used the wholesale price index (WPI) of oil products, namely aviation turbine fuel (atf_t), bitumen ($bitu_t$), furnace oil (fo_t), high-speed diesel (hsd_t), kerosene (ker_t),), liquefied petroleum gas (lpg_t), lubricants (lub_t), naphtha (nap_t), and petrol (pet_t) instead of the actual retail prices in our analysis. Another reason for using WPI data is that absence of consistent monthly data on the retail prices of most of the oil products. The present study make use of more recent data available on the above-mentioned oil products for the analysis. Monthly data from April 2000 to March 2022 on global crude oil prices ($coil_t$) and oil products prices in India are used, which is based on the availability of the data. The WPI of the oil products come from the official website of the Office of the Economic Advisor, Department for Promotion of Industry and International Trade[1]. We sourced the international price of crude oil (Indian Basket) from the official website of the Petroleum Planning and Analysis Cell[2], Government of India. The Indian Basket of crude oil is made up of the averages of Oman and Dubai for sour grades and Brent (Dated) for sweet grades.

[1] https://eaindustry.nic.in/download_data_1112.asp
[2] https://www.ppac.gov.in/content/149_1_PricesPetroleum.aspx

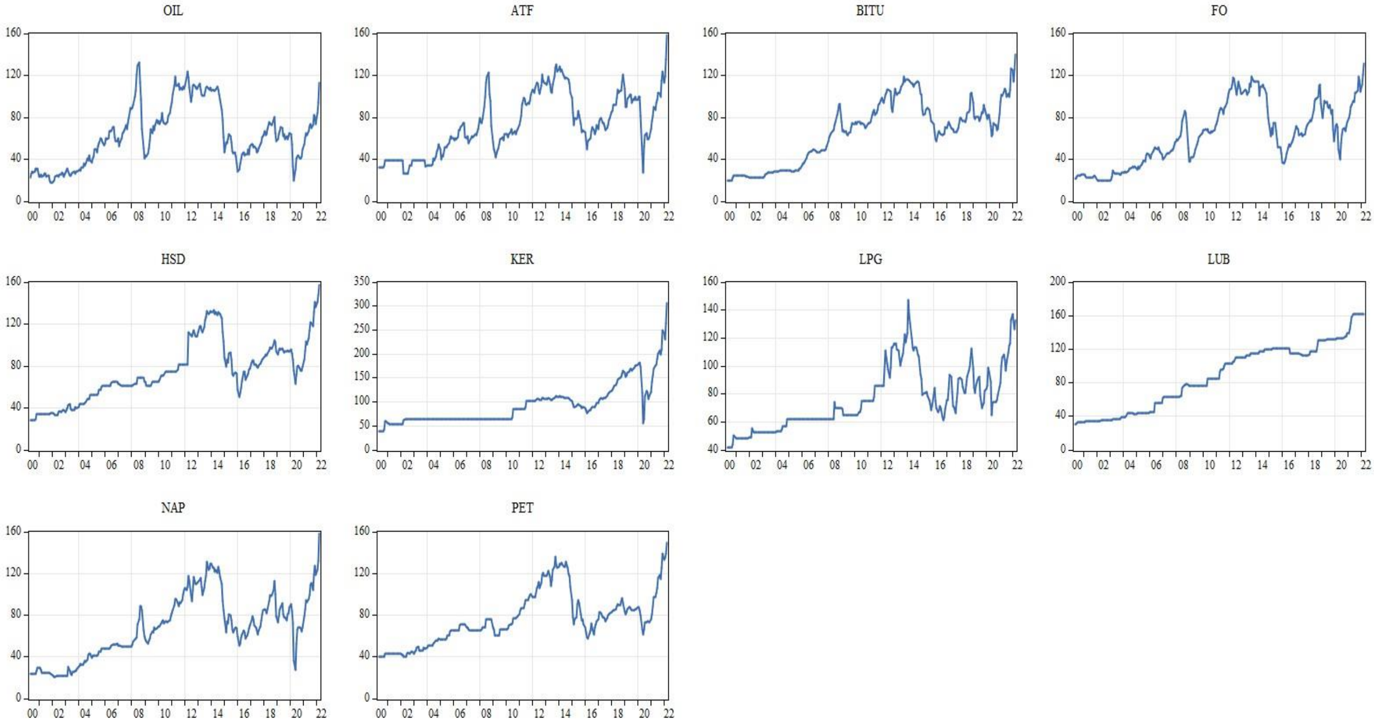


Figure 1: Plot of Global Crude Oil Prices and India's Oil Products Prices

Table 2: Descriptive Statistics

Statistics	$coil_t$	atf_t	$bitu_t$	fo_t	hsd_t	ker_t	lpg_t	lub_t	nap_t	pet_t
Mean	4.03	4.22	4.07	4.02	4.24	4.46	4.29	4.36	4.09	4.29
Median	4.10	4.23	4.26	4.15	4.27	4.46	4.25	4.49	4.21	4.28
Maximum	4.89	5.07	4.95	4.88	5.06	5.73	4.99	5.09	5.06	5.01
Minimum	2.90	3.29	2.98	2.98	3.33	3.67	3.74	3.44	3.04	3.69
Std. Dev.	0.50	0.42	0.55	0.54	0.41	0.40	0.28	0.51	0.52	0.33
Skewness	-0.36	-0.33	-0.60	-0.42	-0.34	0.64	0.30	-0.45	-0.53	0.00
Kurtosis	2.18	2.10	1.97	2.00	2.42	2.87	2.34	1.74	2.26	2.32
Jarque-Bera	13.31	13.53	27.58	18.78	8.74	18.34	8.64	26.48	18.35	5.12
Probability	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.08
Observations	264	264	264	264	264	264	264	264	264	264

Table 3: Pairwise Correlation Among Variables

	$coil_t$	atf_t	$bitu_t$	fo_t	hsd_t	ker_t	lpg_t	lub_t	nap_t	pet_t
$coil_t$	1									
atf_t	0.87	1								
$bitu_t$	0.80	0.90	1							
fo_t	0.88	0.96	0.95	1						
hsd_t	0.80	0.93	0.94	0.96	1					
ker_t	0.47	0.74	0.75	0.76	0.82	1				
lpg_t	0.72	0.88	0.89	0.90	0.95	0.83	1			
lub_t	0.62	0.81	0.94	0.88	0.90	0.84	0.86	1		
nap_t	0.87	0.95	0.96	0.98	0.96	0.75	0.91	0.88	1	
pet_t	0.84	0.94	0.93	0.96	0.98	0.78	0.95	0.85	0.96	1

Source: Authors' own calculation

Figure 1 shows the plot of oil products prices and crude oil prices. The descriptive statistics of the variables are shown in Table 2. The Jarque Bera test statistics for all the variables except the petrol prices are significant, implying they are not normally distributed. The pairwise correlation matrix reported in Table 3 indicates that all the oil products prices positively correlate with the global crude oil prices. Except for the kerosene prices, all-other oil products prices under consideration appear to be strongly correlated with the movement in global crude oil prices.

