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Economic Effects of Global Crude Oil Prices on India: A Time Series Analysis

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Abstract
The dynamics of oil prices is one of the most intriguing economic phenomena that are the subject of numerous pieces of research. Fluctuations in global crude oil prices influence the economy and fuel geo-political and economic tensions across the world. OPEC is the largest supplier of crude oil to nation-states and plays a significant role in controlling these prices. How these prices directly affect India's domestic economy functioning is the main objective of this study. Variables included are Gross Domestic Product, CPI (2015=100) as a measure of the price level, total manufacturing in India, and export of goods and credit included under the current account of the balance of payments. An attempt has been made to study how global crude oil prices set by the OPEC impact these variables in a time series analysis using the Granger causality test and vector auto-regression models. We conclude with favorable results, showing both the short-run and long-run impact of global crude oil prices on these macroeconomic variables.

Keywords: OPEC, Oil Prices, Indian Economy, VAR model, Time series, Macroeconomics, Granger causality, Impulse Response functions.

1. Introduction

"Oil is so significant in the international economy that forecasts of economic growth are routinely qualified with the caveat: 'provided there is no oil shock." Adelman, (1993)
The comment by Morris A. Adelman notes that oil exerts a strong influence on the world economy. As one of the primary factors influencing the volatility of important economic indicators, its price has drawn much attention, and the causal relationship between the price of oil and other variables is confirmed by a wide range of studies. They look at the exchange rate, financial market assets, U.S. interest rate, aggregate output, and the price of goods and services affected by the price of oil – to name a few. OECD (2020)

Termed the 'first truly global energy crisis', Russia's invasion of Ukraine, which began in February 2022, sent shockwaves in the oil market. This crisis – caused especially due to impact on the supply side – is felt increasingly by countries who were already reeling under the effects of the COVID-19 pandemic. Russia, as the key supplier of crude oil, is hit by sanctions and several countries are stepping in to meet global demand. The role of the Organization of Petroleum Exporting Countries (OPEC) is widely discussed in this direction.

The Organization of Petroleum Exporting Countries, or OPEC, is an intergovernmental organization that deals with petroleum policies of 13 major oil-exporting developing nations. Algeria, Angola, Congo,

Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, the United Arab Emirates, and Venezuela make up the consortium recognized as OPEC. The member countries produce about 40 percent of the world's crude oil and their oil exports represent about 60 percent of the total petroleum traded internationally. Because of this market share, OPEC's actions affect international oil prices.

