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OIL PRICE FLUCTUATION, INFLATION, & OUTPUT GROWTH: AN EMPIRICAL STUDY IN INDIA

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Abstract

Using monthly time series data for the period 1995–2020, this research explores the impact of oil price variations on output and inflation in India. According to recent research, fluctuations in oil prices may have asymmetric impacts on macroeconomic indicators. The author decomposes oil price changes into positive and negative portions, as Hamilton suggests, to account for asymmetric impacts (1996). Our findings reveal that whereas higher oil prices have a definite negative impact on production growth, lower oil prices have a negligible influence. Similarly, rises in the price of oil have a positive and considerable impact on inflation. Oil price drops, on the other hand, have little impact on inflation. These findings are also supported by the Granger causality tests. It claims that while these impacts have faded over time, monetary policy should remain watchful in averting inflationary second-round consequences. At the same time, fiscal policy should stay focused on long-term objectives, while structural reforms should help to improve oil market transparency.

Keywords: *Oil price, Causality, Output growth, Asymmetry, Inflation, Monetary Policy*

1. INTRODUCTION

Oil price shocks may have an impact on macroeconomic variables through various transmission channels. First, rising oil prices lead to higher energy costs and lower the usage of oil. Consequently, lower productivity of capital and labor hinders output growth (see Brown & Yücel, 1999; Abel & Bernanke, 2001). This is known as a classical supply-side effect. Second, higher oil prices have an income effect. An increase in oil prices leads to an income transfer from oil-importing countries to oil-exporting countries and thus reduces the disposable income of oil consumers (see Dohner, 1981). The third one is the real balance effect (see Mork, 1994). Oil-price-induced inflation reduces real balances and money demand increases. If monetary authorities do not increase the money supply to meet this growing money demand, interest rates rise and produce recessions. Fourth, oil price uncertainty might reduce investment expenditures (see Hamilton 1988, Bernanke 1983). It is argued that increasing uncertainty may also cause recessions during oil crisis periods (see Pindyck & Rotemberg, 1983). Firms chose to postpone investment expenditures when they face increased uncertainty about future oil prices. Fifth, an oil price shock can affect unemployment through a change in the production structure. When oil prices increase, firms try to adopt production methods that are less oil-intensive. This change leads to a labor reallocation among sectors and can affect unemployment in the long run (see Loungani, 1986). Sixth, oil price shocks have a pass-through effect on inflation (see Fuhrer, 1995; Hooker, 2002). The inflationary impact can be accompanied by second-round effects, through the price-wage loop. Research on the macroeconomic implications of oil price shocks has risen since the oil crisis of the 1970s. In an influential article, Hamilton (1983) found a strong negative relationship between oil price changes and real economic activity in the U.S. data. Other researchers also supported the results of Hamilton (1983) (see, for example, Darby, 1982; Gisser & Goodwin, 1986; Burbidge & Harrison, 1984; Bruno & Sachs, 1985). However, by the 1980s, it was observed that the declines in oil prices have a smaller positive effect on economic activity than estimated by linear models. The seeming breakdown in this interaction led the researchers to focus on the asymmetric relationship between oil price changes and economic activity. While oil price increases have a significant negative impact, oil price decreases may not have a positive effect on macroeconomic variables. Hamilton (1988) explained this asymmetry theoretically by introducing adjustment costs. Some researchers investigated such asymmetry empirically. For example, Mork (1989) established the existence of asymmetric responses of GNP growth in the U.S. to oil price increases and decreases. Mork et al. (1994) find that most OECD countries experienced this asymmetric relationship between oil price and GDP growth. Lee et al. (1995) argue that the highly volatile oil price movements led to a breakdown of the relationship between oil price shocks and U.S. economic activity.

Some studies tried to explain the asymmetric reaction of economic activity to oil price shocks. It is argued that monetary policy may give rise to asymmetry. While monetary authorities may implement a restrictive monetary policy in response to oil price increases, they may not pursue expansionary policies in the case of oil price declines (see Bohi, 1991; Bernanke et al., 1997; Barsky & Kilian, 2001). On the other hand, the analysis of Hamilton & Herrera (2004) and Balke et al. (2002) showed that monetary policy's response is not the sole

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cause of asymmetry. Lilien (1982) and Hamilton (1988) explained the asymmetric response to the cost of changing oil prices. Sectoral imbalances and coordination problems between firms can also induce adjustment costs. Finally, it is argued that increased uncertainty generated by oil price shocks can lead to asymmetry. Ferderer (1996) argued that the increased volatility generated by increases in oil prices reinforces the negative effects, while volatility generated by decreased oil prices offsets the positive effects.