Methodology

To detect asymmetry and nonlinearity in the effect of crude oil shocks on oil products prices, we employ Mork's (1989) slope test. In addition, we apply Kilian and Vigfusson's (2011) innovative IRF test. The above-mentioned tests require an estimate of the non-linear VAR model of the following form:

$$o_t = \gamma_{10} + \sum_{i=1}^{p} \gamma_{1i} y_{t-i} + \sum_{i=1}^{p} \gamma_{2i} o_{t-i} + \varepsilon_{1t} \quad (1a)$$

$$y_t = \delta_{10} + \sum_{i=1}^{p} \delta_{1i} y_{t-i} + \sum_{i=0}^{p} \delta_{2i} o_{t-i} + \sum_{i=0}^{p} \delta_{3i} o_{t-i}^{+} + \varepsilon_{2t} \quad (1b)$$

where, o_t is the log percentage change in crude oil price, and y_t represents the log percentage change in macroeconomic variable of interest (in our case, oil products prices) respectively. The variable o_t^{+} is a non-linear transformation of the crude oil price (censored oil price) proposed by Mork (1989)[3] which is defined as follows:

$$o_t^{+} = max\{0, lnoil_t - lnoil_{t-1})$$

where, $lnoil_t$ denotes the natural logarithm of the nominal crude oil price.

[3] We use Mork's (1989) measure of oil price increase since it is largely compatible with the theoretical literature on the asymmetric influence of oil price changes on macroeconomic variables.

The approach mentioned above possesses a noteworthy benefit of consistently computing the dynamic impulse response, even in the absence of true knowledge regarding the data-generating process. The bivariate model has been maintained as the incorporation of supplementary variables does not affect the economic point of interest and does not require the model to be estimated consistently, as per the findings of Kilian and Vigfusson (2011). Kilian and Vigfusson (2011) developed two tests, the slope test and the IRF test, for the purpose of detecting asymmetry and nonlinearity. The assessment of non-linearity using the conventional slope-based test, as suggested by Mork (1989), requires an evaluation of the joint significance of the lagged impact of upward (o_t^+) and downward (o_t^-) movements in oil prices on the dependent variable y_t. This approach is akin to testing the null hypothesis presented in Eqn. (1b).

$$H_0: \delta_{31} = \delta_{32} =\ldots.= \delta_{3p} = 0 \qquad (2)$$

Kilian and Vigfusson (2011) have suggested that the present values of, o_t^+ and o_t^- could potentially possess significant predictive ability for y_t. Accordingly, they modified the slope test as shown in Eqn. (1b) by incorporating the prevailing positive and negative changes in crude oil prices. Consequently, the null hypothesis pertaining to the modified slope test of Kilian and Vigfusson (2011) can be expressed as follows:

$$H_0: \delta_{30} = \delta_{31} = \delta_{32} =, \ldots., = \delta_{3p} = 0 \qquad (3)$$

The rejection of the null hypothesis in eqn. (3) suggests the presence of a non-linear relationship between crude oil prices and oil product prices. On the contrary, the acceptance of the null hypothesis indicates that the influence of fluctuations in crude oil prices is either linear or symmetrical.

The utilisation of the slope test may result in misleading conclusions due to its failure to consider the magnitude and orientation of asymmetry. In this context, Kilian and Vigfusson (2011) have suggested the implementation of the IRF-based symmetry test as a means of assessing the magnitude and direction of asymmetry. The determination of asymmetry in small and large oil shocks is contingent upon the amplitude of said shocks, rendering it an indispensable component of the test. Also, as pointed out by Kilian and Vigfusson (2011) that in the case of datasets that are identical, the hypothesis of symmetry in the slope test is more likely to be accepted. However, the same may not hold true for the IRF test. The investigation of the null hypothesis is required for the impulse response test, which involves:

$$H_0: I_y(h, \delta) = -I_y(h, -\delta) \qquad (4)$$

The impulse responses of variable y with respect to positive and negative oil price shocks of magnitude δ are denoted by $I_y(h, \delta)$ and $-I_y(h, -\delta)$ respectively in eqn. (4). The IRF test investigate the symmetry of the response of y_t to a positive oil shock and the negative response of y_t to a negative oil shock at a predetermined horizon. In the event that the null hypothesis is rejected at a specified horizon 'h', it can be concluded that the alternative hypothesis is accepted, indicating that the reactions of oil product prices to positive and negative oil price shocks are not statistically symmetrical. The impulse responses of the non-linear vector autoregression (VAR) are generated through the utilisation of the nonlinear impulse response function (NIRF) developed by Kilian and Vigfusson (2011).

EMPIRICAL RESULTS AND DISCUSSION

Prior to estimating the models, we used the Augmented Dickey-Fuller (ADF) (Dickey & Fuller, 1979) and Phillips-Perron (PP) (Phillips & Perron, 1988) tests to investigate the stationary properties of the data. The results show (see Table 4) that the natural logarithm of global crude oil prices and all oil product prices are constant at the first difference. In other words, they are non-stationary and integrated order of one (i.e., it follows an I (1) data producing process). The variables being I (1) raises the prospect of cointegration between the prices of oil and its byproducts.

The co-integration test proposed by Bayer and Hanck (2013) was utilised to determine the existence of co-integration. The utilisation of the Bayer and Hanck (2013) cointegration test offers the benefit of producing joint test statistics through the utilisation of estimation results from multiple cointegration tests, such as Engle and Granger (1987), Johansen (1988), Boswijk (1994), and Baneerjee *et. al.* (1998). Hence, we don’t have to rely on multiple cointegration tests individually to assess long-run relationships. The Fisher's formulae is employed in the computation of statistical significance, specifically based on the probability values derived from the cointegration tests mentioned earlier (Tursoy & Faisal, 2018). The null hypothesis is rejected, and cointegration is inferred when the combined Fisher's test statistics exceed the critical values at conventional levels of significance. We tested the cointegration between crud oil prices and oil product prices individually. The findings indicate that the combined Fisher's test statistics are below the critical values linked with a 5% level of significance, indicating absence of cointegration between crude oil prices and oil product prices in India, as presented in Table 5. We also used the bounds test based on linear and non-linear autoregressive distributed lag (ARDL) models (Pesaran *et. al.*, 2001; Shin *et. al.*, 2014) and Gregory and Hansen's (1996) structural break cointegration test. However, we found no long-run relationship between global crude oil and oil product prices. As a result, we proceed with the technique advanced by Kilian and Vigfusson (2011).

In order to estimate the non-linear VAR model proposed by Kilian and Vigfusson (2011), first we converted all the variables into month-on-month log percentage changes to ensure stationarity as the estimation of VAR model requires stationary variables. Selecting the suitable lag length of the variables is a crucial aspect in the estimation of a Vector Autoregression (VAR) model. Empirical research commonly employs lag selection criteria, including but not limited to the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Although parsimony is often desirable in model selection, it is important to note that strict adherence to such criteria may lead to erroneous conclusions in small sample sizes and may also compromise the validity of inferences drawn from non-linear models (Herrera *et. al.*, 2015). Hamilton and Herrera (2004) have posited that the adoption of a limited number of lags may have a detrimental impact on the oil price effect, as the reaction of economic activity to oil price shocks is known to be sluggish. Incorporating longer lags is a necessary step to ensure the robustness of a non-linear model. Due to the abovementioned issues, we estimated all the models with lag structures of 12 and 18 months, in accordance with the empirical studies conducted by Herrera *et. al.* (2011) and Serletis and Istiak (2013).