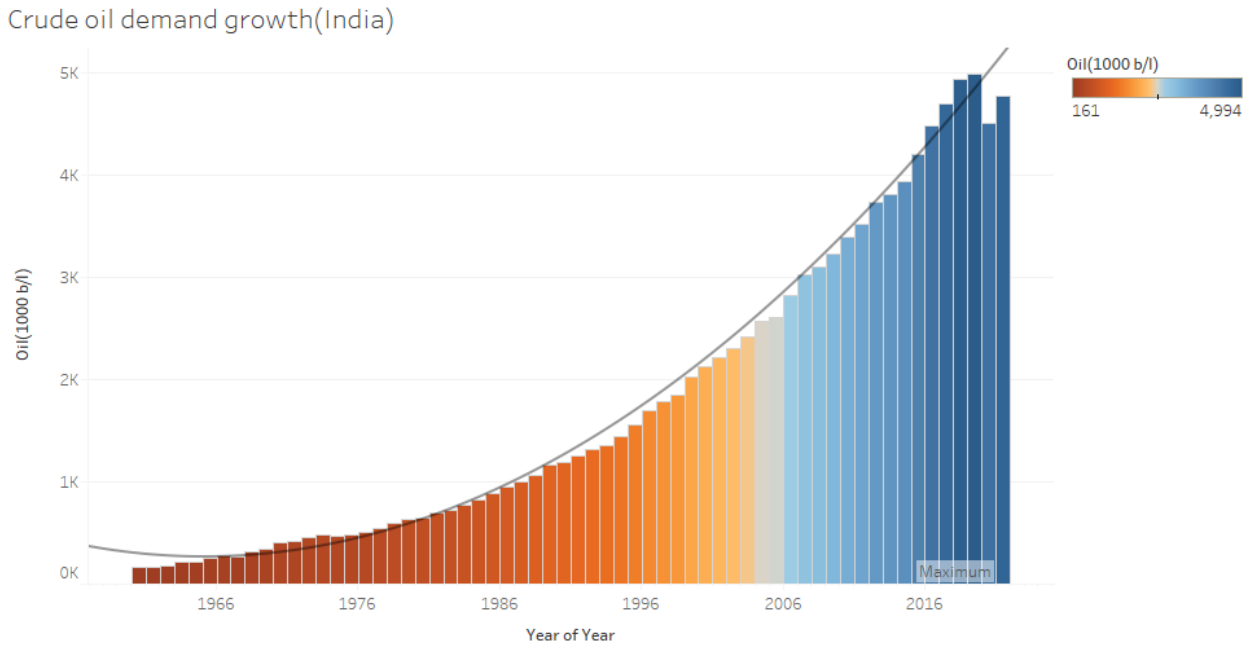

Figure 1: Crude oil demand growth (India)

India is a net importer of oil. India used 129 million tonnes of petroleum products in 2007–2008, and nearly a quarter of its oil requirements were satisfied by local supply. The remainder was mostly imported as crude. Since 2000, India's import bill has been constantly rising Bhattacharya (2009). India's macroeconomic variables were always haunted by the global oil price shocks that occurred. India is also considered one of the largest importers of crude oil from the member countries of OPEC, with 80 percent of total crude oil imports satisfied by OPEC.

Oil-exporting nations are currently suffering an unprecedented twin blow: a worldwide economic downturn brought on by COVID-19 and a collapse in the oil market, with the benchmark price of US crude oil, the West Texas Intermediate, momentarily falling below zero for the first time ever (in April 2020). The International Energy Agency predicts that oil and gas revenues for the number of significant producers would decline by 50 to 85 percent in 2020 compared to 2019, based on an oil price of USD 30 per barrel; however, the losses might be greater depending on future market developments IEA (2020).

As a crude oil importer, India's economy is vastly affected by these oil price fluctuations. The Economic Survey 2023 also noted the effect of high global commodity prices on the country's widening current account deficit, which has ramifications on several economic variables. However, it also noted how softening of oil prices augurs well for India's POL (petroleum, oil, and lubricants) imports. As of February 20, 2023, OPEC's daily basket price stood at $82.02 a barrel.

Consumers' and producers' behavior adjusts to variations in the price of oil and these fluctuations in the oil price have an impact on the economic development of the G-7 nations. As the markets in these nations are more tightly regulated by the government, inflation can be better managed, even though we are unable to corroborate this result for Russia, China, and India. The G-7 countries are the only ones examined in this research since they are interested in maintaining low oil prices in order to maintain economic development.

2. Review Of Literature

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The oil crisis of the 1970s and the subsequent recession gave rise to a great deal of research on the relationship between oil price shocks and macroeconomic variables. The early studies by Rasche, (1977) and Harrison (1984) found an inverse relationship between oil price increase and economic growth. Sadorsky, (1999) and Boyd (2000) too established that the macroeconomic variables of a country can be greatly affected by the volatility of oil prices. Another important point rooted in the research by Sadorsky (1999) and Huang (2005) is that an increase in oil prices affects the economy more vastly than a decrease. This analysis speaks for all developed and developing economies, except for China, as noted by Dua (2010) that China's GDP growth is positively correlated with the world oil price.

Lorde (2009) in his paper empirically investigated the macroeconomic effects of oil price fluctuations in Trinidad and Tobago, a small open oil-producing country, and found an average price-level rise following an oil price shock – the perceived link only discovered post the first oil price shock in the 1970s. A surprising effect is on net exports, which significantly rose with an increase in oil prices, but moved to deficit by the fourth year – indicating a 'Dutch Disease'. Corden (1984) dealt with this phenomenon in detail and decomposed it into: the "spending effect" and the "resource-movement effect", emphasizing on the impacts of a boom in one of the traded goods sectors under various model assumptions regarding the model's factor-market foundations.

