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THE OIL STORY: IS IT STILL THE SAME?

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Abstract

It is not to be doubted that the oil price shocks adversely impact the economy. Enough literature is present in support of this fact but, at the same time, it is equivalently important to determine the changing nature of this relationship. This paper studies the changing behavior of this relation from 1948-2018 and shows that the oil prices are no more as effective in explaining the changes in the output of the economy as it had been before the 1970s. Our results also show the extent to which oil intensity has reduced in effecting the output of the US economy along with explaining the short term and long term impacts of oil shocks. Through variance decomposition analysis, the paper explains the reason for this decline in oil importance in recent time. Various factors like changing technology and political and strategic implications are found to be a few of the many reasons behind this change.

Key words: *Macroeconomic Fluctuations; Oil shocks; Energy and the Macroeconomy; ARDL Model; VAR; Granger causality test; Error Variance Decomposition*

JEL Codes: *E32; C22; C32; Q43*

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INTRODUCTION

Oil is one of the most important commodities and is used for a plethora of reason across the economy. Oil prices throughout history have played an important role in affecting the economy by impacting the macroeconomic variables like GDP, inflation rates, stock prices etc. However, the oil price- macroeconomy relation came into limelight during the mid 1970s. Hamilton in his seminal 1983 paper demonstrated that oil shocks were a contributing factor in all but one US recession since the end of World War II. This finding was the beginning of many more pieces of research that questioned the effect of oil prices on the economy, especially in the post-war period. It has been statistically tested and analyzed by many independent types of research that the relationship has changed for the post 1973¹ period. Several studies such as those by Mark (1996), Mork (1989) and few more advocated that oil price changes are an unreliable instrument for macroeconomic analysis of data post-1973 and they gave many possible explanations for the same. The magnitude of the effect of oil shocks on GDP has also attracted the interest of economist involved in policymaking.

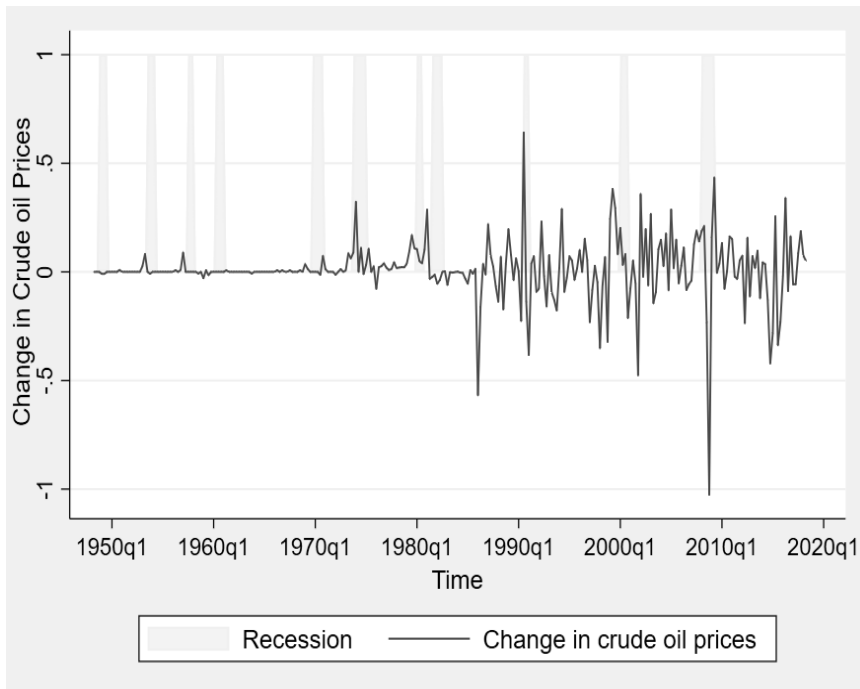
We also test the hypothesis proposed by Hamilton (1983) for the U.S and study the nature of oil shocks to the US economy. The time selected is 1948Q1:2018Q1. Figure 1 shows the changes in crude oil prices (solid line) and the US recessions (shaded region). Along with testing the hypothesis, we also test for the change in the effect of oil prices on the macroeconomic variables for different sub samples². In addition to this, the paper also attempts to test the extent or intensity of the effect of the oil shocks on GDP for all the subsamples. The results are well in line with the previous studies and it is well understood that the oil shocks did matter- affect GDP before 1973 and for periods after, however, the impact has decreased. Thus, it is evident that the

¹ This year is significant as it marks one of the greatest oil shocks which took place when the members of the Organization of Arab Petroleum Exporting Countries proclaimed an oil embargo.

² The sub samples have been estimated according to the structural breaks in the model.

importance of oil as a commodity has declined since the post war period and several factors are to be assessed. Figure 1 shows that almost all the US recessions were preceded by an oil price increase except for a few of them.

Figure 1: Changes in Crude Oil Price and US recessions: 1948-2018



Source: St. Louis Fred, Authors' Calculations

To answer why oil dependency has reduced, we study that one of the major factors that can be attributed is the presence of oil substitutes and the changing nature of people's consumption behavior. As more and more people are getting aware of their environment and future, there is a shift towards renewable energy consumption that is being witnessed. We test this relation and the results obtained show that oil consumption has reduced effect on GDP as compared to the

renewable energy consumption for the second sub-sample period. Although there are several factors that have contributed to oil dependency reduction; the presence of substitutes have played an important role.