Table 6 presents the outcomes of Mork's (1989) and Kilian and Vigfusson's (2011) slope tests, which are obtained using twelve and eighteen lag structures. The table reports the p-values that correspond to the slope tests, as shown in Eqns. (2) and (3), which are grounded on the Chi-square distribution. The results indicate that, apart from kerosene, the p-values for all other oil product prices were statistically insignificant. This implies that the null hypothesis of symmetry and linearity in the impact of crude oil price fluctuations was not rejected. Based on the findings derived from the slope test, it can be deduced that only the prices of kerosene react non-linearly to variations in the global crude oil prices. As previously noted, an exclusive reliance on slope tests is inadequate for assessing the magnitude and direction of asymmetry in the effects of crude oil price shocks. The IRF test is therefore have been implemented in order to acquire a more comprehensive comprehension of the existence of asymmetry or non-linearity within the relationship.

Table 4: Results of Unit Root Test

	Augmented Dickey-Fuller (ADF)		Phillips-Perron (PP)	
Variables	**Levels**	**1st Difference**	**Levels**	**1st Difference**
$coil_t$	-2.24	-11.85*	-2.11	-11.33*
atf_t	-2.25	-11.67*	-1.93	-12.47*
$bitu_t$	-1.29	-11.82*	-1.21	-10.90*
fo_t	-1.67	-11.16*	-1.45	-11.59*
hsd_t	-1.49	-12.06*	-1.30	-12.03*
ker_t	-0.26	-15.59*	-0.33	-11.21*
lpg_t	-1.90	-13.20*	-1.43	-12.93*
lub_t	-1.21	-13.59*	-1.19	-13.70*
nap_t	-1.34	-12.97*	-1.24	-11.67*
pet_t	-1.28	-10.84*	-0.95	-10.56*

Note: The null hypothesis for both the tests is "series have a unit root". * indicates that the test statistics are significant at 1 percent level of significance.

Source: Authors' estimation

Table 5: Results of Bayer and Hanck (2013) Combined Cointegration test

Fishers Combined Test Statistics	atf_t	$bitu_t$	fo_t	hsd_t	ker_t	lpg_t	lub_t	nap_t	pet_t
ENG & GRA-JOHAN	2.90	7.36	5.32	3.62	1.57	6.74	6.18	5.09	5.55
ENG & GRA – JOHAN – BOS – BDM	4.52	9.38	9.34	7.17	469	9.24	9.66	7.92	9.68

Notes: ENG & GRA- JOHAN is Fisher's combined test statistic for Engle and Granger (1987) and Johansen (1988) cointegration tests whereas ENG & GRA – JOHAN – BOS – BDM is the combined test statistic for Engle and Granger (1987), Johansen (1988), Boswijk (1994) and Baneerjee et. al. (1998) cointegration tests. The critical values for the ENG & GRA- JOHAN and ENG & GRA – JOHAN – BOS – BDM at 5 percent significance levels is 11.22 and 21.23, respectively.

Source: Author's estimation.

The findings of the Impulse Response Function (IRF) test, which was conducted using a 12-lag estimation, are presented in Table 7. We reported the results with respect to both 1 and 2 standard deviations (S.D.) shocks as the results of IRF tests sensitive to the size of the shocks. It can be observed that for the models corresponding to atf_t hsd_t, ker_t, fo_t, $bitu_t$ and lub_t,, the p-values for both 1 standard deviation $(\hat{\sigma})$ and 2 standard deviation $(2\hat{\sigma})$ shocks are deemed significant. This suggests that the impulse response of these oil product prices to both positive and negative crude oil price shocks of small and large magnitudes are not statistically symmetrical. The statistical significance of the p-values for both 1 standard deviation and 2 standard deviation shocks in case of lpg_t, remains insignificant across all forecast horizons. This suggests that the prices of liquefied petroleum gas (LPG) exhibit a symmetric response to both positive and negative shocks in global crude oil prices. One plausible explanation for the lack of asymmetry could be attributed to the significant regulation of LPG prices in India. The government provides substantial subsidies for LPG in order to mitigate the adverse effects of escalating global crude oil prices on consumers. The result for LPG aligns with the finding of Chattopadhyay and Mitra's (2015) study, which revealed a lack of asymmetry in the response of LPG to fluctuations in global crude oil prices in the context of India.

The p-values associated with a one standard deviation shock in petrol prices is found to be insignificant for all forecast horizons. In instances where the magnitude of the oil shock reached 2 standard deviations, statistical significance was observed across the majority of horizons. The findings suggest that only large oil shocks exhibit asymmetric effects on petrol prices in India. The present findings are incongruent with the outcomes of Chattopadhyay and Mitra (2015) and Pal and Mitra (2016), wherein no evidence of asymmetry was detected in the response of petrol prices to variations in crude oil prices. The observed discrepancies in the results can be attributed to variations in the sampling duration and methodologies employed during the study. Next, to check the robustness[4] of the results of the IRF test we estimated all the models with an alternative lag structure of 18 lags. The results are similar to those obtained with 12 lags (see Table 8).

Table 6: Result of Slope test

Variable	Mork (1989)		Kilian and Vigfusson (2011)	
	$p = 12$	$p = 18$	$p = 12$	$p = 18$
atf_t	0.78	0.37	0.83	0.42
$bitu_t$	0.46	0.21	0.46	0.21
fo_t	0.27	0.20	0.32	0.25
hsd_t	0.52	0.20	0.56	0.19
ker_t	0.08	0.02	0.03	0.01
lpg_t	0.43	0.45	0.32	0.34
lub_t	0.34	0.30	0.39	0.33
nap_t	0.31	0.15	0.37	0.19
pet_t	0.28	0.49	0.35	0.55

Note: The numbers are p-values for the Wald test statistics.
Source: Authors' estimation

In addition, in order to conduct a comparative analysis, we generated graphical representations of the impulse responses of oil product prices in response to both positive and negative crude oil price shocks (see, Figures 2-10). The response of oil product prices to positive shocks $(I_y(h, \delta))$, is represented by the solid black line, while the response to negative shocks $(-I_y(h, -\delta))$ is indicated by the dashed black line. It is important to note that, to enable effective comparison, the reactions of oil product prices to negative oil shocks have been depicted as the mirror image. A discernible variation can be noted in the reactions of various oil commodities' prices to upward and downward 1 standard deviation crude oil price perturbations. As the magnitude of shocks increases to 2 standard deviations, the disparity becomes more pronounced. The figures indicate

[4] We also used Hamilton and Herera's (2004) net oil price increase over the previous 1 year as alternative measures of censored oil price variables for robustness check. The results, however, appear to be similar to what we obtained with Mork's (1989) measure of oil price increase. The results are not reported in the paper, but they are available on request.

that a doubling of the magnitude of shocks results in a proportional increase in the impulse responses of oil product prices, regardless of the direction of the shock. The findings suggest that the impulse responses of atf_t hsd_t, fo_t, $bitu_t$ and pet_t demonstrate a greater impact of positive oil shocks compared to negative oil shocks. In other words, an increase in crude oil prices results in a more rapid escalation of prices for associated products, whereas a decrease in crude oil prices yields a comparatively slower decline in prices for these products. This observation is in line with the phenomenon known as the "rockets-and-feathers effects." However, in the case of LPG, lubricants, and kerosene, negative oil shocks have more pronounced effects than positive ones in most horizons. The phenomenon under consideration could potentially be ascribed to the occurrence of downward price expectation spirals that tend to manifest during periods of economic contraction.