The relationship between oil prices and inflation are also discussed in the literature. Trehan (2005) observed that while rising oil prices were accompanied by inflation during the 1970s, this relationship deteriorated over the latter part of the sample. Hooker (2002) found a significant impact of oil prices on inflation for the period 1962-1980, but not for the period from 1981 to 2000. As suggested by Trehan (2005), changing inflation expectations are likely to provide a part of an explanation to change in the relationship between oil prices and inflation. Declining inflation and inflation volatility have been accompanied by a decline in inflation expectations since the 1970s. While it was expected that the Fed did not act to offset the inflationary effect of higher oil prices during the 1970s, more recently, it is expected that the Fed act to withstand this inflationary effect. Thus, the inflationary impact of oil shocks has declined. Chen (2009) examined 19 industrial countries and supported this evidence. Cunado & Perez de Garcia (2005) showed that oil prices have significant effects on both economic activity and inflation for six Asian economies. Jacquinot et al. (2009) found that oil price shocks have an important impact on inflation in the short-run in the euro area.

This paper aims to explore the effects of oil price shocks on output and inflation in the case of India. The expected industrial development potential in India represents a significant growth prospective and oil is a critical factor for India's economic growth. Manufacturing, transportation, and electricity generation mainly depend on oil. Since oil is an important input to these sectors, it is probably that oil price shocks have the potential to affect the production level in India. Furthermore, 90 percent of India's crude oil is imported. The oil-dependent structure of India makes oil prices a significant variable for India's economy. Also, India has strategic importance since it is becoming an important oil transit country from Russia, the Caspian Sea, and the Middle East to Europe. The studies on the oil price-macro economy relationship are mostly on advanced economies. There are only a few studies for India. For example, Kapoor (2011) investigates how economic activity in emerging markets may be affected by oil price shocks. He finds that the relationship between net oil price increases and real GDP growth is statistically significant for India from the period 2000-to 2009.

Kibritcioglu & Kibritcioglu (1999) do not find a statistically significant relationship between oil prices and general price level. They assume that factor prices are fixed in nominal values. Berument & Taşçı (2002) show that the inflationary effect of increasing prices of oil is significant in the case of factors of income adjusted to inflation including the oil price increases. Çatık & Önder (2011) investigate the inflationary impacts of oil prices by employing Markov regime-switching models. They compare the oil pass-through under the high and low inflationary periods and find evidence for asymmetric oil pass-through in the high-inflation regime. We considered the possibility of asymmetric responses to oil price increases and decreases, as suggested in the literature. Therefore, we assessed the model following

Hamilton (1988) analyzed the relationship between oil price shocks and macro variables for India. Our results confirm a negative effect of oil price increases on economic activity and a positive effect on inflation. On the other hand, we do not find any significant effects of oil price declines. Also, the author found that positive oil price shocks Granger-cause the macroeconomic variables, but that negative shocks do not.

2. RESEARCH METHODOLOGY

We consider the following regression equations for inflation and output, respectively.

$$\pi_t = \alpha_{\pi 0} + \sum_{i=1}^{l} \beta_{\pi i}\pi_{t-i} + \sum_{i=1}^{m} \gamma_{\pi i} y_{t-i} + \sum_{i=1}^{n} \theta_{\pi i} r_{t-i} + \sum_{i=1}^{o} \partial_{\pi i} oil_{t-i} + \varepsilon_{\pi t}$$

$$y_t = \alpha_{y0} + \sum_{i=1}^{p} \beta_{yi} y_{t-i} + \sum_{i=1}^{q} \gamma_{yi}\pi_{t-i} + \sum_{i=1}^{s} \theta_{yi} r_{t-i} + \sum_{i=1}^{t} \partial_{yi} oil_{t-i} + \varepsilon_{yt}$$

Where π_t is the inflation rate, y_t is the output, rt is the interest rate and oil_t is the real oil price change, ε_t is the disturbance term. Equations (1) and (2) do not allow for analyzing the effects of positive and negative oil price shocks. Therefore, to account for the effects of positive and negative oil price shocks, we decompose oil price changes into positive and negative changes, and amend the system of equations as follows:

$$\pi_t = \alpha_{\pi 0} + \sum_{i=1}^{l} \beta_{\pi i}\pi_{t-i} + \sum_{i=1}^{m} \gamma_{\pi i} y_{t-i} + \sum_{i=1}^{n} \theta_{\pi i} r_{t-i} + \sum_{i=1}^{o} \partial_{\pi i}^{-} oil_{t-i}^{-} + \sum_{i=1}^{o} \partial_{\pi i}^{+} oil_{t-i}^{+} + \varepsilon_{\pi t}$$

$$y_t = \alpha_{y0} + \sum_{i=1}^{p} \beta_{yi} y_{t-i} + \sum_{i=1}^{q} \gamma_{yi}\pi_{t-i} + \sum_{i=1}^{s} \theta_{yi} r_{t-i} + \sum_{i=1}^{t} \partial_{yi}^{-} oil_{t-i}^{-} + \sum_{i=1}^{t} \partial_{yi}^{+} oil_{t-i}^{+} + \varepsilon_{yt}$$