Oil Prices and the Macroeconomy

Oil market plays an important role because of its dominant role as an energy source. Economies fall and rise by the price of oil which then impacts the global economy. The changing oil prices do not only have an ephemeral impact rather, a long term impact on the investment decisions of people ultimately exposes economies to financial imbalances.

The oil impacts the economy through various channels and thus, it is important to study the behavior of oil prices and any changes that take place and the way those changes impact the economy. The two major kinds of implications of the changing oil prices on our economy are on the microeconomic scale and the macroeconomic scale. When there is an increase in oil prices, the gasoline price also increases thus affecting the household budget as they have to shift their expenditure of other commodities to gasoline consumption. Not only are households affected but, the business is also affected as many industries need oil in their production process and thus, it also becomes expensive to produce the goods and services. All these are the microeconomic implications of the change in oil price. Another aspect to look at is the increased inflation due to the increase in crude prices. Any revision in the inflation rate impacts the economic growth of the economy; growth is hampered if inflation is increased. The prices of petroleum-based products are most affected by increasing prices of oil as the production and the transportation costs have tampered. All this restrains the growth of the economy as the supply and demand of other goods are affected.

The demand for oil has changed in recent years and the major factor behind the changing demand has been negative revisions to global economic prospects. The three major factors that impacted the demand

of oil in some time have been the diversification in OPEC countries, change in international oil demand especially developing countries like China and India and the change in inventories of large oil-consuming nations. Increasing demand for oil by China has been due to industrialization and urbanization boom. However, there is another side to the demand story; demand has been low in very recent times since people have changed their preferences and consume less of oil especially in the transportation sector.

Oil substitutes and alternatives, on the other hand, have started replacing the big boy and hence the dependency has started falling. Oil is no more the monopoly and substitutes like natural gas or renewable sources of energy have taken a position in the market. The bio-fuels production increased since the 2000s with the US being the largest producer followed by Brazil and the European Union. Electrification of the car sector and improvement of the fuel efficiency of automobiles has started showing an impact on the demand for oil in developed countries. These efforts towards substitution and conservation of resources are dominant in shaping the oil demand and thus supply. One episode of reduced demand was seen in 2008 and since 2012 the global growth is disappointing. The crude oil inventories have also started piling since 2014. All these demand-side disruptions have had a huge impact on the supply of crude oil.

It is highly important to acknowledge the supply side factors as that determines the market for crude oil. The supply in the past has been hindered due to various factors like the conflict within armed forces, discoveries and extraction techniques, strategic shifts on OPEC part and many more. The oil supply also increased due to increased production of discoveries like shale oil in the US³, oil sand in Canada and North America and deepwater oil in Brazil. These have been a game-changer in the

³ Shale gas expansion since mid 2000's reversed the long-standing decline in the US crude oil production and during 2004-2012 periods US experienced exponential growth in shale oil production.

supply of oil in the world. This increase in new technology did benefit as it brought production to the level of demand without increasing the price of oil. These unconventional oil supply sources are more promising than the conventional oil fields as they have helped in reducing the cost of extraction and have the potential of discovering new oil fields. The supply side has also faced sluggish growth due to an increase in oil reserve growths. Other than these, there are many more factors that affect the price of oil. Geopolitical reasons such as unavailability of much spare capacity at stocks or loss in production affect prices in the short run. Declining dollar leads to a reduction in oil price and increased oil demand. Inflation expectations lead to price pressure and hence problems in oil-importing and exporting countries. The central bank thus has to focus on speculations in the market to keep inflation in line with short and medium-term goal. Thus, speculations need to be examined keenly so that there are no hike in prices due to a shift in future markets.

All these factors have convinced economist and researchers to think about the effect of changing oil prices on economies. A lot of theories have been built to state the reasons for the impact of oil price fluctuations on the macro-economy. It is highly important to understand the role of oil prices in impacting the current economy and whether they have a severe role to play in the recessions or economic downturns that an economy faces or not. The paper tests whether the situation is true and how the oil story has changed since time.

We further discuss the literature on the relationship between oil prices and the macroeconomic variables, the changing pattern of oil shock effect and previous empirical findings. We then present various econometric tests that include unit root tests, structural break tests and Granger Causality estimates. Further, we build the model through system equations to study the role of oil on the macroeconomy. Next, we conduct bound tests to check for the presence of a long run relationship between the variables. To take our research further and to examine the reason for the reduced oil dependency, we conduct the ADL tests to

study the role of increasing renewable energy consumption in recent years and its impact on reduced oil demand and the output of the US economy. The study concludes by testing for the relationship between increasing oil inventories and oil prices. Our results show that the oil prices are no more as effective in explaining the changes in the output of the economy as it had been before the 1970s. Various factors like changing technology and political and strategic implications are found to be a few of the many reasons behind this change.

Impact of Oil Price Change

The foundation stone for the study in this field was laid down by James D. Hamilton in his seminal paper of 1983. His study spanned for the period 1945-75 and he observed that all but one⁴ of the US recessions since WWII have been preceded, typically with a lag by a dramatic increase in the price of crude petroleum. He studied oil prices under two different regimes and found a structural break in the series at 1973. He found that for the period 1948-72, oil prices increase tended to be followed by a reduction in real GNP growth which otherwise would not have been anticipated. The paper also claims that the correlation did not arise because oil prices were proxy of some third variable that was, in fact, a true cause of a recession. He concludes by saying that for postwar recessions it cannot be said that oil price increase are either a necessary or sufficient condition nor shall this correlation be viewed as an immutable structural regime.