Table 7: Probability values for the null hypothesis ($H_0: I_y(h,\delta) = -I_y(h,-\delta)$) for $h = 1,2,3,\ldots.,12$)

Horizon (H)	atf_t		$bitu_t$		fo_t		hsd_t		ker_t		lpg_t		lub_t		nap_t		pet_t	
	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$
1	0.06	0.28	0.95	0.99	0.59	0.76	0.72	0.56	0.91	0.84	0.53	0.51	0.01	0.75	0.33	0.23	0.34	0.26
2	0.12	0.22	0.80	1.00	0.86	0.95	0.58	0.56	0.00	0.17	0.82	0.74	0.00	0.74	0.01	0.01	0.62	0.53
3	0.06	0.32	0.93	0.88	0.22	0.75	0.15	0.74	0.00	0.01	0.16	0.65	0.00	0.00	0.01	0.02	0.29	0.72
4	0.00	0.20	0.98	0.93	0.05	0.52	0.04	0.26	0.00	0.00	0.25	0.80	0.00	0.00	0.00	0.00	0.26	0.53
5	0.00	0.30	0.97	0.97	0.08	0.66	0.00	0.00	0.00	0.00	0.30	0.86	0.00	0.00	0.00	0.00	0.12	0.00
6	0.00	0.00	0.85	0.94	0.01	0.25	0.00	0.00	0.00	0.00	0.41	0.87	0.00	0.00	0.00	0.00	0.07	0.00
7	0.00	0.00	0.81	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.69	0.00	0.00	0.00	0.00	0.11	0.00
8	0.00	0.00	0.06	0.16	0.01	0.01	0.00	0.00	0.00	0.00	0.30	0.29	0.00	0.00	0.00	0.00	0.16	0.00
9	0.00	0.00	0.00	0.21	0.01	0.01	0.00	0.00	0.00	0.00	0.39	0.18	0.00	0.00	0.00	0.00	0.11	0.00
10	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.47	0.17	0.00	0.00	0.00	0.00	0.14	0.00
11	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.56	0.19	0.00	0.00	0.00	0.00	0.03	0.00
12	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.47	0.19	0.00	0.00	0.00	0.00	0.01	0.00

Table 8: Probability values for the null hypothesis ($H_0: I_y(h,\delta) = -I_y(h,-\delta)$) for $h = 1,2,3,\ldots.,12$)

Horizon (H)	atf_t		$bitu_t$		fo_t		hsd_t		ker_t		lpg_t		lub_t		nap_t		pet_t	
	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$	$\hat{\sigma}$	$2\hat{\sigma}$
1	0.29	0.62	0.51	0.91	0.55	0.96	0.11	0.66	0.58	0.69	0.73	0.87	0.51	0.73	0.26	0.60	0.01	0.11
2	0.57	0.53	0.47	0.84	0.78	0.95	0.14	0.36	0.00	0.14	0.94	0.98	0.00	0.52	0.00	0.78	0.02	0.19
3	0.41	0.74	0.65	0.75	0.38	0.71	0.05	0.38	0.00	0.05	0.48	0.99	0.00	0.14	0.01	0.88	0.00	0.01
4	0.04	0.52	0.80	0.29	0.50	0.76	0.09	0.39	0.00	0.09	0.44	1.00	0.00	0.02	0.00	0.01	0.00	0.00
5	0.07	0.61	0.78	0.35	0.64	0.83	0.02	0.00	0.00	0.00	0.52	0.37	0.00	0.01	0.00	0.00	0.00	0.00
6	0.00	0.04	0.87	0.48	0.01	0.89	0.04	0.00	0.00	0.00	0.60	0.35	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.84	0.58	0.00	0.00	0.02	0.00	0.00	0.00	0.36	0.25	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.17	0.64	0.00	0.01	0.02	0.00	0.00	0.00	0.29	0.22	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.09	0.02	0.00	0.01	0.01	0.00	0.00	0.00	0.37	0.30	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.32	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.43	0.19	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.23	0.23	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Results are based on 5000 simulations of Eqn. (1) with 18 lags.

