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The Macroeconomic Effects of Oil Price Shocks: Empirical Evidence for India

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Abstract

This study assesses the oil prices-macaroeconomy relationship by means of multivariate VAR using both linear and non-linear specifications. Scaled oil prices model outperforms other models used in the study. It studies the impacts of oil price shocks on the growth of industrial production for Indian economy over the period 1975Q1-2004Q3. It is found that oil prices Granger cause macroeconomic activities. Evidence of asymmetric impact of oil price shocks on industrial growth is found. Oil price shocks negatively affect the growth of industrial production and we find that an hundred percent increase in oil prices lowers the growth of industrial production by one percent. Moreover, the variance decomposition analysis while putting the study in perspective finds that the oil price shocks combined with the monetary shocks are the largest source of variation in industrial production growth other than the variable itself.

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1. Introduction

After reaching a 25 years low in February 1999, oil prices have sharply been rising over the next decade. Recently, the international price of oil has breached the US$150 mark. Given the macroeconomic developments that followed the oil shocks of the 1970s, the substantial rise in oil prices since 1999 generated concerns about the prospects for growth and inflation and integrally-related questions about the appropriate way for monetary and energy policies to respond.

Much of the empirical literature is concerned with the developed countries, particularly US and Western Europe. In an international context, an oil price shock may have differential impact on each of the countries due to some variables such as their sectoral composition, their relative position as oil importer or exporter or their differential tax structure. We analyze the effects of oil price shocks in oil importing developing economy- India.

India is the seventh largest consumer of oil in the world. In 2003-04, it spent about US$ 20 billion to meet 70 percent of its needs. During the decade 1991-2001, the oil consumption increased by 68 percent to touch 2.07million barrel per day (mbpd) in India only next to South Korea (78%) and China (109%). Oil imports accounted for 3.7 percent of gross domestic product gross domestic product (GDP) during 2003-04. It is estimated that India's fuel consumption will rise to 3.2 million barrels per day by 2010. In the process, India will emerge as the fourth-largest consumer after the United States, China and Japan.

The present study is intended to analyze the oil price – macroeconomy relationship by means of applying vector autoregressive (VAR) approach for Indian economy using quarterly data for the period 1975Q1-2004Q3. In order to account for asymmetry and non-linearities between oil prices and macroeconomic variables, we use different transformations of oil price data, each of one suggesting a different channel through which oil prices may affect real economic activities.

The study is organized as follows. In Section 2 we briefly present the main features of oil price market in order to justify the proxy variables of oil price shocks we use in the study. Section 3 describes the methodology. Section 4 discusses the empirical results. Concluding remarks are offered in Section 5.

2. Oil Price Data

The effective oil prices that a country faces have been influenced by many characteristics such as price-controls, taxes on petroleum products, exchange rate fluctuations and variations in domestic price index. These characteristics raise great difficulty in measuring the appropriate oil price variable. Most of the empirical literature use the US$ world real price of oil as a common indicator of the world market disturbance (see, for example, Jimenez-Rodriguez and Sanchez, 2005) to analyze the effects of oil price shocks on macroeconomic activities. Some studies use the world oil price converted into the currency of the country for which analysis is made by means of exchange rate (see, e.g., Mork et al., 1994 for OECD countries; Cunado and Gracia, 2005 for Asian countries). The differential in these two prices reflects whether the oil price shock is due to evolution of world oil prices or due to other factors such as exchange rate fluctuations or national price index variations. In the present study we use the world oil prices converted into Indian Rupees (INR) by the market rate of exchange deflated by the domestic wholesale price index (WPI) to analyze to effect of oil shocks on Indian Economy.

Figure 1 shows the evolution of both the real oil price expressed in US$ and in INR over the period 1970Q1-2004Q4. In both the series we observe the effects of the five main negative oil shocks (1973-74, 1978-79, 1990, 1999-2000, 2003-04) and the fall in oil price in 1986 and 1998-99. However, there is different evolution of oil prices when they are expressed in US$ and INR.

Until 1986, the oil prices were unidirectional in change, but since then they are characterized by large declines and high volatility. This differential behavior of oil price movements and apparent asymmetric response of macroeonomy to oil price shocks in US and Western European economies have led researchers to explore different oil price-GDP specifications in order to re-establish the relationship between these variables (see, for example, Mork, 1989; Hamilton, 1996, 2003; Lee et al., 1995). Following this literature, we define the next four variables for oil price changes expressed both in $US and INR:

Δoil_t: quarterly changes of real oil prices, that is, the conventional first difference transformation of oil price variables (in logs):

$\Delta oil_t = ln\ oil_t - ln\ oil_{t-1}$,

where, oil_t is the real oil price in period *t* in $US or in INR, as defined above.

A significant relationship between this variable and economic activity would lead to a linear oil-output relationship. An asymmetric specification distinguishes between the positive rate of change in oil price oil_t^+ and its negative rate of change oil_t^-, which are defined as follows:

$\Delta\, oil_t^+$: *real oil price increases,* $\Delta\, oil_t^+ = max\ (0, \Delta oil_t)$, *and*

$\Delta\, oil_t^-$: *real oil price decrease,* $\Delta\, oil_t^- = min\ (0, \Delta oil_t)$.

In this case, we treat in a different way oil price increases and decreases, that is, we separate oil price changes into negative and positive changes in a belief that oil price increases may have a significant effect on macroeconomic variables even though this might not occur for oil price decreases. The asymmetric model can be rationalized in terms of the dispersion hypothesis described in Section 2.

Hamilton (1996) proposed a different non-linear specification; by using the explanatory variable what he calls *net oil price increase* (NOPI). NOPI (expressed in real terms) defined as the quarterly percentage change in real oil price levels from the past 4 (and 12) quarters' high if that is positive and zero otherwise (NOPI4 and NOPI12). Hamilton (1996) argues that if one wants a measure of how unsettling an increase in the price of oil is likely to be for the spending decisions of consumers and firms, it seems more appropriate to compare the current price of oil with where it has been over the previous years rather than during the previous quarter alone. Hamilton thus proposes to use the amount by which the log oil price in quarter *t* exceeds its maximum value over the previous periods; if oil prices are lower than they have been at some point during the most recent years, no oil shock is said to have occurred. That is,

$NOPI4_t = max\ (0, (ln(oil_t) - ln(max(oil_{t-1}, oil_{t-2}, oil_{t-3}, oil_{t-4}))),$

$NOPI12_t = max\ (0, (ln(oil_t) - ln(max(oil_{t-1}, ..., oil_{t-12})))$

Lee et al. (1995) proposed *scaled oil price increases* (SOPI) (where oil price is expressed in real terms). They focus on volatility arguing that an oil shock is likely to have greater impact in an environment where oil prices have been stable than in an environment where oil price movements have been frequent and erratic because price changes in a volatile environment are likely to be soon reversed. In order to put this idea into practice, Lee et al. (1995) proposed the following AR(4)-GARCH(1,1), representation of oil prices:

$$\Delta Oil_t = \alpha + \sum_{j=1}^{k} \beta_j \Delta Oil_{t-j} + \varepsilon_t , \varepsilon_t \left| I_t \right. \to N(0, h_t)$$

$$h_t = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 + \gamma_2 h_{t-1}$$

$$SOPI_t = \max\left(0, \frac{\hat{\varepsilon}_t}{\sqrt{\hat{h}_t}}\right)$$

$$SOPD_t = \min\left(0, \frac{\hat{\varepsilon}_t}{\sqrt{\hat{h}_t}}\right)$$

where SOPI stands for scaled oil price increases, while SOPD for scaled oil price decreases. A significant relationship between this variable and economic activity implies that a "certain" oil price increase will cause a decrease in economic activity, while a price increase in a period of high volatility is less likely to cause it.