Taking the research further ahead, Hooker (1996) investigated what happened to the relationship after the 1973 period and oil shocks were proved incomplete in capturing the impact of 1980-82 recessions. The results showed that oil prices no longer Granger caused many macroeconomic variables which have been explained by a number of potential reasons. He concluded that price increase/decrease asymmetry

⁴ The recession of 1960-61 has been the exception in this case as it was not preceded by any oil price increase.

could not represent the oil price-macro-economy relationship well. Hooker through his paper clearly demonstrated that neither the linear relationship proposed by Hamilton (1983) nor the asymmetric relation based on oil prices by Mork (1989) is consistent with the observed economic performance over the last decade. In addition to the above studies, Bernanke (1997) also studied the role of monetary policy in postwar US recessions and found that the effect of oil price shock on the economy does not come from the change in oil prices rather, from the tightening of monetary policy. This explained the large effects of oil price changes found by Hamilton and other notable economists. However, Kilian and Vigfusson (2009) in their paper showed that models that support a decline in GDP in response only to unexpected increases and not decreases are invalid. Their results showed that in structural model encompassing both symmetric and asymmetric models, the impulse responses are of roughly the same magnitude in either direction, consistent with tests for symmetric responses.

Kilian (2008) also studied the effect of the exogenous oil shock on the US GDP and CPI inflation. The results depicted that the shocks made little contribution to the US economy since the 1970s though they did matter for some historical episodes. Segal (2011) studied both the microeconomic and macroeconomic perspective of the role of an oil price increase and concluded that microeconomic mechanisms could not truly explain the impact of oil price on the economy through the 1970s and that the monetary policy mechanism was the more promising explanation. However, the results depicted that the shocks made little contribution to the US economy since the 1980s though they did matter for some historical episodes.

The Changing Pattern of the Oil Price Effect

In comparing 2000s to the 1970s, Blanchard and Riggi (2009) found that in the 2000s even with larger increases in the price of oil its effect of inflation and output has been milder than the 1970s. This according to them has been reflected in large part in the change in causal relation

from oil price to inflation and output. In a similar paper, Blanchard and Gali (2010) estimate that the effects of oil price shocks have changed over time with much smaller effects on the macroeconomic variables in recent times. They have stated three plausible explanations for this; decrease in real wage rigidities increased credibility of monetary policy and decrease in the share of oil.

In a recent study, Baumeister and Peersman (2013) studied the time-varying effect of oil shocks on the US economy since 1974. They find a decline in the short-run price elasticity of demand since mid-1980s. They showed that an exogenous supply shock in time-varying parameter model leads to declining GDP over time. They also conclude by stating that the oil supply disruptions mattered for mainly two periods and did not matter much for the recessions after the 1980s.

Many more studies have been conducted in the past that have tried to understand the effect and intensity of the oil shocks to the economy through various channels. In a paper by Loungani (1986), the author explains the impact of oil shocks across industries which lead to dispersion in the employment growth. In an altogether different study, Ramey and Vine (2011) studied the impact of oil shocks on the US economy and its motor vehicle industry. Their results show that real output has been as sensitive to oil shocks in mid-1980s as it had been in 1970s, however, the inflation had seen a dip. They also analyze that monetary policy has helped in reducing volatility.

The role of energy in the US economy has also been studied in the past and has presented some important results regarding the same. Stern (1993) examined the causal relationship between GDP and energy use and found that though there is no evidence that gross energy use Granger cause GDP; adjustments with fuel composition do changes the results altogether. Extending his paper for further estimations, Stern (2000) shows that co-integration does occur and that energy input cannot be excluded from co-integration space. He concludes by stating

that energy is a limiting factor in economic growth and that any shock to energy will tend to reduce output. However, a totally contrasting result has been estimated by Payne (2009) who compared the causal relationship between renewable and non-renewable energy consumption and real GDP. His results support the absence of the Granger-Causality between the variables thus supporting the neutrality hypothesis⁵.

Few more studies have been conducted in different countries related to economic growth with various types of energy consumption (Bloch *et. al.* 2015 for China). They studied three main energy sources and found that Chinese growth is determined by all three. They also pointed out that with improving economic and environmental stability; preferences are shifting from coal to renewable energy consumption.

This paper also tries to answer some relevant and important questions about the correlation between oil prices and the macroeconomic variables. The hypothesis raised by Hamilton has been tested for the period considered in the estimation. Along with that, extents to which the changes have been observed through time have been carefully studied and whether it is a long term or a short term relation have also been analyzed. An important argument as to why the oil dependency has reduced over time has also been acknowledged through this paper.

Methodology

To begin with the estimations, we first checked for the stationarity condition for the series used in the model. There are possibly two sources of non-stationarity in this analysis. Thus, to test for the non-stationarity we conduct the Augmented Dickey-Fuller (ADF) test. The ADF tests for the presence of a unit root in a time series sample as the null

⁵ Out of the four hypotheses given by him regarding the causal relation between energy consumption and real output, the neutrality hypothesis states that energy consumption plays a minor role in determination of real GDP.

hypothesis and the alternative hypothesis is usually stationarity or trend stationarity. The testing procedure for the ADF test is

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{i=1}^n \rho_i \Delta y_{t-i} + \varepsilon_t \quad (1)$$

This test has relatively low power to reject the null hypothesis that the series is non-stationary rather than stationary. To deal with the low power of this test, a more powerful test DF-GLS is used. The following results have been observed for the time 1948:Q1- 2018:Q2 for the ADF test.