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Where oil^-_t represents the negative changes in the oil price and oil_t^+ represents positive changes and are defined as $oil^-_t = \min(oil_t, 0)$ and $oil_t^+ = \max(oil_t, 0)$

In principle, the system of equations given in eq. (1) and (2) (or in (3) and (4)) can be estimated using ordinary list squares (OLS) estimator. However, this approach does not take account of mutual dependence between the equations and hence may not produce efficient estimates. Therefore, we apply a systematic approach and estimate the equations simultaneously. The model specification and estimation procedure are as follows. First, we define each equation in the system with a maximum lag order of 12 and estimate each equation separately by the OLS estimator. Then we delete the intermediate lags one by one (starting with the least statistically insignificant one according to the t-statistics), provided that such deletion increases Akaike Information Criterion. Once the optimal lag order of each covariate is determined, we estimate the system of equations using the Generalized Least Squares (GLS) estimator iteratively. Employing GLS iteratively gives Maximum Likelihood (ML) estimates and brings efficiency gains over OLS estimates (Greene, 1997; 681-682).

3. EMPIRICAL RESULTS & DISCUSSION

In this study, we use monthly data for the period 1995-to 2020. Real oil price (oil_t) is obtained by multiplying the nominal oil price expressed in U.S. Dollars by the nominal exchange rate and deflating it by using the consumer price index (CPI). Output gap (gap_t) is proxied by (logarithm of) the industrial production index detrended by Hodrick-Prescott (HP) filter. Inflation (π_t) is measured as the logarithmic first difference in CPI. In the empirical application, we used logarithmic first differences of real oil price (oil_t) and the logarithm of annualized interest rate, (r_t). The data are taken from WDI World Bank except for the interest rate, which is taken from the Central Bank of India. Before estimating the system of equations, we test the stationarity of the data using the Augmented Dickey-Fuller (ADF) test. The results of the ADF test are given in Table 1. As the results of the ADF test suggest, all variables are stationary.

Table 1: Results of the ADF Unit Root Test

Variable	Constant	Constant and Trend	None
Inflation Rate	-1.011	-10.070*	-1.172
Output Gap	-5.894*	-5.883*	-5.906*
Real interest rate	-2.843***	-5.233*	-1.695***
Change in oil prices	-13.756*	-13.758*	-13.770*

Notes: *, and *** denote rejection of the null hypothesis of unit root at 1%, and 10% significance levels

We proceed to estimate both systems of equations, namely the system consisting of equations (1) and (2), and the system consisting of equations (3) and (4) because all variables are determined to be stable. The set of equations (1) and (2) assumes that changes in oil prices affect both inflation and production symmetrically, as briefly stated above. The set of equations (3) and (4), on the other hand, assume that changes in oil prices affect inflation and production asymmetrically. Table 2 shows the findings of estimates for the inflation equations (i.e., estimates for equations 1 and 3). Table 3 shows the parameter estimates for the output equation (i.e., estimates for equations 2 and 4).

Table 2: Estimation Results of Inflation Equations

	Equation 1		Equation 3	
	Coefficient	Standard error	Coefficient	Standard error
Constant	0	0	-0.001	0
π_{t-1}	0.350*	-0.058	0.359*	-58
π_{t-2}	-0.104***	-0.059	-0.098***	-0.059
π_{t-7}	0.095***	-0.053	0.102***	-0.053
π_{t-8}	-0.127**	-0.057	-0.126**	-0.057
π_{t-9}	0.171*	-0.057	0.174*	-0.057
π_{t-10}	-0.099***	-0.059	-0.092	-0.059
π_{t-11}	0.190*	-0.059	0.192*	-0.059
π_{t-12}	0.204*	-0.055	0.211*	-0.055
r_{t-1}	0.059*	-0.008	0.058*	-0.008
r_{t-2}	0.014***	-0.008	0.015***	-0.008
r_{t-3}	-0.047*	-0.009	-0.052*	-0.01
r_{t-5}	0.022*	-0.007	0.023*	-0.007
r_{t-12}	-0.021*	-0.007	-0.021*	-0.007
oil_{t-3}	0.019***	-0.01	-	-