Farzanegan (2008) studied the effect of oil price shocks in the Iranian economy using VAR technique and highlighted the asymmetries in how oil price shocks affect economies; for instance, both positive and negative oil price shocks had a considerable impact on inflation. Then they found a significant correlation between rising industrial output and favorable fluctuations in oil prices. They also found that real effective exchange rate appreciation allows us to notice the 'Dutch Disease' condition.

An interesting observation is made by Olomola (2006) that Nigeria's output and inflation rate were not significantly affected by oil price shocks. The study, which conducted VAR and deconstructed the forecast error variance, however, showed that changes in oil prices do have a significant impact on Nigeria's real exchange rates. Additionally, they discovered that the real exchange rates and money supply, which serve as a proxy for GDP rather than the oil price itself, affects the oil price's fluctuations. Thus, it was inferred that, over the long run, money supply—rather than oil—is a more important predictor of real exchange rates than oil price shock.

The study by Antonakakis (2014) investigated the dynamic link between changes in oil prices and the economic policy uncertainty index and found that aggregate demand-driven oil price shocks have a

negative impact on economic policy uncertainty (oil price shocks) or economic policy uncertainty shocks. Furthermore, overall spill-overs significantly rose to previously unheard-of heights during the 2007–2009 recession and in the years following 2009, the supply-side and oil-specific demand shocks played a substantial role in the transmission of spill-over effects. They incorporated spill-over methodology and impulse response functions in order to reach their conclusions.

The paper by Cuando (2015) analyzes the macroeconomic impact of structural oil shocks in four of the top oil-consuming Asian economies, using a VAR model. They identified three different structural oil shocks via sign restrictions: an oil supply shock, an oil demand shock driven by global economic activity and an oil-specific demand shock. The main results suggest that economic activity and prices respond very differently to oil price shocks depending on their types. They also stated that CPIs are marginally affected by the oil price shocks.

Made in the Indian context, Kumar (2004) used multivariate VAR techniques with both linear and non-linear parameters to find that oil price shocks negatively affect the growth of industries. Author uses variance decomposition analysis and finds out that when oil price shocks are combined with the monetary shocks, the largest source of variation is in industrial production growth other than the variable itself.

Bhattacharya (2009) made a detailed analysis based on two different scenarios where global prices affect the economy using the innovation accounting method where the differential effect analysis has been carried out inside a structural VAR framework. The study found that there is no co-movement between changes in domestic diesel and gasoline prices and the current international pricing for these goods. The main finding of this study-based variations of correlation estimates is that changes in domestic fuel costs and international fuel price changes in India do not occur simultaneously.

Demand and supply shocks in the oil industry during the advent of COVID-19 are noted by Bourghelle (2021) in a paper, which led to both economic uncertainties across the world and trade wars among the oil-producing nations – which caused high levels of oil price volatility. The study also found that investor apprehension and uncertainty increase the volatility of the oil price.

Hamilton (2009) compares and contrasts the rise in oil prices in 2007–2008 with prior oil price shocks by examining the factors that contributed to the price increase and its repercussions on the US economy. In contrast to past oil price shocks, which were mostly triggered by physical supply interruptions, the 2007–2008 price run-up was brought on by high demand against stagnant global output. Despite having distinct root causes, the effects on the economy seem to have been quite similar to those seen in previous episodes, with notable impacts on general consumer expenditure and, in particular, purchases of domestic cars.

Papapetrou (2001) studied dynamic interactions between economic variables in Greece without imposing a priori limits, in contrast to earlier research. According to the empirical data the author collected, fluctuations in the price of oil have an impact on employment and actual economic activity. Oil prices are crucial in understanding changes in stock values; but stock returns do not affect employment or actual economic activity.