The oil price shock proxies (e.g., oil price increases, positive oil price increases, NOPI4 and SOPI) defined in INR are plotted in Fig. 3, 4 and 5.[1] As we can see in the figures, the oil price shock proxies detect quite well all the main oil shocks in the period 1970Q1–2004Q4. However, we can also detect some differences between each of the variables. For example, we can observe that the variable $\Delta\, oil_t^+$ takes a much higher value after the increase in oil prices in 1990Q3 than the NOPI variable, a difference which is due to the decrease in oil prices occurred in 1990Q2.

3. Methodology

We consider the following vector auto-regression model of order *p* (or simply, VAR(p)):

$$y_t = c + \sum_{t=1}^{p} \phi_i y_{t-1} + \varepsilon_t \ , \qquad (1)$$

where y_t is a *(n×1)* vector of endogenous variables, $c = (c_1, \ldots, c_n)'$ is the *(n×1)* intercept vector of the VAR, ϕ_i is the *ith (n×n)* matrix of autoregressive coefficients for *i = 1, 2,….,p*, and $\varepsilon_t = (\varepsilon_{1t}, \ldots\ldots, \varepsilon_{nt})'$ is the *(n × 1)* generalisation of a white noise process.

In this paper we use a quarterly five-variable VAR for India. The variables considered for the model are the following: index of industrial production (IIP)[2], real effective exchange rate (REER)[3], real oil price, inflation[4], and short-term interest rate[5]. Some variables (IIP, REER and real oil price) are expressed in logs, while the remaining ones are simply defined in levels. We include real oil prices and industrial growth[6] since our main objective is to analyze the effects of the former variable on the latter. We use only one measure of economic activity, namely, industrial growth, while the remaining variables are included to capture some of the most important transmission channels through which oil prices may affect economic activity indirectly, in part by inducing

[1] Although all these variables are also constructed in US$, we do not plot them but are available by request from the author.

[2] The aggregate economic activity is proxied by IIP since the quarterly GDP series in India is available since 1996-97 only.

[3] REER is defined such that a decrease means a real depreciation of the INR. A depreciation of the REER is expected to increase India's external competitiveness.

[4] Inflation is defined as the change in consumer price index (CPI), i.e. $\Delta CPI = CPI_t - CPI_{t-1}$.

[5] Money market interest rate is considered as the short-term interest rate.

[6] Industrial growth is defined as the change in logarithmic value of IIP, i.e. *Industrial Growth* = $\ln(IIP_t) - \ln(IIP_{t-1})$.

changes in economic policies. Those channels include effects of oil prices on inflation and exchange rates, which then induce changes in real economic activity. Our VAR model also incorporates a monetary sector (by means of short-term interest rate rather than money supply indicators), which can react to inflationary pressures. As is customary in studies focusing on the impact of oil prices, we do not use import prices as a whole but only oil prices, while also allowing for the exchange rate to capture part of the pass-through from import prices (in foreign currency) into domestic prices.

Before studying the effects of oil shocks on economic activity, we proceed to investigate the stochastic properties of the series considered in the model by analysing their order of integration on the basis of a series of unit root tests. Specifically, we perform the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Results of these formal tests are summarized in Tables 1, indicating that the first differences of all five variables are stationary. We therefore follow the related literature in defining the vector y_t in equation (1) to be given by the first log-differences of the first three aforementioned variables (IIP, REER, and real oil price), along with the first differences of the remaining ones (inflation, and short-term interest rate).

In order to assess the impact of shocks on endogenous variables, we examine the orthogonalized impulse-response functions, using Cholesky decomposition, as well as the accumulated responses. To do so, we should choose an ordering for the variables in the system, since this method of orthogonalization involves the assignment of contemporaneous correlation only to specific series. Thus, the first variable in the ordering is not contemporaneously affected by shocks to the remaining variables, but shocks to the first variable do affect the other variables in the system; the second variable affects contemporaneously the other variables (with the exception of the first one), but it is not contemporaneously affected by them; and so on. In our case, we have assumed the following ordering: industrial growth, real oil price, inflation, short-term interest rate, and REER. This ordering assumes, as in much of the related literature, that industrial growth does not react contemporaneously on impact to the rest of the variables. The oil price variable is also ranked as a largely exogenous variable, which have an immediate impact on the rate of inflation. The latter is then allowed to feed into changes in short-term interest rate, while the exchange rate, close the system.[7]

The VAR model in equation (1) is estimated for both a linear specification[8] and the three main non-linear specifications as defined above. The latter are the following: (1) *asymmetric specification* in which increases and decreases in oil prices are considered as separate variables; (2) *net specifications,* where the relevant oil price variable is defined to be the net amount by which these prices in quarter *t* exceed the maximum value reached in the previous four and twelve quarters; and (3) *scaled specification,* which takes the volatility of oil prices into account.

The sample period runs from 1975Q1 to 2004Q3, for a total of T=119 available quarterly observations (see Appendix for details on data). To select the suitable lag length, different tests are considered, the modified Likelihood Ratio test (Sims, 1980), as well as the Akaike, Schwarz and Hannan-Quinn tests. Wherever, there is conflict among different tests, the optimal lag length is chosen using the Likelihood Ratio test.

[7] As a robustness check, other possible ordering are also considered, including the case of an alternative ordering that only differs from the baseline model in that one allows for the contemporaneous influence of real oil price innovation on industrial growth. It was verified that the impulse responses do not change considerably with the baseline specification.

[8] Quarterly changes in real oil prices are used in the linear approach to VAR estimation, and are transformed, as discussed in Section 3, for their use in non-linear models.

4. Empirical Results

This section analyzes the empirical results for all the models described in the Section 3. In subsection 4.1 we test the significance of different oil price variables and analyze the Granger-causality in a multivariate context. In the next subsection we estimate the model. In subsection 4.2, we compare the performance of different specifications under consideration. Then the effects of oil price shocks on macroeconomic variables are examined.[9] The results on impulse-response functions and accumulated responses are first presented; the results of variance decomposition are next discussed. The cases of both impulse response and variance decomposition analysis, for all linear and non-linear specifications, are examined while focusing on the preferred specification.

4.1 Testing for Significance and Granger-causality

We carry out different tests to investigate the relationship between oil prices and other variables of the model, focusing on the significance of the impact of oil prices on real activities approximated by industrial growth.

First, the Wald test statistics is performed to test the null hypothesis that all of the oil price coefficients are jointly zero in the industrial growth equation of the VAR model. Table 2 displays the χ^2 and p-values of the Wald test statistics. The results indicate that we cannot reject the null hypothesis when the oil price variable is decreasing, but the null hypothesis is rejected when the oil prices are increasing in most of the variables. This implies that the oil prices increases appear to have a significant direct impact on real activities but the decreases in oil prices do not appear to influence the real activities directly. These results support the asymmetric impact hypothesis of oil prices changes on real economic activities. [10]

Second, we test the significance of oil price variable for the VAR system as a whole. We hypothesize that all of the oil price coefficients are jointly zero in all equations of the system but its own equation (see Table 3). This Likelihood Ratio (LR) test provide the information that oil price variable not only affects real activities directly (as assessed through the Wald test), but through third variables also in the system. It is found that oil price variable in the linear model, the positive changes in asymmetric model, the NOPI measured over previous four quarters (when the oil prices are measured in US dollars), the NOPI measured over the previous twelve quarters, scaled oil price and SOPI are significant for the system. The negative changes in the oil price variable are not statistically significant in any of the model. The price decrease variable is subsequently eliminated from those models in which it is not significant.

Finally, we perform some so-called test of block exogeneity. A block exogeneity test is useful for detecting whether to incorporate a variable into a VAR. We test whether an oil price variable Granger-causes the remaining variables of the system. We find that oil price change or increase variable generally Granger-cause the remaining variable of the system at the 1% significance level.

4.2 Macroeconomic impacts of oil price shocks

This subsection assesses the impact of oil shocks on real macroeconomic activities using different linear and non-linear models described in Section 3. To facilitate the description of the results, we first evaluate the relative performance of the different linear and non-

[9] Although the analysis of impulse response functions and variance decomposition is also conducted by using the oil price variable in US$, we do not present them as the results are not qualitatively different from using oil price variable in Indian rupees but are available by request from the author.