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oil $^{+}_{t-3}$	-	-	0.043**	-0.02
oil $^{-}_{t-3}$	-	-	-0.002	-0.018

Notes: *, **, and *** denote the significance of the coefficient at the 1%, 5%, and 10% level

As can readily be seen from Table 2, the effect of oil price changes on inflation is positive and statistically significant only at a 10% significance level. On the other hand, when oil price changes are decomposed into positive and negative changes, it is found that only positive change in oil prices affects the inflation rate. The coefficient of positive oil price change (oil $^{-}$) is positive and statistically significant at a 5% significance level whereas the coefficient of negative oil price change (oil $^{+}$) is negative but statistically insignificant.

Table 3: Estimation Results of Output Equations

	Equation 2		Equation 4	
	Coefficient	Standard error	Coefficient	Standard error
Constant	0.001	-0.002	0.005	-0.003
gap $_{t-1}$	0.223*	-0.049	0.211*	-0.051
gap $_{t-2}$	0.426*	-0.053	0.394*	-0.053
gap $_{t-5}$	0.152*	-0.052	0.151*	-0.054
gap $_{t-10}$	-0.152*	-0.056	-0.160*	-0.058
gap $_{t-12}$	0.202*	-53	0.210*	-0.054
gap $_{t-13}$	-0.287*	-0.048	-0.281*	-0.05
□ $_{t-2}$	0.229***	-0.127	0.206	-0.13
□ $_{t-4}$	0.242***	-0.124	0.238***	-0.127
r_{t-1}	-0.059*	-0.018	-0.057*	-0.018
r_{t-2}	-0.052*	-0.019	-0.047**	-0.02
r_{t-6}	0.035**	-0.016	0.031**	-0.016
r_{t-11}	0.033**	-0.015	0.029**	-0.015
oil t	0.090*	-0.025		
oil $_{t-2}$	0.042***	-0.025		
oil $_{t-5}$	-0.053**	-0.024		
oil $_{t-10}$	-0.040***	-0.024		
oil $^{+}_{t}$			0.083***	-0.047
oil $^{+}_{t-2}$			0.004	-0.05
oil $^{+}_{t-5}$			-0.095**	-0.048
oil $^{+}_{t-10}$			-0.072***	-0.042
oil $^{-}_{t}$			0.099**	-0.045
oil $^{-}_{t-2}$	0.066	-0.046		
oil $^{-}_{t-5}$	-0.01	-0.045		
oil $^{-}_{t-10}$	-0.002	-0.045		
□oil = 0 5.153 [0.000]				
□oil $^{+}$ = 0 2.529 [0.041]				
□oil $^{-}$ = 0 1.704 [0.150]				

Notes: *, **, and *** denote the significance of the coefficient at the 1%, 5%, and 10% levels. p-values of the test statistics are reported in brackets.

Table 3 shows the parameter estimations for the output equations. We test the null hypothesis that the sum of the coefficients of the delayed oil price changes is equal to zero to see if a change in oil prices affects production. The hypothesis tests' findings are listed at the bottom of the table. The consequences of oil price fluctuations are statistically distinct from zero, as the hypothesis tests reveal. When oil price changes are decomposed into negative and positive parts, we find that the sum of the parameters of oil price increases (oil $^{+}$) is negative and statistically significant at a 5% significance level whereas the sum of the parameters of oil price decreases is statistically insignificant, suggesting that oil price decreases do not affect output.

Table-3: Causality test of oil and output

Null hypothesis H_0	□ -statistic	*p*-value
oil does not Granger cause *gap*	21.748	0.000
oil does not Granger cause □	3.328	0.068
oil □ does not Granger cause *gap*	11.044	0.026
oil □ does not Granger cause *gap*	7.440	0.114
oil □ does not Granger cause □	4.393	0.036
oil □ does not Granger cause □	0.012	0.912

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In addition, we also conducted Granger-causality tests, results of which are presented in Table 4. Although the evidence for Granger-causal effects extending from oil prices to inflation is statistically poor, the findings show that changes in oil prices influence both output and inflation in India. When we break down oil price changes into positive and negative components, we find that higher prices influence both inflation and the production gap, whereas lower prices do not affect either. This study implies that the consequences of oil price fluctuations are mostly due to the negative effects of rising oil prices on macroeconomic factors.
The economic crisis and monetary policy shift are likely to have an impact on the oil price-output and oil price-inflation links. We used the Chow structural stability test to see if there was any structural change as a result of the economic crisis. Table 5 displays the results of the Chow stability test.