Source: Author's estimation

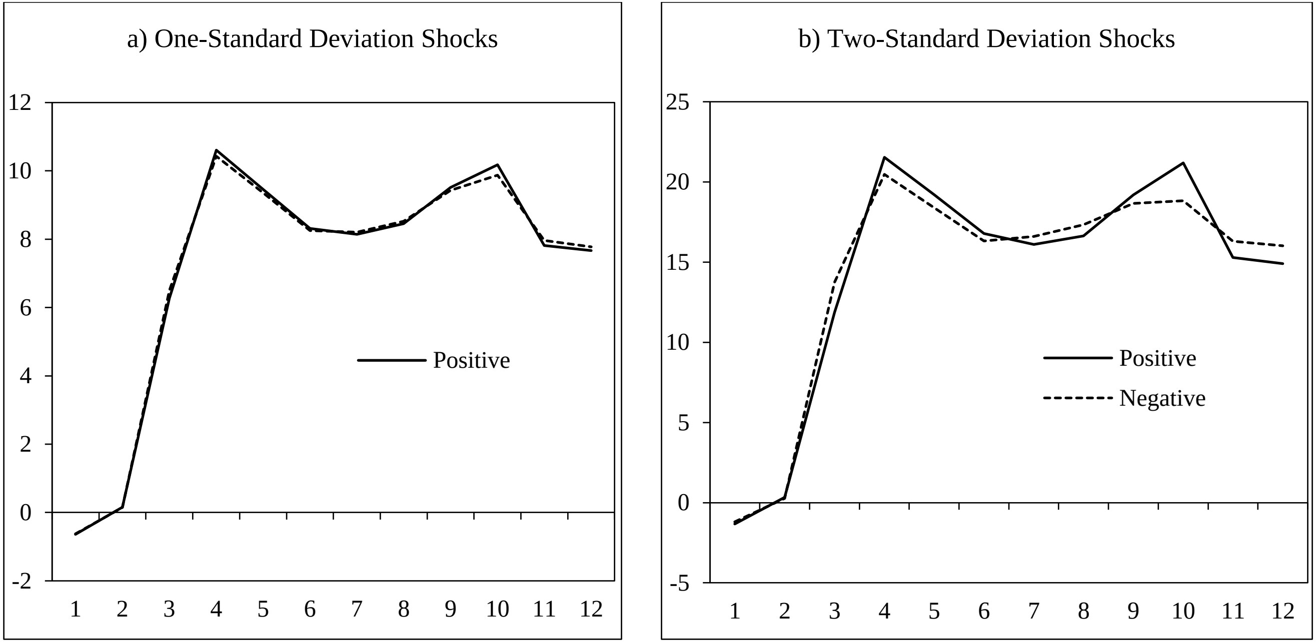


Figure 2: Response of atf_t to Positive and Negative Crude Oil Price Shocks

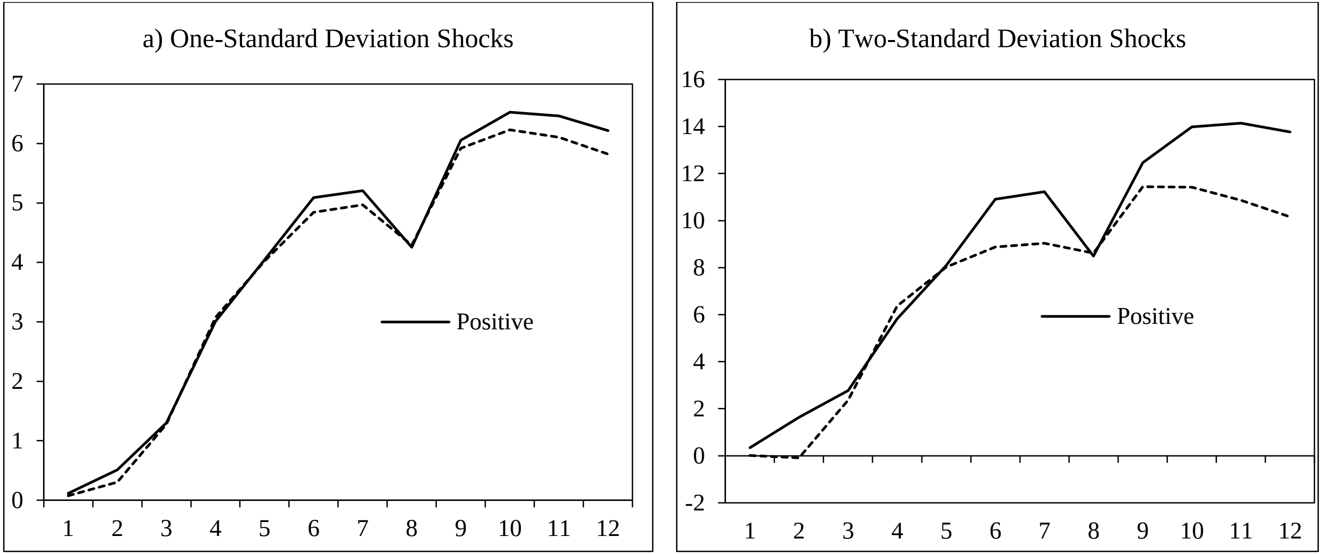


Figure 3: Response of $bitu_t$ to Positive and Negative Crude Oil Price Shocks

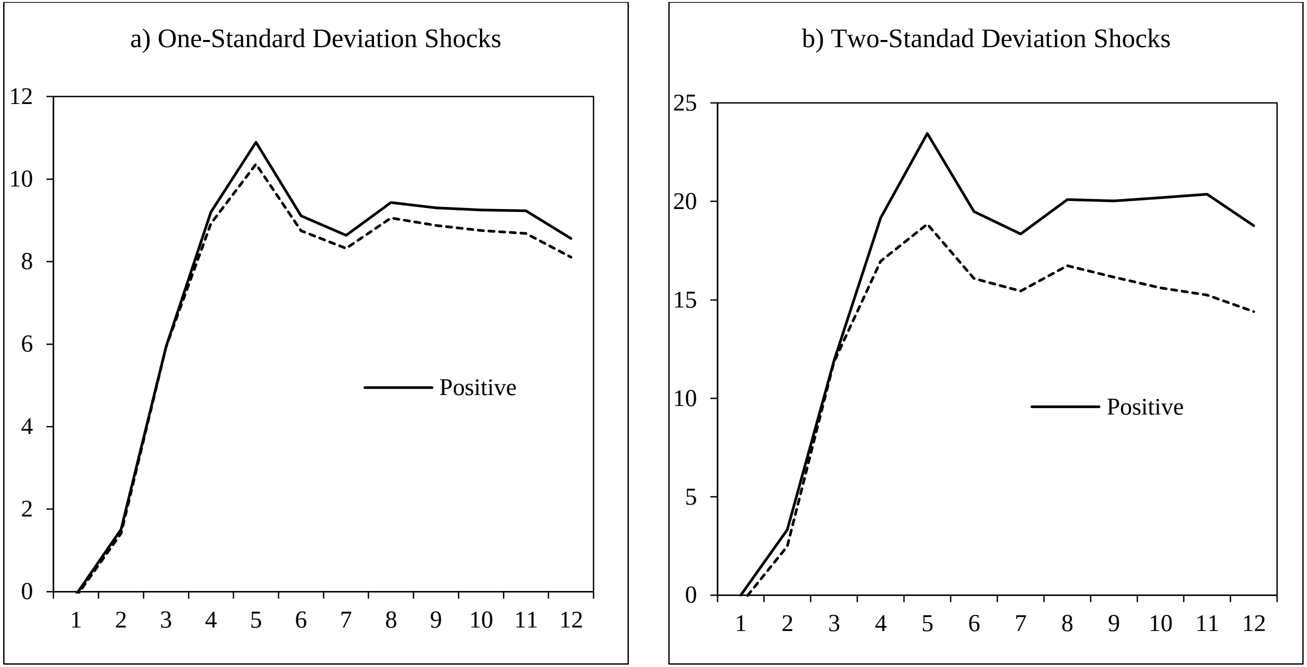


Figure 4: Response of fo_t to Positive and Negative Crude Oil Price Shocks