Table 1: Unit Root Test

Variables	Level	First Log-difference
Oil Prices (O)	-1.973	-16.282***
Unemployment (UNP)	-1.202	-9.736***
Gross National Product (GNP)	-1.256	-7.982***
Consumer Price Index (CPI)	1.849	-7.592***
Producer Price Index (PPI)	1.363	-8.455***

Source: Authors' Calculations

Note: *, ** and *** denote significant at 10 percent, 5 percent and 1 percent levels, respectively.

We performed both ADF and DF-GLS test on the oil price index and the macroeconomic variables in level and the results for ADF are presented in Table 1. Since we are unable to reject the null hypothesis that the series has a unit root, we are unable to say that they are stationary. The results from both the tests do not support stationarity for any of the variables. Thus, we correct for the non-stationary nature of the series. The first source of non-stationarity is the time trend which is common to many macro series. This has been corrected by first-differencing the series. The results of ADF of the differenced series are presented in Table 1 under the first log-differenced heading and since we are able to reject the null hypothesis for all the variables at 1 percent significance level

meaning that all the series are stationary. These results obtained would be used in the estimations further.

The other source of non-stationarity comes from the different institutional regime which has been observed for the oil prices for the time period considered. To distinguish between different regimes, we have tested for the presence of structural breaks in the series. The CUSUM test and multiple structural break tests have been conducted to check for the breaks in the series. Bai and Perron (2003) described an algorithm for the detection of multiple structural breaks in linear regression. If we assume that there are m breakpoints thus we can say that there are $m + 1$ segments in which the coefficients of regression are constant then, the model can be written as

$$y_i = x_i^T \beta_j + u_i \quad (2)$$

Where, $i = i_{j-1} + 1, \dots, i_j$ and j (segment index) = $1, \dots, m+1$. The minimum BIC partition estimator is selected as the one with optimal number of breakpoints along with the corresponding break dates.

Granger Causality test

To assess the relationship between oil prices and the macroeconomic variables, it is important to see whether there is the endogeneity of crude oil prices. To test this we conduct the Granger causality test⁶ (Granger 1969). The test is useful for determining whether one-time series is useful in forecasting another series or not. A multivariate Granger causality analysis is performed by fitting a vector autoregressive model (VAR) to the series. If,

$$X(t) \in \mathbb{R}^{d \times 1}, \text{ for } t = 1, \dots, T \quad (3)$$

be a d -dimensional multivariate time series, then Granger causality is performed by fitting a VAR model with L lags at a time as

⁶ Granger Causality is usually tested through t-tests or F-tests on lagged values of one variable on another variable. A time series X is said to Granger cause Y if lagged values of X provide statistically info about future values of Y .

$$X(t) = \sum_{\tau=1}^L A_{\tau} X(t - \tau) + \varepsilon(t) \quad (4)$$

$\varepsilon(t)$ is the random vector and A_{τ} is a matrix of every τ . X_i Granger causes X_j if at least one element of $A_{\tau}(j, i)$ is significantly larger than zero. However, there are limitations to this kind of test. Even if we are able to statistically prove that 'x does not Granger cause y', it is neither necessary nor sufficient condition for a VAR model to yield consistent parameters. Also, the assertion that 'x Granger cause y' does not say anything about x forcing or producing y.

Thus, we test the Granger causality test for oil prices (x) and other macroeconomic variables (y) and check if the null hypothesis is rejected or not using a system on the lines of those proposed by Sims (1980b). The best approach to test it is by performing an ordinary least square regression on

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \alpha_k x_{t-k} + \beta_1 y_{t-1} + \beta_k y_{t-k} + \varepsilon_t \quad (5)$$

The Model

We begin the analysis by studying the role of oil on the macroeconomy through a system equations proposed by Geweke (1978). He proposed that to test whether output Granger causes oil prices; we must use a model where oil prices appear as the independent variable as:

$$y_t = \alpha_0 + \sum_{i=1}^k \alpha_i y_{t-i} + \sum_{i=0}^k \beta_i o_{t-i} + c_1 o_{t+1} + \dots + c_s o_{t+s} + \varepsilon_t \quad (6)$$

Here, y denotes the output variables, o represents the oil prices, k is the number of lags selected in the model, and ε is the error term. Thus, we test the hypothesis y does not Granger cause oil prices in the form $c_1 = \dots = c_s = 0$. This type of model has been proposed in place of a simple model where output or oil prices being the dependent on own and other variable lagged value as the error terms in those cases are not

compatible with the Gaussian process⁷ unlike Equation (5). We conduct this test for the output variables conducted in our study to check if they Granger cause oil prices or not.

Next, an F-test has been conducted to check for structural change among the coefficients of the following model of Equation (5). This model also tells us about the relation and intensity by which output is impacted by oil prices. We must keep in mind that any change in the structural equation of the system would lead to a change in the coefficients of the relation between oil prices and macroeconomic variables. As discussed earlier, oil shocks not only have a direct effect on output through the supply-side shock rather, also have a long term effect on the output which is carried out through price/monetary transmission mechanism. To show the stickiness of oil price change in the US we use Auto-regressive Distributed Lag (ADL) model with CPI and PPI as the dependent variables. The ADL has re-parameterization in the Error Correction (EC) process which is equivalent to co-integration of non-stationary variables. Since we test both the short and the long run co-integrating relationship between the oil price and the macroeconomy, EC representation is important to assess it. Bounds test/ procedure for testing the long-run relation is based on the EC representation of the ARDL model.