Table-5: Chow stability test

	F-Statistic
Inflation Equation	1.934*
Output Equation	1.758*

Note: The asterisk indicates significance at the 5% significance level.
The Chow stability tests indicate that the null hypothesis of regression coefficient stability is severely rejected for both equations. As a result, for these sub-periods, we use Granger causality tests. Table 6 summarizes the findings.

Table-6: Causality test pf sub-period

	□ -statistic	*p* -value
1996-2008		
oil does not Granger cause *gap*	8.477	0.076
oil does not Granger cause □	3.664	0.056
oil □ does not Granger cause *gap*	4.248	0.373
oil □ does not Granger cause *gap*	1.247	0.870
oil □ does not Granger cause □	4.263	0.039
oil □ does not Granger cause □	0.000	0.991
2008-2020		
oil does not Granger cause gap	16.240	0.003
oil does not Granger cause □	0.002	0.968
oil □ does not Granger cause *gap*	12.221	0.016
oil □ does not Granger cause *gap*	6.337	0.175
oil □ does not Granger cause □	0.088	0.767
oil □ does not Granger cause □	0.051	0.821

Although the evidence is statistically poor, Granger causality tests for the period 1996-2008 imply that oil price Granger causes output. During this sub-period, both negative and positive oil price fluctuations do not Granger-cause. For the period 2008-2020, however, our findings imply that higher oil prices Granger-cause output, whereas lower prices have no statistically significant influence on the output. It's worth noting that we came to the same conclusion throughout the duration. During the period 1996-2008, we discovered that only increases in oil prices Granger-cause inflation, whereas drops in oil prices did not influence the inflation rate. However, we show that neither positive nor negative oil price movements Granger-cause inflation rate during the 2008-2020 sub-period. The disappearance of causation from oil prices to inflation might be explained by the Central Bank of India's inflation targeting policy. Furthermore, fuel taxes are regularly modified, resulting in a lag in the domestic price of fuel goods in response to changes in oil prices. As a result, it's not unexpected that variations in oil prices have less impact on domestic inflation rates.

4. DISCUSSION

The bulk of empirical studies looking at the link between oil prices and macroeconomic factors have used a combination of linear and nonlinear approaches. While the majority of this research focused on advanced economies, the growing need for oil from emerging economies makes studying oil prices and developing nations extremely important. In this study, we look at how the price of oil affects actual economic activity and how the price of oil affects inflation in India, a developing country. Oil prices are a crucial variable for India because it is the primary source of energy for many industries. India is also a big oil market due to its population and economic growth potential. Furthermore, because domestic oil production is limited, oil is one of India's most crucial imports. We first look at the impact of oil prices on economic activity and inflation, assuming that increases and declines in oil prices have symmetrical effects on economic indicators. According

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to our findings, oil prices have a statistically significant impact on both inflation and economic activity. However, inequalities in the relationships between oil price and inflation and oil price and economic activity are well established. We construct an asymmetric model based on Hamilton to account for the impact of positive and negative oil price shocks (1996). Our findings reveal that rising oil prices have a positive and considerable impact on inflation. Oil price declines, on the other hand, have little effect on inflation. We also discover that as oil prices rise, production decreases. On the other hand, a drop in oil prices is small in explaining output fluctuations, and the total impacts of oil price drops are not statistically significant. The Granger causality tests also demonstrate that while an increase in oil prices impacts both production and inflation, a decrease in oil prices does not. These findings show that the linear approach, which posits that oil prices have symmetric impacts on macroeconomic variables, is incorrect. Furthermore, taxes are one of the largest contributors to fuel prices in India since the government charges substantial taxes on gasoline. Drops in international oil prices are not reflected in domestic pricing due to hefty levies. Market flaws in other markets, in addition to asymmetric price transmission from world oil prices to domestic prices, contribute to such asymmetries. If prices are not flexible downwards, a decrease in input costs will not result in a decrease in prices, and hence changes in intermediate costs will have an unequal effect on the economy. Finally, we looked at the consistency of the impacts of changes in oil prices on inflation and production. Our findings reveal that whereas higher oil prices have a definite negative impact on production growth, lower oil prices have a negligible influence. Similarly, rises in the price of oil have a positive and considerable impact on inflation. Oil price drops, on the other hand, have little impact on inflation. These findings are also supported by the Granger causality tests.

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