[10] The null hypothesis that the sum of positive and negative real oil price variable coefficients is equal in VAR framework has been tested, obtaining the rejection of null hypothesis in all cases.

linear specifications for the whole VAR system of equations. The goodness of fit of the different model specifications is assessed. We look at the *Akaike Information Criterion* (AIC) and *Schwarz Bayesian Information Criterion* (SBC) since the models are non-nested. Table 5 reports the AIC and SBC obtained from each econometric specification. On the basis of these two criteria, we find that the *scaled specification*, i.e., SOPI performs somewhat better than the other approaches used in the present study.

We examine the impact of oil price shocks on macroeconomic activities in terms of both orthogonalised impulse response functions and accumulated responses for the linear and non-linear specifications of the model. Impulse response function is a dynamic function comprising of the partial derivatives of industrial growth at a given time with respect to the oil price shock at each of a number of periods in the past, possibly beginning with the contemporaneous period. The sum of the impulse response coefficients for a shock at a specific time yields the equivalent of cumulative oil price-industrial growth elasticity for a single period shock.

Figures 6.1 through 6.6 present the orthogonalised impulse response functions of industrial growth to one standard deviation oil price shock for the specifications used in the study. Table 6 reports the accumulated responses of macroeconomic variables to an oil price shock normalized to correspond to one percent increase in all linear and non-linear specifications. In order to understand the mechanism behind the impulse and accumulated responses of industrial growth, impulse and accumulated responses of other variables have been analyzed. It is found that one of the key channels playing a role in the effect of oil prices on real activity is related to the REER.

It is found that the results of the linear specification and that of real oil price increase, NOPI and SOPI are qualitatively similar, however, the results of all the specifications are described at the same time, stressing the results obtained for the preferred model. While the linear model supposes that the impacts of an oil price increase and those of a decline are totally symmetric, non-linear specifications allow for differential effects of oil shocks of the same magnitude and opposite sign. It was reported in subsection 5.1 that the negative movements of oil prices in non-linear specifications are not statistically significant, therefore, we describe the effects of positive oil price shocks for all specifications (Figures 6.1-6.6).

In the case of positive movements in oil prices, it is observed that the real impact of oil prices is negative in the short-term. The largest negative short-term influence takes place within the year of the shock, being reached in the third quarter after the shock in most of the specifications and then the impact of the shock becomes smaller in size, dying out almost completely after three years.

Table 6 indicates that the accumulated responses of industrial growth to a positive oil price shock in the linear and non-linear specifications are qualitatively similar. An oil price shock has a negative accumulated effect on industrial growth. It is seen that the accumulated loss to industrial growth for a 100 percent oil price shock is about one percent. One important mechanism that helps explain this small amount of impact is the depreciation of the REER, which partially offsets the negative impact of oil price increases.[11]

Turning to the variables other than industrial growth and REER, the results indicate that an oil price shock increases inflation and short-term interest rate. These results are

[11] According to Huntington (1998) the crude oil price shocks are essentially energy price shocks that are transmitted to the economy through changes in refined petroleum products. In India, the prices of petroleum products are administered (although theoretical dismantled in 2002 but not in practice) and do not change according to changes in the prices of crude oil.

plausible and provide evidence of transmission mechanism- other than the exchange rate channel- playing the expected role.

Table 7 presents the results of the forecast error variance decomposition for all the specifications used in the study. The forecast error variance decomposition tells us the proportion of the movements in a sequence due to its *own* shocks versus shocks to the other variable. The variance decompositions suggest that oil shocks are a considerable source of volatility for many of the variables in the model. For industrial growth, oil prices together with short-term interest rate are the largest source of shock other than the variable itself. Innovations in short-term interest rate represent monetary shocks in our model. The contribution of oil prices and short-term interest rate to industrial growth variability is about four percent in the preferred model SOPI. REER exhibits a contribution to industrial growth variability of the magnitude of around three percent. Moreover, it is found that the movements in short-term interest rate arise from changes in oil prices. For the SOPI model, the oil price variable contributes to industrial growth, inflation, short-term interest rate and REER 1.75%, 5.16%, 6.38% and 3.90% respectively. The contribution of oil prices to short-term interest rate variability can be interpreted as a reaction of monetary policy to oil price shocks.

5. Concluding Remarks

This paper studies the oil price-macroeconomy relationship in Indian economy by means of analyzing the impact of oil price shocks on the growth of industrial production over the period 1975Q1-2004Q3. Vector auto-regressions are used to measure the impact of oil prices on the macroeconomic variables. We obtain higher impact when oil prices are measured in Indian rupees (INR) in comparison to when they are expressed in US$. This could be due to the role of exchange rate and variation in domestic prices. We also find that oil price shocks (especially increase in real oil prices) Granger cause the growth of industrial production.

It is found that increase in real oil prices negatively affects the growth rate of industrial production in linear and non-linear specifications. For the Indian economy we find that a 100 percent increase in real oil prices reduced the growth of industrial production by one percent. This small impact of the growth of industrial production can be traced, among other factors, to depreciation in the real effective exchange rate. Furthermore, we find that the inflation rate and short-term interest rate are positively affected by the increase in real oil prices.

We also obtain evidence on asymmetric relationship between oil prices and the growth of industrial production confirming the relationship found in developed economies. Among all specification used for oil prices the one that turns out to be best performing from a statistical standpoint is SOPI model. This implies that it is not just only price changes, but also the environment in which the movements take place. An oil price shock in a stable environment has larger economic consequences than one in a volatile price environment.

The variance decomposition analysis shows that the oil price shocks are a considerable source of volatile for the variables used in the study. For the growth of industrial production the oil price shocks combined with the monetary shocks are the largest source of variation other than the variable itself, thus, the variance decomposition analysis put the relationship between oil price-industrial growth into perspective, while the focus of the study is to analyze the impact of oil price shocks on the growth of industrial production.

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Appendix

The quarterly data used in this study are mainly obtained from two sources: International Financial Statistics (IFS) CDROM and the Reserve Bank of India (RBI) Database of Indian Economy. The variable and source details are these:

Economic Activity: The aggregate economic activity is proxied by Index of Industrial Production (IIP) since for India quarterly GDP series is available since 1996-97 only. The series for IIP cover the period 1975Q1 to 2004 and is taken from IFS-CDROM.

Oil Price Variable: The world oil price measured in US$ for India is calculated as the average of UK Brent and Saudi Prices since India's oil imports are mainly based on the prices of these two markets. To convert these oil prices into real world prices we deflated the nominal prices by the world consumer price indices. The real oil prices measured in Indian rupees (INR) is calculated by converting the world oil prices by the market rate of exchange and deflated by the wholesale price indices (WPI) found in India. The series for oil price cover the period 1970Q1 to 2004Q4 and is taken from IFS-CDROM.

Inflation Rate: calculated from consumer Price Index (CPI) and is taken from the IFS-CDROM for the period 1975Q1 to 2004Q3.

Short-term Interest Rate: measured by the money market rate of interest (MMR) and is obtained from RBI for the period 1975Q1 to 2004Q3. RBI provided monthly estimated of money market rate of interest. To convert the series into quarterly data we have taken the simple three months average.

Real Effective Exchange Rate (REER): REER series is taken from the RBI for the period 1975Q1 to 2004Q3. RBI provided monthly estimated of money market rate of interest. To convert the series into quarterly data we have taken the simple three months average. RBI constructs the 5-countrytrade based nominal effective exchange rate (NEER) and REER on a daily basis. The countries chosen are USA, Germany, Japan, United Kingdom and France (G-5 countries). REER is defined as weighted average of NEER adjusted by ratio of domestic inflation rate to foreign inflation rates. In terms of formula,

REER = $\prod_{i=1}^{5}\left[\left(\frac{e}{e_i}\right)\left(\frac{P}{P_i}\right)\right]^{w_i}$ where: e: Exchange rate of rupee against numeraire (SDRs) (i.e., SDRs per Rupee) (in index form), e_i: Exchange rate of currency i against the numeraire(SDRs) (i.e., SDRs per currency i) (in index form) (i = US Dollar, Japanese Yen, Deutsche Mark, Pound Sterling, French Franc), w_i: Weights attached to currency/country i in the index, P: India's wholesale price index (WPI) (in Index form), and P_i: Consumer Price Index (CPI) of country i (in Index form). The increase in the value of REER implies the appreciation of the currency and decline in the competitiveness of the country.