Saudi Arabia's economy is greatly reliant on oil. Alqahtani (2016) in his paper states the effects of oil price shocks on economic activities in Saudi Arabia using yearly data (1970–2015) to cover all oil price shocks, including the recent drop in oil prices in 2014. VAR and VECM models pointed to a long-term, considerable positive link between oil prices and Saudi Arabia's GDP. The cointegration findings also note an important and favorable long-run link between oil prices and GDP. Additionally, there was a long-term association between government spending, trade balances, and GDP, which is consistent with existing research.

3. Research Gap

There is an opportunity for research as the impact of crude oil prices that are influenced by OPEC is examined from the context of India, a non-member nation, for which only a little or no literature is available. Examination of total Manufacturing production in India is also taken into consideration. The available research also dealt particularly with metal or mineral-based industries, which is limited in scope. Considering the crude oil price fluctuations cause certain undulations on Indian macroeconomic variables both in the short run and long run, the research aims to establish causality and check for structural breaks.

4. Objectives

The study has the following objectives:

1. To observe the ways in which the price fluctuations in OPEC influence the select macroeconomic variables in India.
2. To understand the short-run and long-run trends exhibited by these variables due to oil price shocks, if any.

5. Research Methodology

Time series data was used for this study, including feature variables like OPEC oil price, GDP data of India, CPI data of India (with base year taken as 2015), export data of India, and Total Manufacturing production data of India. All the analyses are done using the R studio tool.

```
tibble [105 x 5] (S3: tbl_df/tbl/data.frame)
 $ OOP: num [1:105] 19.4 20.8 23.2 21 18.4 ...
 $ EXP: num [1:105] 9.04 9.01 9.01 9.14 9.07 ...
 $ CPI: num [1:105] 27.2 28.4 28.9 29 29.3 ...
 $ TM : num [1:105] 14.2 7.91 5.38 4.13 4.71 ...
 $ GDP: num [1:105] 29.2 29.2 29.2 29.2 29.2 ...
```

Figure 2: Variables used

OOP: OPEC oil price from 1996 (2) to 2022 (2) taken from the OECD (Organization of Economic Co-operation and Development) website (in Dollars per barrel).
EXP: goods/Credit exports taken from the RBI (Reserve Bank of India) website.
CPI: Consumer Price Index of all Items in India.
TM: Total manufacturing for India, Growth rate same period the previous year, Quarterly, Seasonally Adjusted
GDP: Gross domestic product of India at current prices (Indian Rupee, Seasonally Adjusted).
All the non-stationary series were converted into stationary series using a differencing method.

6. RESULTS AND DISCUSSION

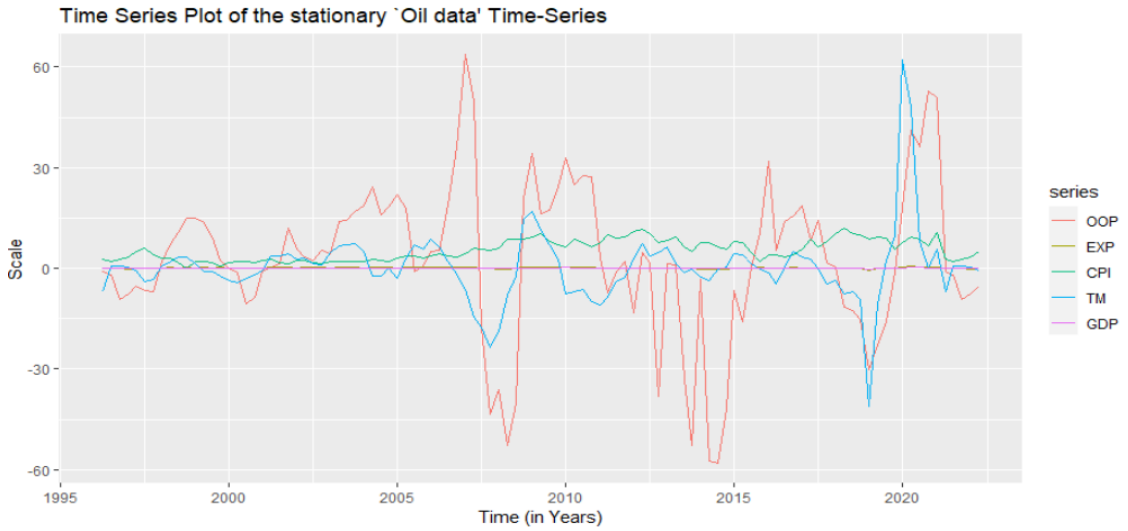

Figure 3: Time series plot of variables(Stationary)