The model that will be estimated to test the relation between price indexes and oil price is

$$y_t = c_0 + \sum_{i=1}^p \alpha_i y_{t-i} + \sum_{i=0}^q \beta_i x_{t-i} + u_t \quad (7)$$

where, $t = \max(p, q), \dots, T$, $y_t =$ Price Indexes, $x_{t-i} =$ Oil price. After this, we have conducted the bounds test developed by Pesaran *et. al.* (2001) and test the presence of a long run relation between the variables.

⁷ The leptokurtic error terms calculated for the other models have been high due to which their exclusion in the analysis will not give correct estimates.

Next, to find a reason for the decreasing oil dependency in recent years, we try to study the role of increasing renewable energy consumption in recent years and its impact on reduced oil demand and the output of the US economy. The presence of oil substitutes is believed to have led to a shift in the oil consumption patterns and thus its impact on the US economy; through this paper, we try to estimate the same effect. To test this relation, ADL test has been conducted and the bound test has used to determine the co-integration effect. The following equation has been taken into account for testing this relation:

$$y_t = \alpha + \alpha_y y_{t-1} + \alpha_o o_{t-1} + \alpha_r r_{t-1} + \varepsilon_t \quad (8)$$

Where, y_t = GNP, o_{t-1} = Oil consumption, r_{t-1} = Renewable energy consumption.

For the co-integration, the null hypothesis of no co-integration thus is:

$$H_0 = \alpha_y = \alpha_o = \alpha_r = 0$$

Along with that we study the variance decomposition of the forecast errors. The variance decomposition of the GDP has been conducted to indicate the amount of information that is contributed by oil consumption and renewable energy consumption to it. This will tell us which variable is contributing more to the variance of the GDP. Thus we will be able to make a decision whether the role of oil has really declined or not.

To test for the sensitivity of oil prices with those of various oil inventories which ultimately affect the economy through supply and demand disruptions, we have used a simple model:

$$O_t = \alpha + \beta \text{Inventories}_t + \gamma \text{Trend} + \text{AR}(1) + \varepsilon_t \quad (9)$$

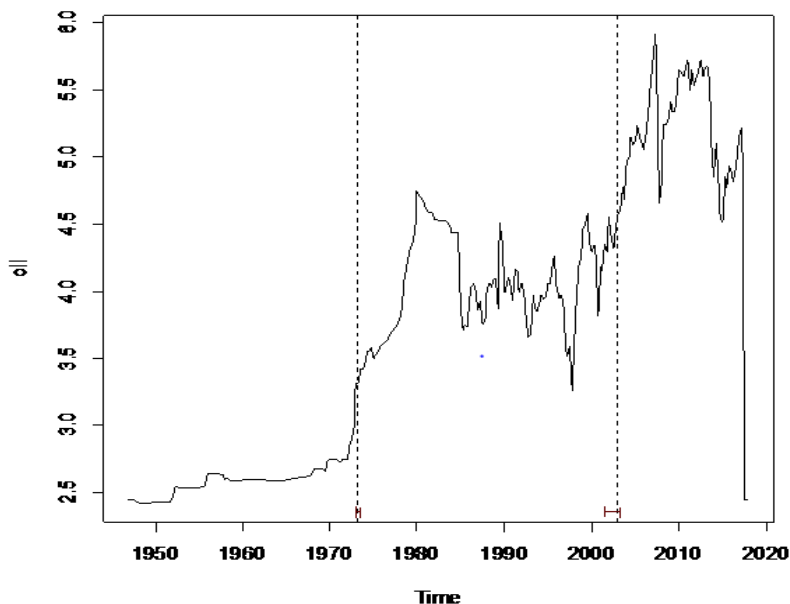
Where, O_t is Oil price US \$/barrel, Inventories be Crude, CPP, SPR and AR (1), the autoregressive scheme of order one.

RESULTS

There are many sources of non-stationarity in a model and thus to correct for them one of the methods that we adopted is to distinguish between the different institutional regimes that are present in the model. While estimating the CUSUM test for the index used in this analysis, we find that the CUSUM series crosses the critical lines thus representing model instability. This supports that there is the presence of structural breaks in the oil price series. Hence, to get the exact dates for the breaks present in the model the Bai-Perron multiple structural breaks gave two break dates for our model. One of the breaks identified is consistent with what has been discussed in Hamilton (1983) and the break date is the year 1973. The other break that has been identified is 2003. The 1973 break is justified as during that time the members of the Arab petroleum exporting countries proclaimed an oil embargo towards the countries supporting Israel. This led to a shortfall in supply as compared to the demand produced and ultimately led to the 1973 crisis. When we look at the 2003 break, it seems to explain as the 2003 Q4 prices started rising for various demand side and supply-side reasons. This was the beginning of what is well known as the 2000's oil crisis which continued till 2008. The Figure2 below depicts the break dates denoted by dotted lines along with the confidence interval and the series used for testing this is the log of oil prices.

Thus, for our analysis, we break the whole time series sample into subsamples for our convenience. The subsamples considered in our model are 1948:Q1- 1972:Q4, 1973:Q1- 2002:Q4 and 2003:Q1- 2018:Q2. For some parts of the analysis, we also consider only two subsamples i.e. 1948:Q1- 1972:Q4 and 1973:Q1- 2018:Q2.