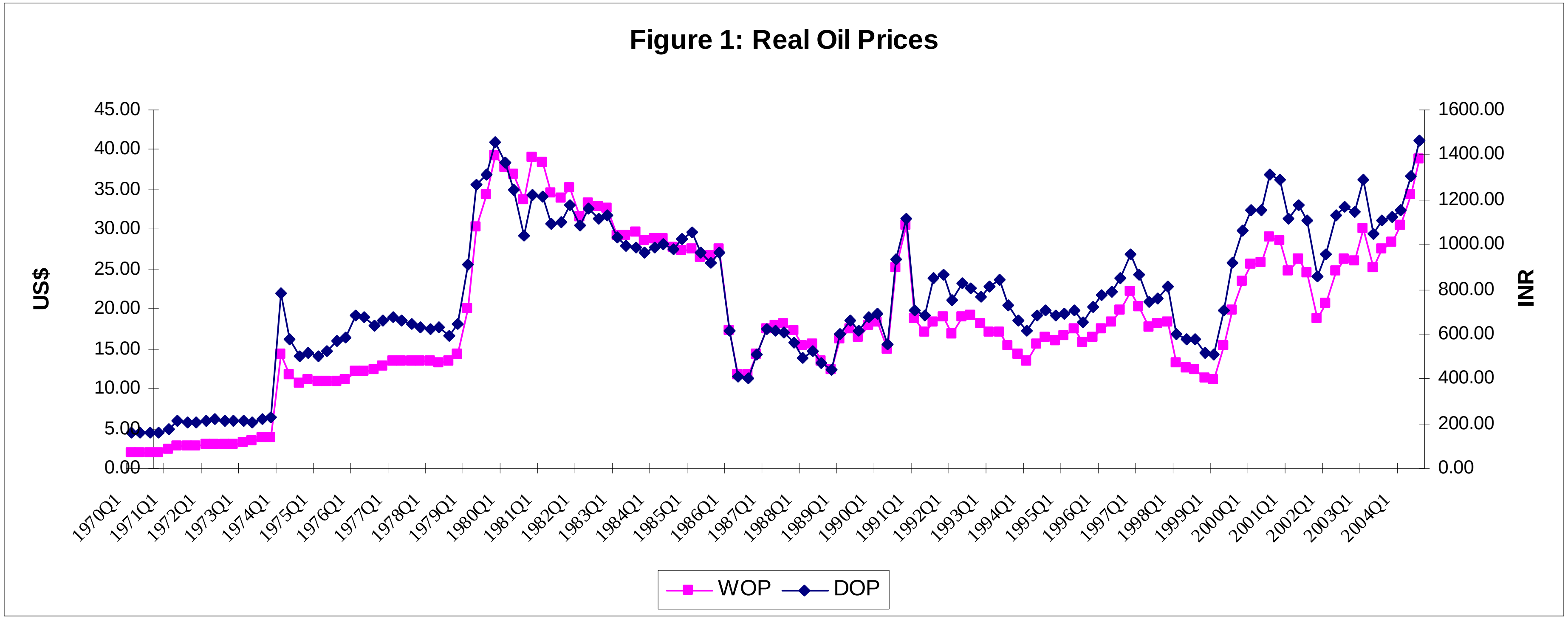
Figure 1: Real Oil Prices
US$
INR
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
1970Q1
1971Q1
1972Q1
1973Q1
1974Q1
1975Q1
1976Q1
1977Q1
1978Q1
1979Q1
1980Q1
1981Q1
1982Q1
1983Q1
1984Q1
1985Q1
1986Q1
1987Q1
1988Q1
1989Q1
1990Q1
1991Q1
1992Q1
1993Q1
1994Q1
1995Q1
1996Q1
1997Q1
1998Q1
1999Q1
2000Q1
2001Q1
2002Q1
2003Q1
2004Q1
WOP
DOP

Figure 2: Oil Price Changes in INR

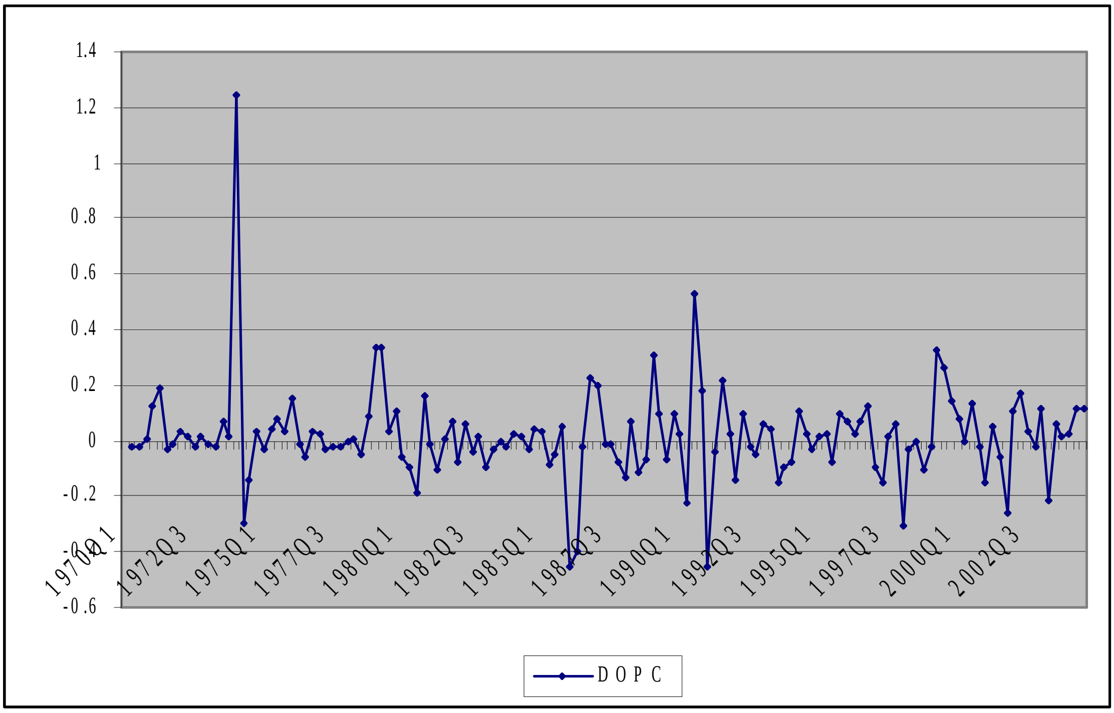

Figure 3 Oil Price Increases in INR (Real Oil Price Increase)