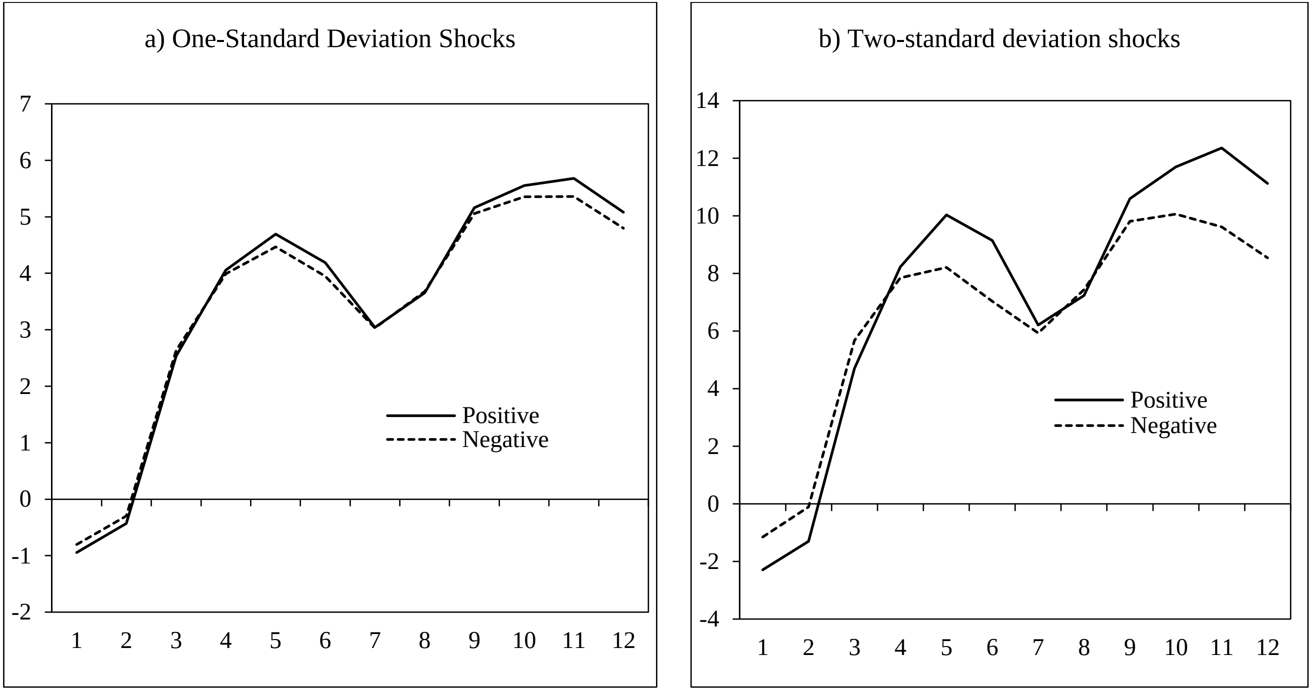


Figure 5: Response of hsd_t to Positive and Negative Crude Oil Price Shocks

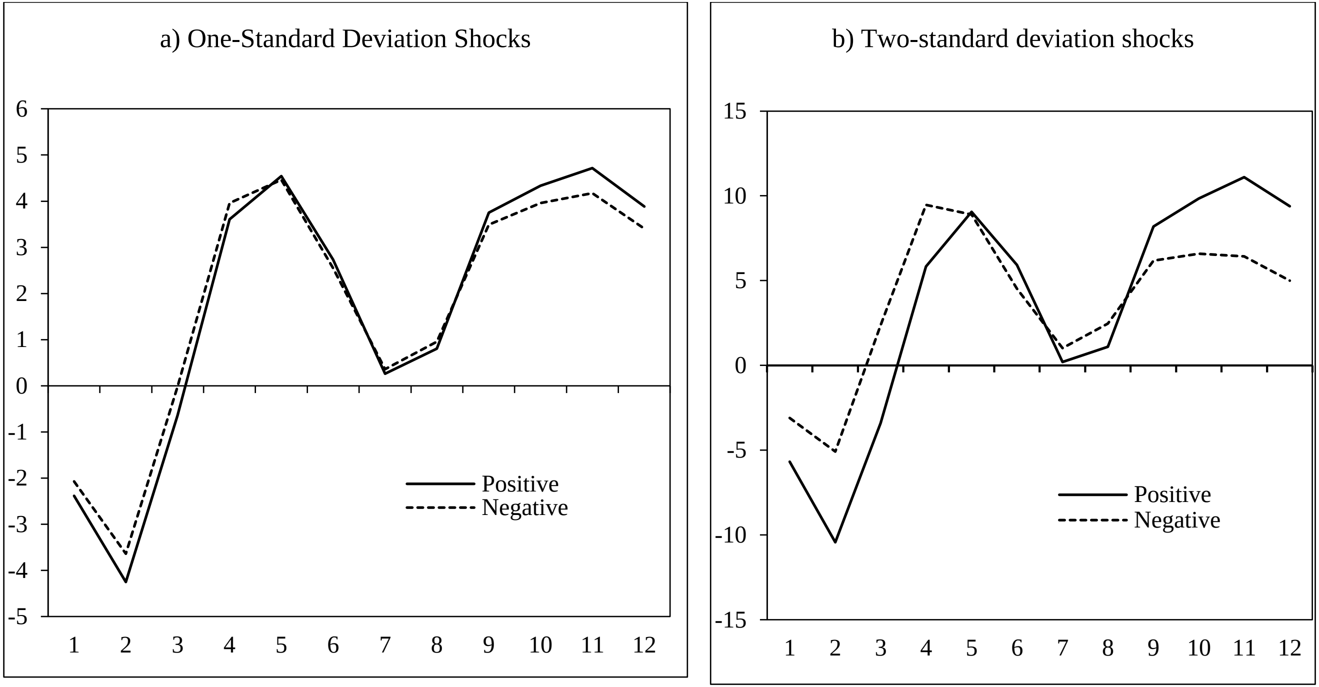


Figure 6: Response of ker_t to Positive and Negative Crude Oil Price Shocks

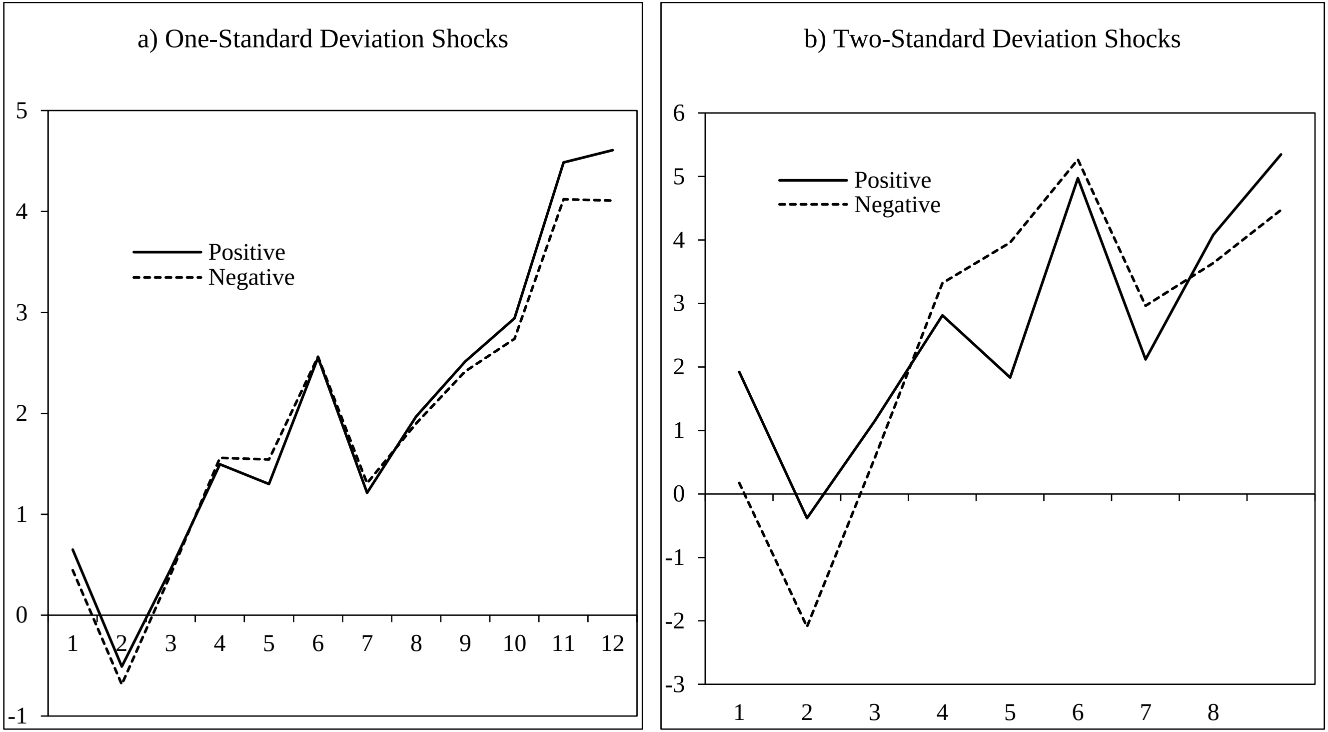
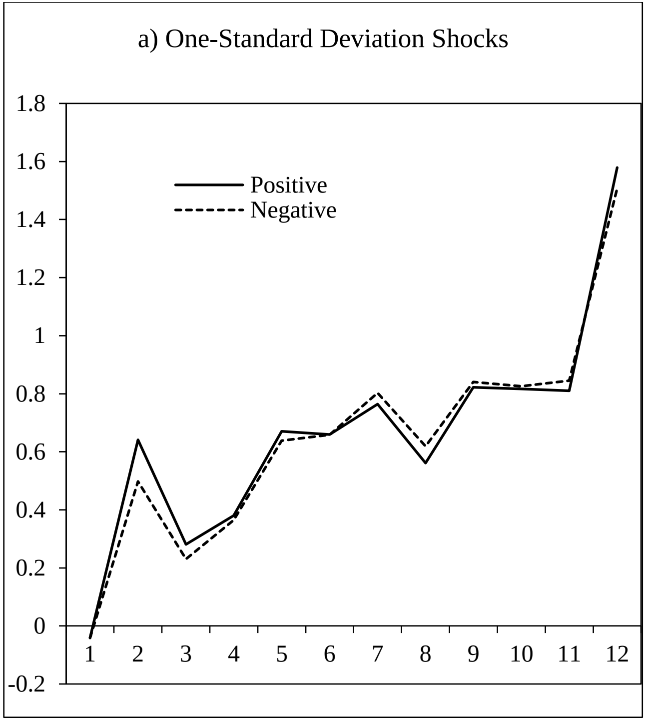