Table 2: Structural Breaks in Oil Price: 1948- 2018



Source: Authors' Calculations

Granger Causality Relation

The results from Granger Causality tests (Table 2) show that changes in real output were not effective in predicting oil price changes over the early subsample of 1948:Q1-1973Q4. However, during the same time oil prices were Granger causing GNP as we are able to reject hypothesis H_2 . When we look at the later subsamples of 1973:Q1-2003:Q4 and 2003:Q1-2018Q2, we are unable to reject both the hypothesis i.e. H_1 and H_2 . Even if we consider only the subsample after 1972 as a full sample (1973:Q1-2018:Q2) even then we are unable to reject the hypotheses.

Table 2: Granger Causality tests

NULL HYPOTHESIS	<u>T:1948Q1- 1972Q4</u> F(5,94) P-value	<u>T:1973Q1- 2002Q4</u> F(5,115) P-value	<u>T:2003Q1- 2018Q2</u> F(5,60) P-value	<u>T:1973Q1- 2018Q2</u> F(5,177) P-value
$H_1: y \Rightarrow o$.701 .628	.956 .448	.258 .773	.478 .791
$H_2: o \Rightarrow y$	2.85 .001	.637 .671	.899 .412	.563 .728
$H_3: u \Rightarrow o$	2.24 .057	.559 .731	.368 .776	.344 .885
$H_4: o \Rightarrow u$	4.99 .005	.958 .446	.731 .886	1.58 .167

Source: Authors' Calculations

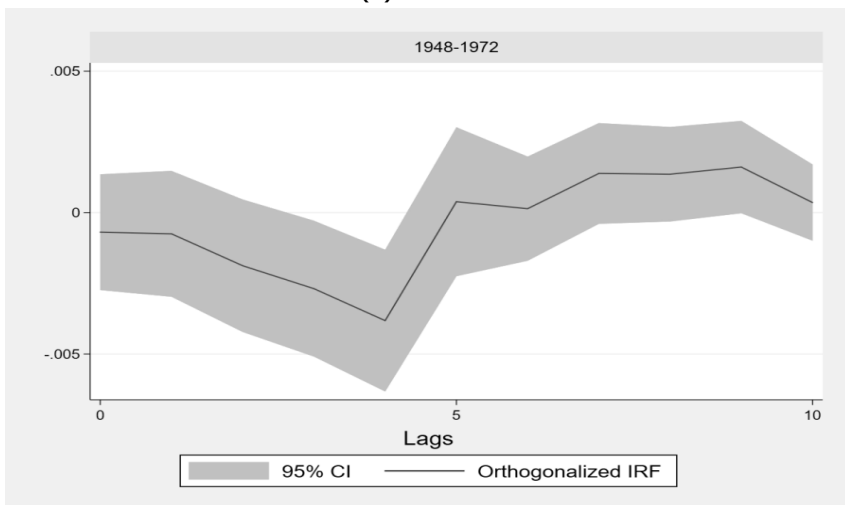
Note: \Rightarrow : does not Granger Cause, y is the GNP, o is the oil prices and u is the unemployment.

The results for unemployment which has been considered as the second output variable are also the same. Though unemployment does a better job at predicting oil prices than GNP, it is not statistically significant at 5 percent level. Thus, through the rejection of the hypotheses that oil prices did not Granger Cause GNP or unemployment before 1973 points towards the fact that it was not just a coincidence. In addition to test, we also tested for the Equation (6) to test if output Granger causes oil prices through it as the output in this case is the dependent variable. The impulse response function (IRF) which represents the reaction of any variable(s) in response to some external shock has been plotted using this model. Thus, we plot the IRF for when a shock for GNP are significantly informative about future oil prices based on the specification when $s=5$.

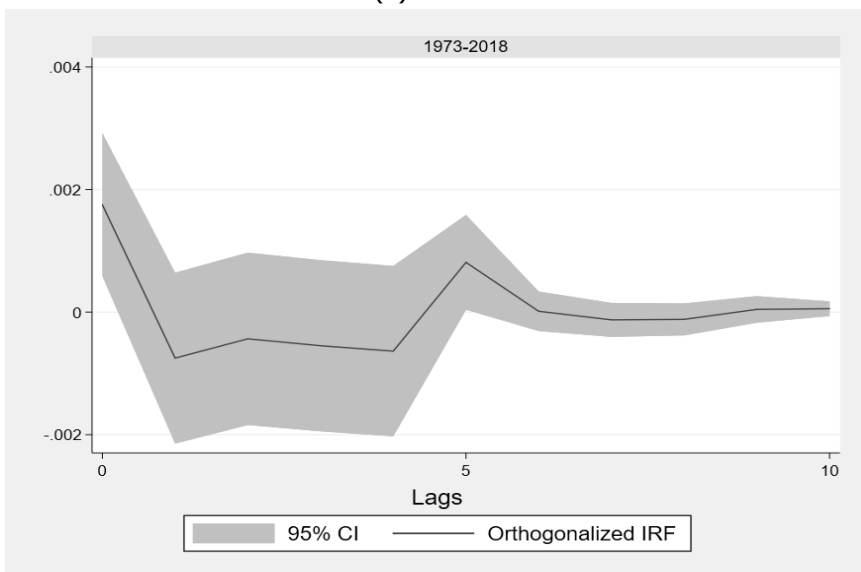
The impulse is given to the oil prices to calculate its effect on the output in the economy for the periods 1948:Q1-1972Q4 and 1973:Q1-2018:Q2 separately.