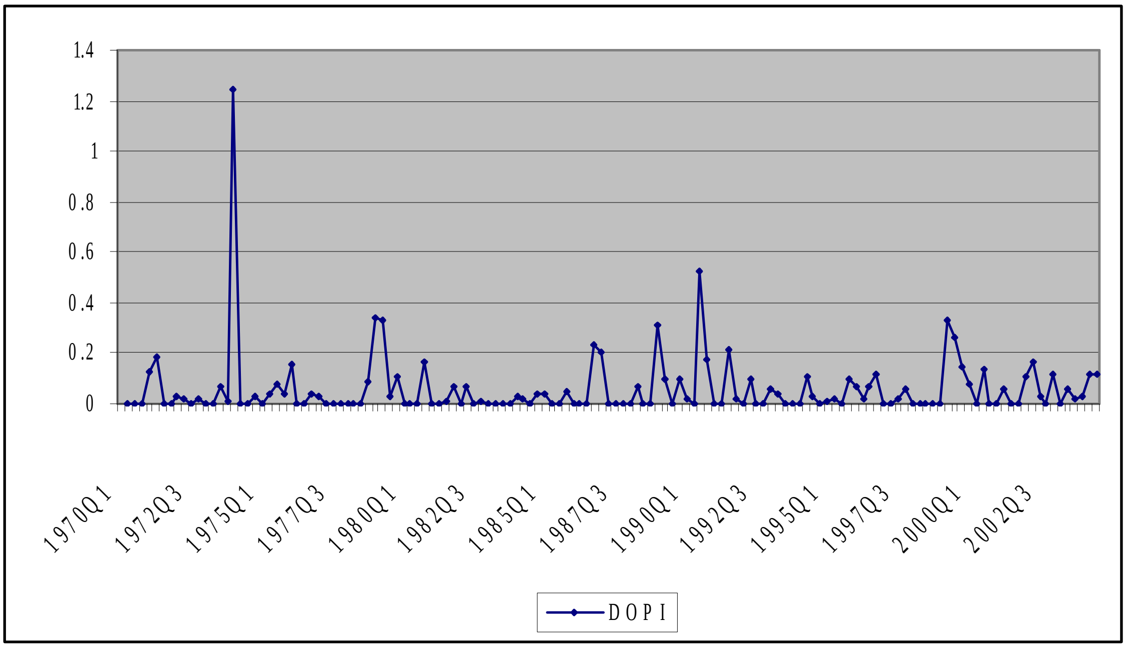

Figure 4 Net Oil Price Increases in INR (NOPI4)

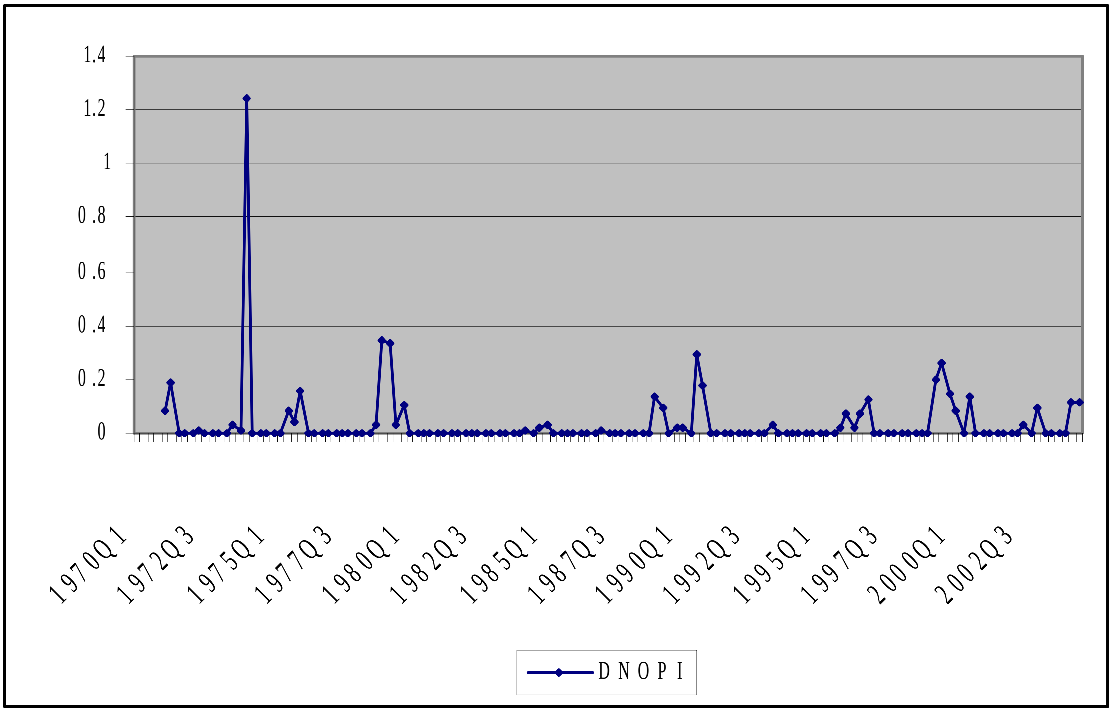

Figure 5 Scaled Oil Price Increase in INR (SOPI)

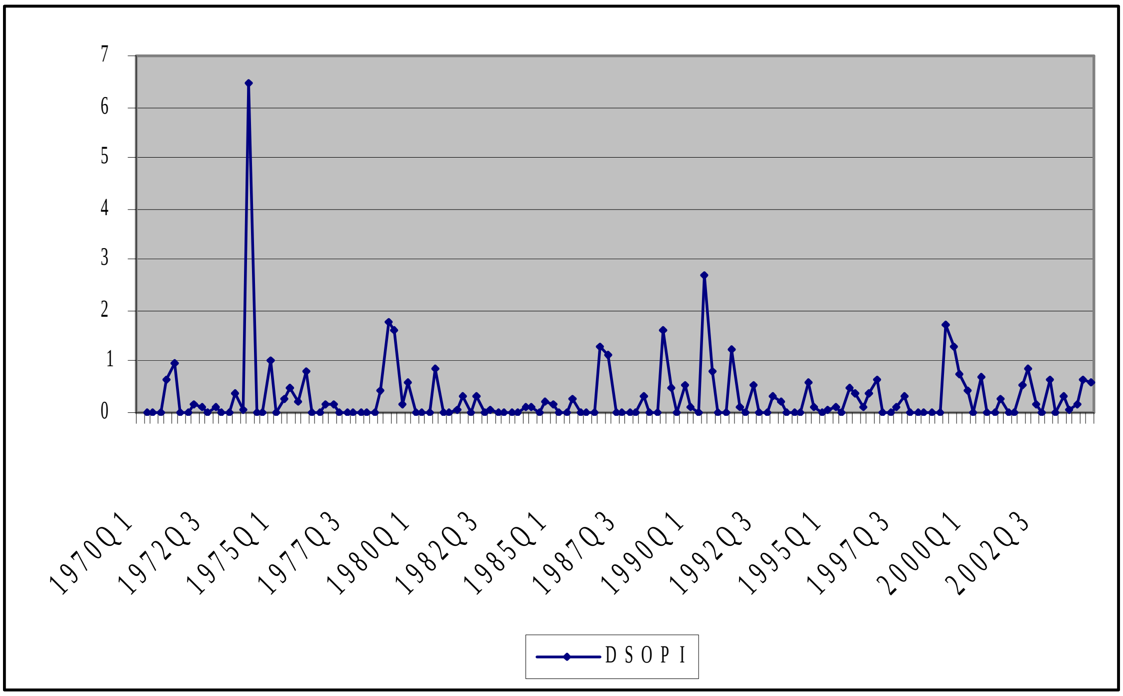

Figure 6.1 Orthogonalised impulse-response function of industrial growth to a one-standard-deviation oil price innovation (real oil price change)

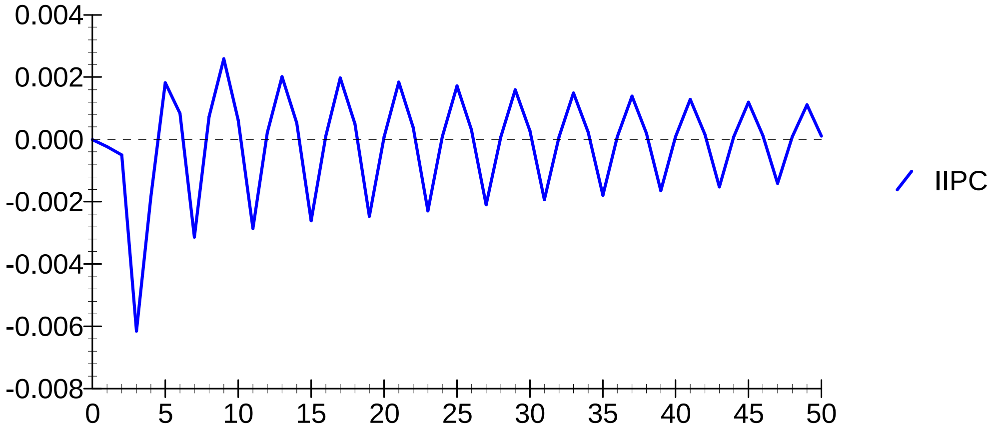

Figure 6.2 Orthogonalised impulse-response function of industrial growth to a positive one-standard-deviation oil price innovation (real oil price increase)