Figure 7: Response of lpg_t to Positive and Negative Crude Oil Price Shocks



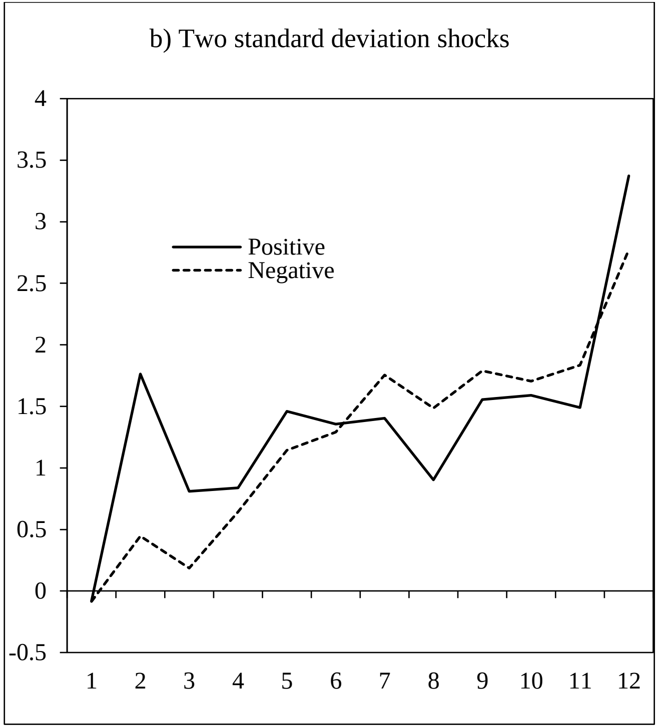


Figure 8: Response of lub_t to Positive and Negative Crude Oil Price Shocks

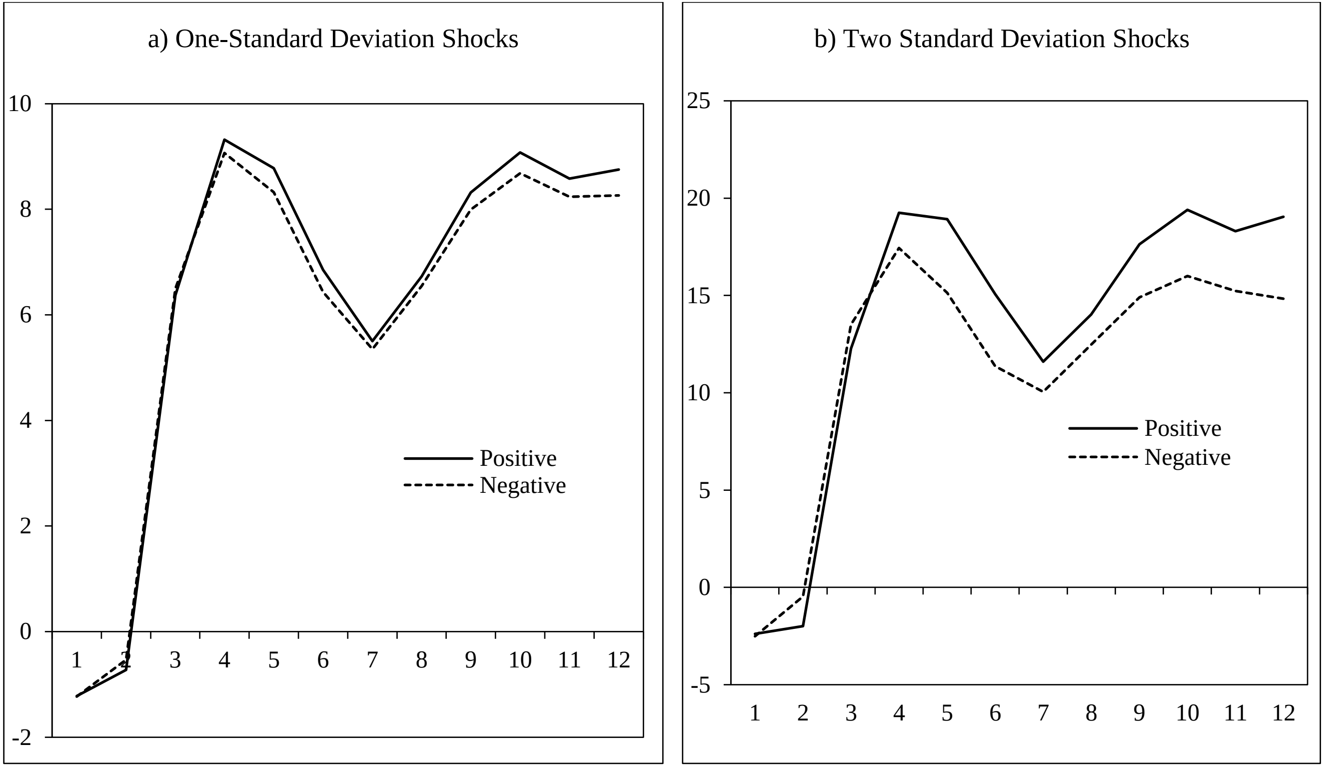
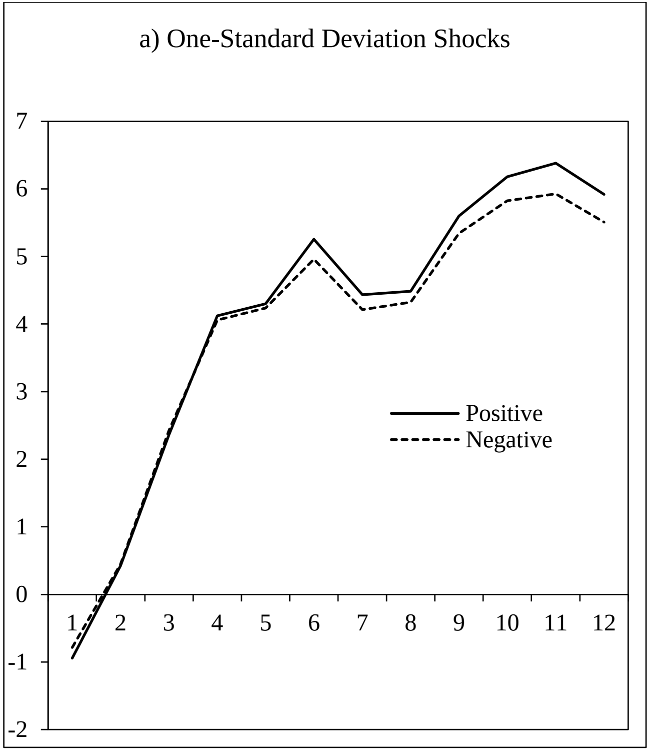