Johansen cointegration test was used (long-run analysis) to identify the long-term correlations between macroeconomic variables and the variation in the price of oil, as stated by Engle (1987) and Nkoro (2016). If there is co-integration between the variables, there is a long-term relationship between them. Poh (1997) mentioned that in order to determine the number of associations and to provide an approximation of those links, the Johansen cointegration test was performed.

Better non-stationarity tunings and long-lasting relationships between components are established using vector autoregressive approaches (Crane, 2002). The conclusion of the short-run relationship among variables is the confirmation of causation. The Granger causality test assumes that the time series data of the provided variables offer the necessary information for the estimate of these variables. The Cholesky decomposition approach proposed by Doan (1992) was used to factorize the variance-covariance matrix of the VAR in order to find orthogonalized innovations in each of the variables and the dynamic reactions to such innovations. Using this approach, the variables in the VAR are forced into a specific order, and any shared component effects are all attributed to the first variable in the VAR system. The impact of a one-time shock to one of the innovations on the current and future values of the endogenous variables is tracked by an impulse response function (IRF). After the Johansen cointegration test, VAR was used over VECM technique. Then this paper critically examines the Impulse response function plots, which tells how the shocks from Oil prices actually did affect the Indian economy.

After doing a VAR modelling, Impulse response function's plot were analyzed. Traditional impulse response explains the effect of how a shock hits a system at a time, given that no other shocks hit the system Koop et. al (1997). These plots will explain how shocks from OPEC oil price fluctuations are affecting Indian macroeconomic variables. Runkle (1987) asserts that omitting standard error bars when providing impulse response functions is analogous to omitting t-statistics when reporting regression coefficients. In this paper, 68% confidence intervals are calculated for the IRFs as a measure of significance (see in Zha (1999)). These confidence bands were created using 1000 Monte Carlo

simulations. The main lines in the images represent the impulse response function, while the bars represent confidence intervals.

The Granger causality test is used to determine the short-term association. If there is cointegration among the variables, the Granger causality test is used to determine whether there is a short-term relationship between the variables Engle (1987). This test was also used in this paper. This paper uses Granger Causality tests to check the short run effects of OPEC crude oil prices on India's macroeconomic variables.

7. RESULTS

7.1 Data and Correlation plots:

Data of the variables used in this study were collected, cleaned, and merged into a single dataset. Before merging, GDP, EXP, and TM variables were log-transformed. A correlation plot was made to check the existence of correlation between the variables.

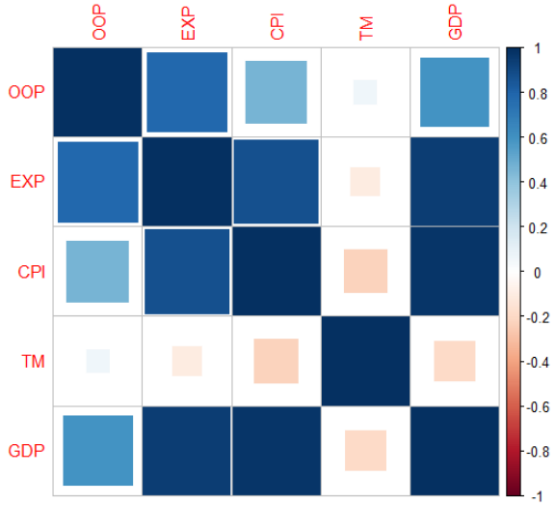

Figure 4: Correlation plot

As per the plot obtained, we can observe the existence of a high correlation between:

- Exports and OPEC oil prices
- CPI (or inflation) and Exports
- GDP and Exports
- CPI and GDP