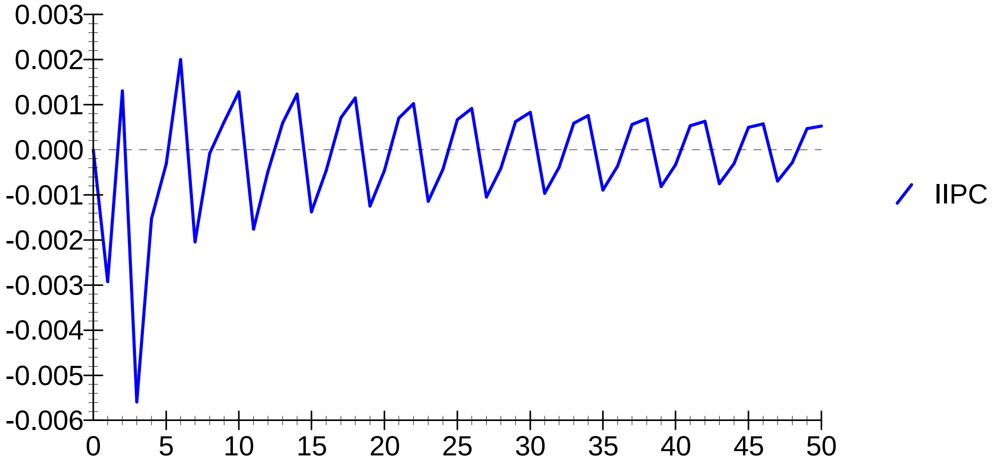

Figure 6.3 Orthogonalised impulse-response function of industrial growth to a positive one-standard-deviation oil price innovation (net oil price increase, NOPI4)

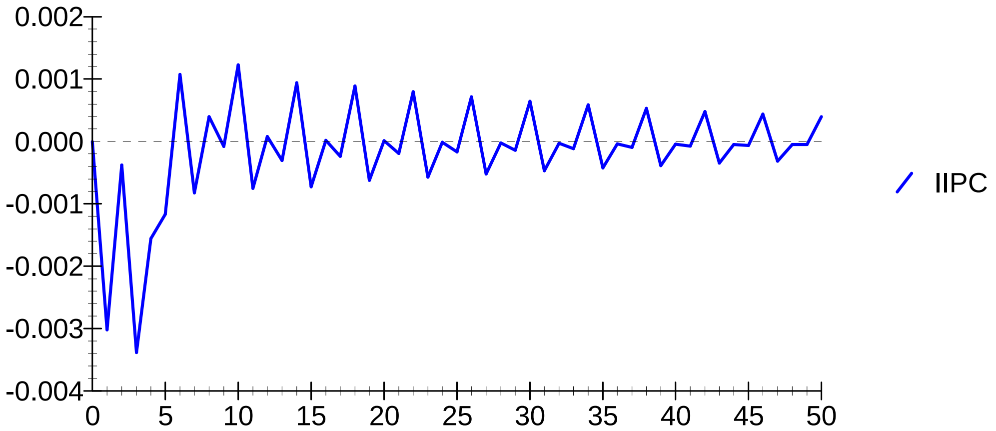

Figure 6.4 Orthogonalised impulse-response function of industrial growth to a positive one-standard-deviation oil price innovation (net oil price increase, NOPI12)

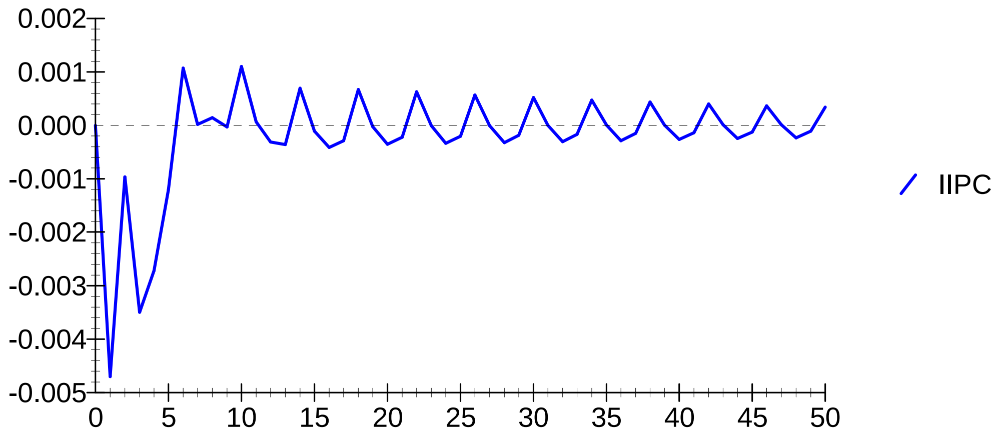

Figure 6.5 Orthogonalised impulse-response function of industrial growth to a one-standard-deviation oil price innovation (scaled oil price change, SOPC)

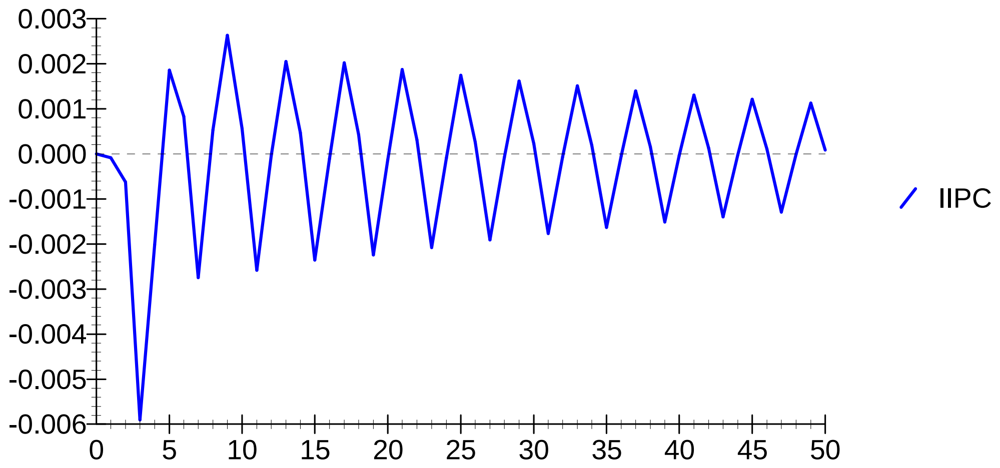

Figure 6.6 Orthogonalised impulse-response function of industrial growth to a positive one-standard-deviation oil price innovation (scaled oil price increase, SOPI)