Figure 3: Impulse Response Function of GNP to Shock in Oil Prices

(a) 1948- 1972



(b) 1973-2018



Source: Authors' Calculations

From the Figure 3 (a) we see that an increase in the oil prices was followed 3-4 quarters later by slower output growth, with coming back to initial levels only by the 5-6 quarters. This in layman terms means that the oil price shock did impact the economy not immediately but with a lag. On a similar note, the results of the same for the period 1973-2018 have a lower impact on GNP of the shock to oil prices as compared to that of the early sub sample. This shows that the effect of oil price shocks on the output of the US economy though have an impact, it has reduced in intensity since the 1970's.

The Impact of Relation

We also test this dynamics of the relation between oil prices and output by comparing the estimates of Equation (5) for the sub samples considered in our analysis. The data rejects the null hypotheses of no structural break for the sample periods $t=1949:Q1-1972:Q4$ and $t=1973:Q1-2018:2$ for the nine coefficients of the Equation (5) with F statistics: $F(9, 259) = 1.19, p = .012$.

The subsamples results shows statistically significant relation between oil prices and GNP and that the different subsamples in col. 1 and 2 give similar results but the later subsample in col.2 gives smaller values of the coefficients on oil price increase. A similar phenomenon has been observed when the results are further tested for the period 1974-2002 and 2003-2018. Thus, there are some dynamics of the relation between oil prices and output that are similar across time; the intensity with which oil prices impacted output has rather reduced with time.

To study the nature of price transmission mechanism in US and the effect of oil shock on it, we use the ARDL technique for estimation purpose. Equation (7) is estimated where y is PPI and CPI and x for our data is oil prices and the results are presented in Table (4).

Table 3: Regression Results Relating Output to Oil Prices

Co-efficient	1948:Q1- 1972Q4	1973:Q1- 2018:Q2	1948:Q1- 2018:Q2
Y_{t-1}	.309 (.003)***	.231 (.000)***	.402 (.000)***
Y_{t-2}	.207 (.003)***	.225 (.006)***	.258 (.000)***
Y_{t-3}	-.224 (.030)**	-.047 (.563)	-.119 (.067)*
Y_{t-4}	-.356 (.204)	-.195 (.210)	-.202 (.879)
O_{t-1}	-.012 (.861)	.002 (.398)	.002 (.606)
O_{t-2}	-.082 (.235)	-.101 (.098)*	-.0004 (.091)*
O_{t-3}	-.122 (.078)*	-.211 (.032)**	-.001 (.022)**
O_{t-4}	-.147 (.039)**	-.254 (.020)**	-.003 (.030)**
Constant	.013 (000)***	.004 (.002)***	.007 (.000)***
F-statistics	F(4,86)=1.69	F(4,169)= 2.44	F(4,268)=2.24
P-value	.053*	.006**	.0007***

Source: Authors' Calculations

Note: *, ** and *** denote significant at 10 percent, 5 percent and 1 percent levels, respectively. F-test: Coefficients on lagged o_t are all zero.

Table 4: Regression Results Relating CPI, PPI and Oil Prices

Co-efficient	<u>1948:Q1-1972:Q4</u>	<u>1973:Q1-2018:Q2</u>
	PPI CPI	PPI CPI
O _t	.048 .057 (.288) (.275)	.004 .017*** (.227) (.000)
O _{t-1}	.064 .134 (.158) (.318)	.007 .027*** (.326) (.003)
O _{t-2}	-.087* .024 (.060) (.251)	-.102 .0006 (.437) (.808)
O _{t-3}	-.002 -.039 (.950) (.487)	-.034*** -.0009 (.000) (.678)
O _{t-4}	.059 .027 (.201) (.426)	.015*** .003* (.000) (.091)
Trend	2.14*10 ⁻⁵ 2.4*10 ⁻⁵ (.420) (.240)	-4.77x10 ⁻⁵ *** 5.62x10 ⁻⁵ *** (.000) (.000)
Constant	.001** .002*** (.028) (.000)	.011*** .013*** (.000) (.000)
R ²	.622 .587	.648 .677

Source: Authors' Calculations

Note:*, ** and *** denote significant at 10 percent, 5 percent and 1 percent levels, respectively.

The results from the Table 4 show that the positive relation of PPI with oil price index fades away after 2 periods and starts recovering

by the fourth period. However, we also notice that the coefficient of lagged item is larger than those of the immediate once meaning that the impact of oil shocks emerges gradually and takes 2-3 periods to complete the transmission chain. On the other hand, when we look at the CPI results, we notice that the consumer price index has a much stronger relationship with oil prices than the PPI and this may be because in developed countries, the commodity prices are flexible and hence the oil shocks affect consumption more than production. Another thing that is evident from the CPI results is the fact that the relationship between oil price and CPI starts fading only after 3 periods. This trend has been noticed for both the subsample periods.

However, when we examine the coefficients of the subsamples separately, we find that the relation for both PPI and CPI has weakened after the structural break of 1973. The samples for the later periods have smaller yet significant coefficient values and this indicates to the diminishing role of oil prices on impacting the transmission mechanism. Thus, we might say that it is not only the direct channel through which oil prices affect the economy but through various other transmission channels as well. Also, it is observed and statistically tested that the role of oil has been diminishing for the period after 1970s. The same test was conducted by considering the 2003 break and dividing the sample accordingly. The results obtained from those subsamples are in line with what we have received in Table 4 and it is observed that the earlier sample period had better and larger coefficients of oil price and its lagged values.