7.2. Granger Causality:

Granger causality tests prove that by using export data, it is possible to forecast and predict OPEC oil price fluctuations. That is, fluctuations in OPEC oil prices granger-causes variations in Indian exports. The results show that OPEC oil causes short run fluctuations in Indian exports.

```
> grangertest(EXP~OOP,order = 3)
Granger causality test

Model 1: EXP ~ Lags(EXP, 1:3) + Lags(OOP, 1:3)
Model 2: EXP ~ Lags(EXP, 1:3)
  Res.Df Df      F Pr(>F)
1     90
2     93 -3 3.4994 0.0187 *
```

Figure 5: Granger Causality

The above results give us a clear indication that OPEC oil Prices granger-causes (‘or G-causes’) exports of commodities in India. This simply means that past values of OPEC oil price fluctuations can be used to predict further exports of commodities. It is interesting to note that correlation between exports of commodities data and OPEC oil price data is high, around 0.90. On the other hand, granger causality tests suggest that OPEC oil prices can be used to predict exports. Thus, there is both correlation and causation.

This may be explained as when OPEC oil price increases/decreases, exports also react to the same increase and decrease as directly or indirectly Indian prices of Crude oil also exhibit a fluctuation to the same. OPEC oil price fluctuations can lead to an increase in production costs for Indian industries, particularly those that rely heavily on energy and fuel. This can impact the competitiveness of Indian exports in international markets. Increase in production costs happens as there may be several reasons including the spike of transportation costs and raw materials. Except for this, there were no significant observations in or implications from granger causality tests.

Analysis of Johansen cointegration summarizes that the use of vector autoregressive modeling is possible and better than using a vector error correction model.

```
######################
# Johansen-Procedure #
######################

Test type: trace statistic , without linear trend and constant in cointegration

Eigenvalues (lambda):
[1]  3.462581e-01  2.516006e-01  1.465260e-01  3.784442e-02 -2.428613e-17

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 3 |  3.78  7.52  9.24 12.97
r <= 2 | 19.31 17.85 19.96 24.60
r <= 1 | 47.71 32.00 34.91 41.07
r = 0  | 89.36 49.65 53.12 60.16

Eigenvectors, normalised to first column:
(These are the cointegration relations)
```

Figure 6: Johansen Procedure : Trace statistic

```
######################
# Johansen-Procedure #
######################

Test type: maximal eigenvalue statistic (lambda max) , without linear trend and constant in
tegration

Eigenvalues (lambda):
[1]  3.462581e-01  2.516006e-01  1.465260e-01  3.784442e-02 -2.428613e-17

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 3 |  3.78  7.52  9.24 12.97
r <= 2 | 15.53 13.75 15.67 20.20
r <= 1 | 28.40 19.77 22.00 26.81
r = 0  | 41.65 25.56 28.14 33.24

Eigenvectors, normalised to first column:
(These are the cointegration relations)
```

Figure 7: Johansen Procedure: Eigenvalue Statistic

After the Johansen Cointegration test, results were compared between the test and 5pct values (as we took 5% as level of significance). After comparing, in both trace and Eigenvalues statistics, it was found that two were significant and two weren't significant. In that case, from Johansen Cointegration tests (both trace and Eigenvalues), we can conclude the usage of VAR model over VECM model.

7.3. Impulse Response Functions:

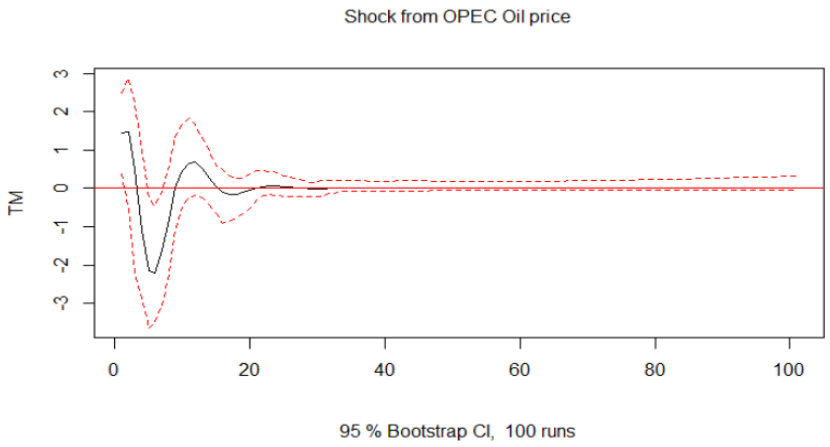

Figure 8: Impulse response graph (response of TM)