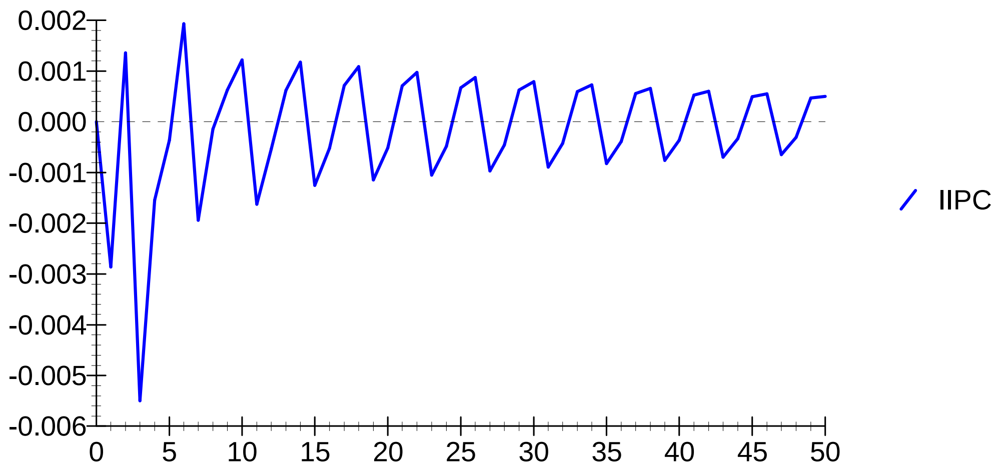

Table 1 Unit Root Test

ADF Test						
	Level			First Difference		
	(i)	(ii)	(iii)	(i)	(ii)	(iii)
Log (IIP)	4.22	-0.05	-2.69	-1.67***	-4.05*	-4.03**
Log (Oil Price) INR	0.68	-2.64***	-2.69	-5.86*	-5.92*	-5.90*
Log (Oil Price) US$	-0.69	-0.71	-2.39	-5.64*	-5.67*	-5.68*
Log (REER)	-2.00**	-0.17	-2.01	-3.43*	-4.03*	-4.04*
CPI	2.94	1.98	-2.42	-1.82***	-3.25**	-4.74*
MMR	-1.35	-3.41**	-3.46**	-5.18*	-5.17*	-5.15*
Phillips-Perron (PP) Test						
Log (IIP)	4.63	-0.27	-7.68*	-14.92*	-20.17*	-20.05*
Log (Oil Price) INR	0.56	-2.57	-2.66	-9.28*	-9.27*	-9.23*
Log (Oil Price) US$	-0.66	-0.73	-2.28	-10.81*	-10.79*	-10.78*
Log (REER)	-2.84*	-0.13	-1.58	-8.99*	-9.53*	-9.50*
CPI	8.60	3.50	-2.43	-6.22*	-8.53*	-9.61*
MMR	-1.59	-5.40*	-5.47*	-18.76*	-18.71*	-18.64*

Note: (i): with no regressors; (ii): with an intercept; (iii): with an interecept and a linear time trend. *, ** and *** indicate that the test statistics is statistically significant at 1%, 5% and 10% level respectively.

Table 2 Wald Test

Model	Oil Price in Indian Rupees	Oil Price in US Dollars
Δoil_t	4.2076[0.040]**	4.8879[0.027]**
Δoil_t^+	5.3402[0.021]**	5.4992[0.019]**
Δoil_t^-	0.14663[0.702]	0.62921[0.428]
NOPI4	5.1911[0.023]**	8.3977[0.004]*
NOPD4	1.9987[0.157]	1.1881[0.276]
NOPI12	12.4496[0.000]*	10.7450[0.001]*
NOPD12	2.1667[0.141]	1.3991[0.237]
SOPC	4.2694[0.039]**	4.9789[0.026]**
SOPI	5.2349[0.022]**	5.4760[0.019]**
SOPD	0.20145[0.654]	0.75492[0.385]

Note: Δoil_t: Real oil price change; Δoil_t^+: increase in real oil prices; Δoil_t^-: Decrease in real oil prices; NOPI4: Increase in real oil prices over previous four quarters; NOPD4: Decrease in real oil prices over previous four quarters; NOPI12: Increase in real oil prices over previous twelve quarters; NOPD12: Decrease in real oil prices over previous quarters; SOPC: Scaled real oil price change; SOPI: Scaled real oil price increase; and SOPD: scaled oil price decrease. Values in parentheses are p-values of the asymptotic distribution Chi-squared for the different models considered. H_o: the oil price coefficients are jointly equal to zero in the IIP growth equation of the VAR model. *, **, *** asterisks mean a p-value less than 1%, 5%, and 10% respectively.

Table 3 Likelihood Ratio Test

Model	Oil Price in Indian Rupees	Oil Price in US Dollars
Δoil_t	9.7469[0.045]**	12.2309[0.016]**
Δoil_t^+	10.0428[0.040]**	13.0313[0.011]**
Δoil_t^-	4.9952[0.288]	7.4244[0.115]
NOPI4	7.3431[0.119]	11.4006[0.022]**
NOPD4	7.0485[0.133]	7.4828[0.112]
NOPI12	15.6486[0.004]*	13.7186[0.008]*
NOPD12	5.9627[0.202]	5.9212[0.205]
SOPC	9.6345[0.047]**	12.0660[0.017]**
SOPI	9.8780[0.043]**	12.7647[0.012]**
SOPD	5.6185[0.230]	8.1028[0.088]***

Note: Δoil_t: Real oil price change; Δoil_t^+ : increase in real oil prices; Δoil_t^- : Decrease in real oil prices; NOPI4: Increase in real oil prices over previous four quarters; NOPD4: Decrease in real oil prices over previous four quarters; NOPI12: Increase in real oil prices over previous twelve quarters; NOPD12: Decrease in real oil prices over previous quarters; SOPC: Scaled real oil price change; SOPI: Scaled real oil price increase; and SOPD: scaled oil price decrease. H_o: All oil price coefficients are jointly zero in all equations of the system but its own equation. *, **, *** asterisks mean a p-value less than 1%, 5%, and 10% respectively.

Table 4 LR Test of Block Granger Non-Causality in the VAR

Model	Oil Price in Indian Rupees	Oil Price in US Dollars
Δoil_t	47.1234[0.000]*	47.3433[0.000]*
Δoil_t^+	39.0555[0.001]*	39.1276[0.001]*
Δoil_t^-	45.7280[0.000]*	47.0713[0.000]*
NOPI4	20.8415[0.185]	21.9508[0.145]
NOPD4	33.5816[0.006]*	35.6992[0.003]*
NOPI12	33.7852[0.006]*	23.7708[0.095]***
NOPD12	22.4802[0.128]	36.9883[0.002]*
SOPC	47.6201[0.000]*	47.3668[0.000]*
SOPI	38.9706[0.001]*	38.2700[0.001]*
SOPD	46.5717[0.000]*	48.6510[0.000]*

Note: Δoil_t: Real oil price change; Δoil_t^+ : increase in real oil prices; Δoil_t^- : Decrease in real oil prices; NOPI4: Increase in real oil prices over previous four quarters; NOPD4: Decrease in real oil prices over previous four quarters; NOPI12: Increase in real oil prices over previous twelve quarters; NOPD12: Decrease in real oil prices over previous quarters; SOPC: Scaled real oil price change; SOPI: Scaled real oil price increase; and SOPD: scaled oil price decrease. H_o: oil price variable Granger-causes the remaining variables of the system. *, **, *** asterisks mean a p-value less than 1%, 5%, and 10% respectively.

Table 5 Relative Performance of the Models

	Oil Price in Indian Rupees		Oil Price in US Dollars	
Model	AIC	SBC	AIC	SBC
Δoil_t	120.5876	-23.5214	120.9693	-23.1397
Δoil_t^+	163.0239	18.9149	173.9208	29.8119
Δoil_t^-	173.9277	29.8187	168.2319	24.1229
NOPI4	195.9130	51.8041	220.5335	76.4246
NOPD4	199.7075	55.5986	175.3543	31.2454
NOPI12	221.0581	76.9491	248.7439	104.6350
NOPD12	231.8209	87.7120	193.2329	49.1239
SOPC	-68.1654	-212.2744	-69.2026	-213.3115
SOPI	-26.4226	-170.5315	-16.5021	-160.6110
SOPD	-14.0370	-158.1459	-20.7109	-164.8199

Note: Δoil_t: Real oil price change; Δoil_t^+ : increase in real oil prices; Δoil_t^- : Decrease in real oil prices; NOPI4: Increase in real oil prices over previous four quarters; NOPD4: Decrease in real oil prices over previous four quarters; NOPI12: Increase in real oil prices over previous twelve quarters; NOPD12: Decrease in real oil prices over previous quarters; SOPC: Scaled real oil price change; SOPI: Scaled real oil price increase; and SOPD: scaled oil price decrease. AIC: Akaike's information Criterion; SBC: Schwarz Bayesian Information Criterion