Figure 9: Response of nap_t to Positive and Negative Crude Oil Price Shocks



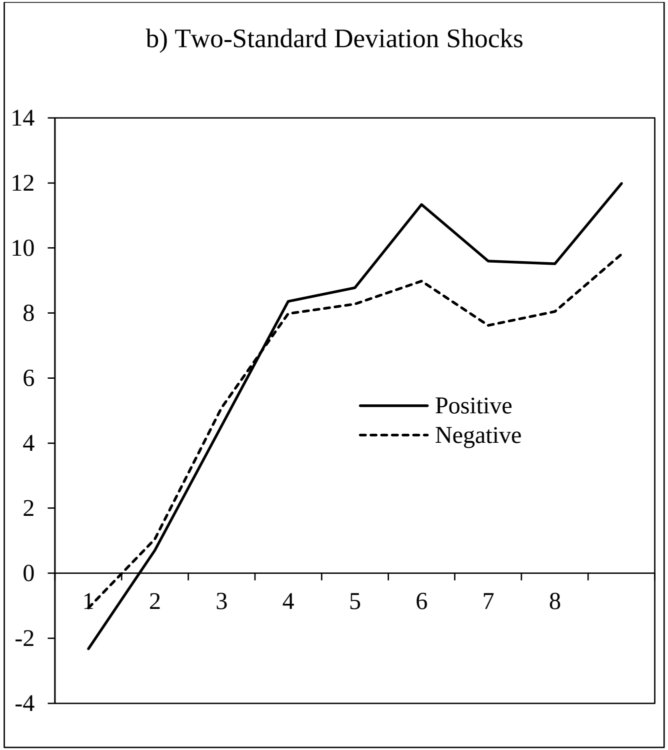


Figure 10: Response of pet_t to Positive and Negative Crude Oil Price Shocks

The monopolistic position of Indian oil market businesses may be regarded as a significant factor in producing asymmetric responses in major oil product pricing such as gasoline and diesel. Large public-sector firms dominate India's oil industry. Because of their monopolistic position, these corporations do not lower the prices of major oil products such as gasoline and diesel when global crude oil prices fall, instead booking anomalous profits by pricing their goods above their marginal cost, which results in a slower response of petrol and diesel prices to falls in crude oil prices, resulting in an asymmetric reaction (Pal and Mitra, 2016).

An additional factor contributing to the presence of asymmetries may be the taxation levied on oil products by both the Union and state governments of India. The purchase of one litre of petrol or diesel incurs an excise duty ranging from 31% to 32% levied by the Union Government. In addition, the state governments levy value-added taxes on certain goods, with rates varying between 12% and 30%. Furthermore, it is common practise for governments to raise these levies as a means of supplementing revenue during periods of significant decline in global crude oil prices, resulting in a comparatively sluggish response of oil product prices to decreases in crude oil prices.

CONCLUSIONS AND POLICY IMPLICATIONS

The present study investigates the potential non-linear and asymmetric effects of global oil price shocks on the pricing of oil products in India, for which the slope and impulse response function (IRF) tests developed by Mork (1989) and Kilian and Vigfusson (2011) were adopted for the empirical analysis. Based on the results obtained from the slope test, it was observed that the null hypothesis of symmetry and linearity in the impact of crude oil price fluctuations on the majority of oil product prices could not be rejected. The results of the IRF test, on the other hand, reveal evidence of asymmetry in the responses of all oil product prices, except for LPG, to oil shocks of equal magnitude. We rejected the null hypothesis of symmetry in the responses to small and large positive and negative oil price shocks. The results also demonstrate that gasoline prices respond asymmetrically to only large oil shocks. According to the impulse response plots, most oil product prices rise faster in response to positive crude oil shocks but fall more slowly in response to negative crude oil shocks. Overall, the results are consistent with earlier studies and support the existence of the rockets-and-feathers effect in the Indian oil products market.

According to Pal and Mitra (2016) and Deheri and Ramchandran (2023), asymmetric oil price transmission raises consumer welfare losses or deadweight losses in the economy since the decline in crude oil prices is not totally passed on to the end consumer. In this context, our research suggests that the government not allow oil companies to totally control oil product pricing, which seems to be the root cause of the asymmetric response of the majority of oil product prices in India. To transparency in the pricing, the government should establish an impartial organization to ensure that the benefit of decreased crude oil prices is totally passed on to oil products. It will also assist to lessen the deadweight loss in society caused by asymmetries in the transmission of oil prices. Furthermore, governments should ensure that oil firms cannot impose monopoly surcharges on customers. We also urge that the Union and state governments lower oil product taxes to ensure a symmetric transmission of crude oil prices to its byproducts.

The present study sought to identify asymmetry and nonlinearity in the link between global crude oil prices and different oil product prices in India. However, it is important to acknowledge that there exist additional crucial and empirical considerations that fall outside the purview of this study and may warrant exploration in subsequent research endeavors. For example, we did not discriminate between different demand and supply shocks in the global oil market, which might have an asymmetric impact on oil product prices. As a result, it would be interesting to analyze the existence of asymmetry in the relationship between various oil market shocks and oil product prices in various countries. Furthermore, an empirical examination of the sources of asymmetry in the relationship between oil shocks and oil product prices would give additional policy-relevant insights. Furthermore, the results of this article apply to India, a significant oil-importing country. In light of this, it would be interesting to conduct a comparative analysis between oil-importing and exporting nations.

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