According to the above plot, total manufacturing in India shows a decreasing trend to OPEC's impulse. It can be inferred that OPEC oil prices have an impact over total manufacturing in India as whenever there is a positive shock, TM increases and vice versa. But just after the 20th quarter, the lines tend to submerge into 0, that means no significant change.

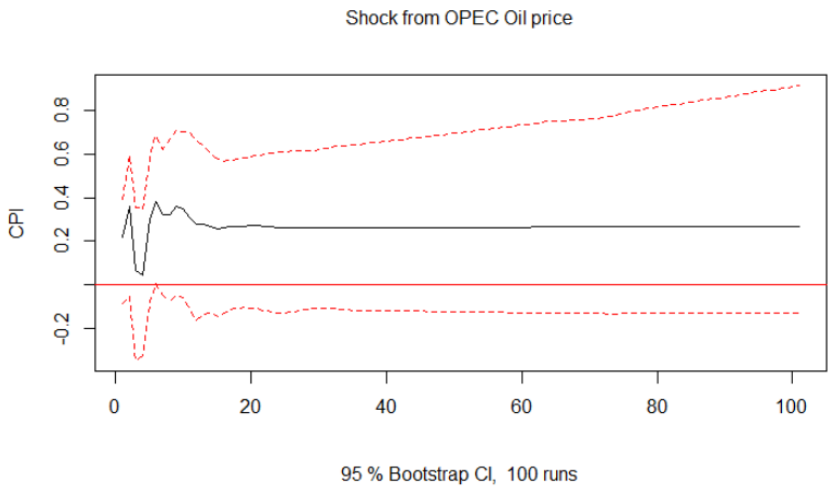

Figure 9: Impulse response graph (response of CPI)

For the first two quarters, CPI had an increase and peaked. This was when OPEC oil prices were decreasing. Then CPI started to decrease until the fourth quarter. Then just after the fourth quarter, CPI spiked and peaked during the sixth quarter. After that, there was a very minute decrease, then the results became insignificant.

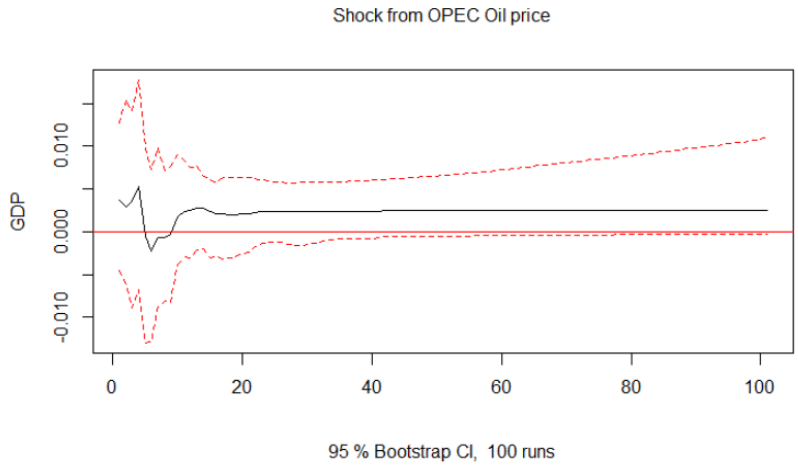

Figure 10: Impulse response graph (response of GDP)

This graph indicates how OPEC prices are bringing fluctuations in India's total manufacturing production. OPEC oil price fluctuations can impact the cost of inputs, transport costs, demand, and competitiveness of manufacturing firms in India, 'potentially' leading to a decrease in output and economic growth. It's worth noting that the impact of OPEC oil prices on total manufacturing in India may vary depending on the specific industry and the level of dependence on oil and energy inputs.