Table 6 Accumulated Impulse response functions

Industrial Growth										
	Δoil_t	Δoil_t^+	Δoil_t^-	NOPI4	NOPD4	NOPI12	NOPD12	SOPC	SOPI	SOPD
4 Q	-0.0087	-0.0087	-0.0036	-0.0083	-0.0075	-0.0118	-0.0078	-0.0087	-0.0086	-0.0038
6Q	-0.0062	-0.0072	-0.0012	-0.0086	-0.0042	-0.0122	-0.0055	-0.0060	-0.0072	-0.0014
8Q	-0.0084	-0.0091	-0.0039	-0.0088	-0.0085	-0.0117	-0.0103	-0.0081	-0.0090	-0.0040
10Q	-0.0054	-0.0074	-0.0003	-0.0079	-0.0039	-0.0109	-0.0055	-0.0051	-0.0074	-0.0002
12Q	-0.0079	-0.0094	-0.0028	-0.0083	-0.0080	-0.0109	-0.0097	-0.0076	-0.0094	-0.0028
Consumer Price Index (CPI)										
	Δoil_t	Δoil_t^+	Δoil_t^-	NOPI4	NOPD4	NOPI12	NOPD12	SOPC	SOPI	SOPD
4 Q	-0.3088	-0.0425	-0.4307	-0.2026	-0.1953	-0.0097	-0.2052	-0.3034	-0.0446	-0.4199
6Q	-0.2126	0.1192	-0.4451	-0.1131	-0.1054	0.1519	-0.1336	-0.2101	0.1170	-0.4399
8Q	-0.2221	0.0774	-0.4114	-0.1115	-0.0646	0.1124	-0.1083	-0.2252	0.0725	-0.4130
10Q	-0.2793	0.1019	-0.5059	-0.1000	-0.1556	0.1450	-0.1682	-0.2819	0.0976	-0.5042
12Q	-0.2616	0.1070	-0.4885	-0.1069	-0.1455	0.1279	-0.1788	-0.2647	0.1023	-0.4893
Money Market Interest Rate (MMR)										
	Δoil_t	Δoil_t^+	Δoil_t^-	NOPI4	NOPD4	NOPI12	NOPD12	SOPC	SOPI	SOPD
4 Q	0.7004	1.6860	-0.5929	1.0384	0.3673	1.0085	0.4671	0.5663	1.6169	-0.7130

6Q	0.1432	1.6542	-1.3156	1.0751	0.1027	1.0209	0.3175	-0.0633	1.5568	-1.5099
8Q	-0.1328	1.8901	-1.9282	1.1247	-0.1972	1.1277	-0.0052	-0.3914	1.7681	-2.1843
10Q	-0.2511	1.9427	-2.1990	1.0644	-0.3318	1.0672	-0.2297	-0.5084	1.8135	-2.4812
12Q	-0.3647	1.9309	-2.3755	1.0114	-0.3979	0.9918	-0.3251	-0.6215	1.7994	-2.6647
Real Effective Exchange Rate (REER)										
	Δoil_t	Δoil_t^+	Δoil_t^-	NOPI4	NOPD4	NOPI12	NOPD12	SOPC	SOPI	SOPD
4 Q	0.0296	-0.0168	0.0576	0.0066	0.0397	0.0029	0.0467	0.0287	-0.0173	0.0574
6Q	0.0434	-0.0371	0.0976	0.0028	0.0606	-0.0107	0.0716	0.0430	-0.0367	0.0979
8Q	0.0560	-0.0592	0.1385	-0.0040	0.0797	-0.0275	0.0954	0.0565	-0.0579	0.1397
10Q	0.0713	-0.0796	0.1811	-0.0097	0.0995	-0.0422	0.1200	0.0727	-0.0775	0.1833
12Q	0.0876	-0.0995	0.2248	-0.0143	0.1209	-0.0554	0.1466	0.0900	-0.0965	0.2281

Note: Δoil_t: Real oil price change; Δoil_t^+: increase in real oil prices; Δoil_t^-: Decrease in real oil prices; NOPI4: Increase in real oil prices over previous four quarters; NOPD4: Decrease in real oil prices over previous four quarters; NOPI12: Increase in real oil prices over previous twelve quarters; NOPD12: Decrease in real oil prices over previous quarters; SOPC: Scaled real oil price change; SOPI: Scaled real oil price increase; and SOPD: scaled oil price decrease.

Table 7 Estimated Orthogonal Variance Decomposition

Real oil price change					
	Industrial Growth	Oil Price	CPI	MMR	REER
Industrial Growth	91.33	2.64	0.63	2.59	2.81
Oil Price	1.88	92.82	3.07	1.17	1.06
CPI	16.33	10.95	53.96	15.72	3.05
MMR	10.31	2.69	5.73	73.73	7.54
REER	0.82	3.47	9.91	35.30	50.49
Real oil price increase					
Industrial Growth	92.70	1.84	0.48	2.35	2.63
Oil Price	0.65	91.44	4.22	1.72	1.97
CPI	18.01	5.21	60.69	13.51	2.59
MMR	11.15	6.55	6.00	68.06	8.25
REER	1.76	4.24	13.33	25.75	54.93
Real oil price decrease					
Industrial Growth	91.93	3.32	0.47	2.56	1.71
Oil Price	3.48	92.94	0.74	0.87	1.97
CPI	16.62	13.00	51.90	15.81	2.67
MMR	11.09	4.65	3.46	74.43	6.37
REER	1.47	21.25	5.33	32.96	38.99
Net oil price increase over last 4 quarters (NOPI4)					
Industrial Growth	93.90	0.88	0.35	3.03	1.85
Oil Price	3.00	90.52	3.59	0.95	1.95
CPI	18.55	3.82	60.39	14.14	3.10
MMR	12.73	1.64	5.41	70.36	9.85
REER	1.26	0.20	12.85	30.35	55.34
Net oil price decrease over last 4 quarters (NOPD4)					
Industrial Growth	92.28	4.03	0.32	2.09	1.28
Oil Price	2.81	91.16	1.48	2.02	2.54
CPI	16.30	12.46	54.22	13.55	3.47
MMR	10.59	1.01	3.94	76.90	7.56
REER	0.56	5.88	8.57	38.81	46.18
Net oil price increase over last 12 quarters (NOPI12)					
Industrial Growth	93.35	1.35	0.16	3.53	1.60
Oil Price	3.49	91.07	3.67	1.14	0.63
CPI	18.47	2.51	63.15	12.71	3.16
MMR	17.06	3.14	4.00	66.55	9.25
REER	5.16	2.14	12.57	25.76	54.36
Net oil price decrease over last 12 quarters (NOPD12)					
Industrial Growth	93.09	3.47	0.07	2.30	1.07

Oil Price	3.13	91.96	0.42	1.96	2.53
CPI	16.85	6.88	58.88	14.21	3.19
MMR	10.20	0.98	4.47	76.68	7.67
REER	0.92	7.99	9.99	36.78	44.32
Scaled oil price change (SOPC)					
Industrial Growth	91.57	2.42	0.56	2.66	2.79
Oil Price	1.93	92.33	3.20	1.28	1.26
CPI	16.32	10.92	53.98	15.71	3.07
MMR	9.89	2.93	5.69	74.32	7.16
REER	0.76	3.67	9.66	35.49	50.42
Scaled oil price increase (SOPI)					
Industrial Growth	92.72	1.75	0.47	2.35	2.71
Oil Price	0.61	90.90	4.32	1.93	2.24
CPI	17.94	5.16	60.77	13.55	2.58
MMR	10.80	6.38	6.04	68.66	8.12
REER	1.54	3.90	13.31	26.61	54.66
Scaled oil price decrease (SOPD)					
Industrial Growth	92.03	3.27	0.40	2.63	1.67
Oil Price	3.87	92.24	0.84	0.91	2.14
CPI	16.58	13.04	51.82	15.86	2.70
MMR	10.95	5.34	3.25	74.31	6.14
REER	1.42	21.70	5.13	32.47	39.29

Note: CPI: Consumer price index; MMR: Money market interest rate; REER: Real effective exchange rate. This table presents the results of the estimated variance decomposition at 12-period horizon.