Overall, in exports and GDP of India, there was a very minute response. As OPEC oil Prices decrease during that quarter, Exports increase. But as it increases, Exports start to decrease. As far as GDP is concerned, we can say that India's GDP is not very highly dependent on OPEC oil prices but there is some

response to the shocks. As OPEC increases the crude oil prices, the GDP of India goes down. The fact that Indian GDP not being correlated to OPEC oil price can also be inferred from the correlation plot.
It is to be pointed out here that much of the fluctuations took place in the first 10 quarters. After the first 10 quarters, inflation in India wasn't affected much by OPEC oil prices – indicating some sort of structural adjustment. After plotting and analyzing the Impulse response function of GDP and exports of India, it was noticed that OPEC oil prices affected the variables very minutely. The reason for a slight change being shown in the result may be due to the Price stickiness. Inflation in India may not respond immediately to changes in oil prices due to the stickiness of prices. Prices of goods and services do not adjust immediately to changes in input costs, such as oil prices, leading to small and delayed fluctuations in inflation. Also, an increase in oil prices can lead to a depreciation of the Indian rupee, which can lower the cost of imports and potentially offset the inflationary impact of higher oil prices.

8. Conclusion

India is vastly affected by whatever goes around the world, even if it's not at its epicenter. This is why it is crucial to study the phenomenon that has the ability to deter and hamper our nation's well-being, with one such priority being the oil crisis. This study aimed to observe the ways in which the price fluctuations in OPEC influence the select macroeconomic variables in India and understand the short-run and long-run trends exhibited by these variables due to oil price shocks, if any.

Using the causality tests, it was found that OPEC oil prices can explain the short-run fluctuations caused by exports of commodities in India alone. In the long run, however, it was observed that fluctuation in OPEC oil prices impact the total manufacturing in India; whereas GDP, CPI and exports have very slight fluctuations on the other hand. Granger causality tests prove that using exports data, it is possible to forecast and predict the OPEC oil price fluctuations. That is, fluctuations in OPEC oil prices granger-causes variations in Indian exports. This means that as OPEC oil causes short run fluctuations in Indian Exports. Impulse Response functions were also plotted. In total manufacturing production of India, the trend is decreasing for the first 5 quarters. Just after the 5th quarter, it starts to increase until it becomes positive. In the case of CPI, there is only a slight fluctuation—as noted in the initial upward movement and subsequent fall. In case of GDP, there is a very slight response to the shocks of OPEC oil prices. Even the results of correlation plots also tell that OPEC oil prices are very weakly correlated to the GDP of India. This means that OPEC oil contributes positively but very weakly to the Indian GDP. India has very low oil intensity as compared to other major global economies like China.

9. Policy implications

1. India's policymakers should pay close attention to global crude oil price fluctuations, as they have a significant impact on the country's domestic economy. As such, policymakers should be proactive in developing strategies to mitigate the adverse effects of oil price fluctuations on the country's economy.
2. Since OPEC plays a vital role in controlling global oil prices, India should develop a more constructive relationship with OPEC to ensure that oil prices remain stable and predictable. This can be achieved through diplomatic channels, trade agreements, and other forms of engagement.
3. Given the impact of oil prices on India's GDP, policymakers should take measures to diversify the economy and reduce its dependence on oil. This can be achieved by investing in alternative sources of

energy, such as solar and wind power, and by promoting other sectors of the economy, such as manufacturing and services.

4. The study's findings highlight the need for India to have a robust balance of payments position. This can be achieved by promoting exports of goods and services and by maintaining a healthy level of foreign exchange reserves. Such measures will help India to withstand external shocks and maintain stability in the domestic economy.

10. Conflict of Interest

The author declares that there is no conflict of interest concerning the publishing of this paper. There are also no relevant financial or non-financial competing interests to report.

11. Acknowledgement

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12. Authors' Biography

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