After conducting the ARDL analysis, we tested for the co-integration among the variables PPI/CPI and oil prices. The bound tests conducted for this gave us results that for the period 1948:Q1-1972:Q4 and it was found that there is co-integration among both PPI and oil prices and CPI and oil prices. We are able to reject the null of no levels relationship for this period meaning that the variables have a long run relationship. However, the same test when run for the later subsample

i.e.1973:Q1-2018:Q2 showed that the null could not be rejected and we are not able to confirm for a long run relationship between the variables any more. Thus, the bounds test also shows that the overall effect of the oil prices on the economy is diminishing with time.

The analysis also involves the testing of impact of oil price shock to the GNP of US by using variance decomposition of forecasted error results. Each variables contribution to the other variable in an auto-regression is calculated by the variance decomposition mechanism. When the graph for variance decomposition analysis (Appendix A.2) was plotted for the period 1947-1973, it showed that oil price shocks contributed about 6 percent and 4 percent to the GNP variability. Whereas when the same test was done for the period 1973-2018, the contribution accounted for about 2 percent and 4 percent respectively. We find that the importance of the oil prices as a source of volatility for both GNP and unemployment has reduced throughout analysis.

Reasons for Reduced Dependency

To analyze the reducing oil dependency over time, the first thing we estimated was the different energy consumption levels of US and their impact on the US growth. To achieve these objectives we performed the ARDL bounds test of US output levels and for the sources of energy, we looked at renewable and oil energy consumption levels in the US. Both ARDL bound test and Johansen (1988) maximum likelihood co-integration test are used to examine if there is co-integration among variables.

The results from conducting the tests on Equation (8) show that there is long run equilibrium relationship among the variables for all the sub samples taken into consideration. Thus, there is both long run and short run co-integration among the variables. The results for the ARDL estimates from the two periods have been show in Table 5.

Table 5: ARDL Long and Short Run Results for Energy Consumption and Output

Co-efficient	T: 1949-2018	T: 1949-1972	T:2003-2018
Long run			
Oil Consumption	2.59 (.245)	.9898 (.004)***	.430 (.005)***
Renewable energy Consumption	1.09 (.290)	.4750 (.015)**	.549 (.004)***
Short Run			
Oil Consumption	.366 (.000)***	.6597 (.006)***	.623 (.033)**
Renewable energy Consumption	.167 (.115)	.293 (.042)**	.773 (.080)*
R ²	.5659	.884	.964

Source: Authors' Calculations

Note: *, ** and *** denote significant at 10 percent, 5 percent and 1 percent levels, respectively.

Both in the long run and the short run, both the sources of energy contribute towards growth of US; this is only for the sub samples and not for the full sample. However, we observe from the results that for the pre-war sample period, oil consumption have been more contributing towards growth than renewable energy consumption. On the other side, for the sample period of 2003:2018, renewable energy consumption started showing better coefficient than oil consumption and thus contributed more to the growth. All this can be attributed to the fact that until the 2000s renewable energy consumption was not in fashion and people were still highly dependent on oil and other substitute consumption and there has been a change in preferences of the society that has been reflected through these results.

To indicate how long these results will be effective, we conduct generalized variance decomposition analysis. Table 5 depicts the results for the same over a 10 year time horizon for each variable separately.

Table 6: Forecast Error Variance Decomposition

Horizon	Output	Oil consumption	Renewable energy consumption
1	.6249	.3189	.0562
5	.4405	.3010	.2635
10	.3086	.3215	.3699

Source: Authors' Calculations

The results from the variance decomposition analysis indicate that after 5 years 62 percent of the variation in forecast in output is explained by its improvements and at the end of 10 years it is only 30 percent. While on the other hand both oil consumption and renewable sources of energy consumption has been explaining the variation of forecast error better after the end of 10 years rather than at the starting of the time horizon.

A rather different result is that the variation explained by oil remains rather stagnated for the period considered and the renewable energy consumption explains better variation than it by the end of 10 years. As we see, renewable energy consumption explained output only 5 percent after 5 years rising to 36 percent after 10 years. Thus, shocks to renewable energy consumption have lasting impacts on the economy.

The estimated relation between oil prices and the inventories/stocks is present in Table 7.

Table 7: Relationship Between Oil Prices and US Oil Stocks

TIME PERIOD	1982Q2: 2002Q4			2003Q1:2018Q2		
	Crude	CPP	SPR	Crude	CPP	SPR
Co-efficient	-.320**	-.911**	.240	-.055*	-.095	-.17***
AR(1)	.753	.720	.749	.851	.851	.841
Constant	5.90	7.15	-4.46	1.68	2.25	9.71
R ²	.688	.691	.690	.753	.753	.758

Source: Authors' Calculations

Note: *, ** and *** denote significant at 10 percent, 5 percent and 1 percent levels, respectively.

The oil prices react inversely to the inventories positions of crude and petroleum. From Table 7 we see that the strong position of Crude and CPP stocks influenced oil prices in both the periods of consideration. However, we see that the effect of impact has reduced in the later half and that can be attributed to the fact that there are several other things also that affect the oil prices. It can also be said that the government of US is focusing on some other sources or processes to control the price of oil rather than increasing inventories. It is also seen from the data that in the last few years, the crude oil stock position and the petroleum products and crude oil positions have been decreasing and all this has been because of the supply and demand disruptions. This creates less supply than the demand in the market and hence the prices go up which is evident from the decreased unit of stocks in the second period from Table 7.

However, US have also been engaged in focusing on SPR since the late 1970s and this reserve is being maintained to be used in case of any major shortfall in the long run in the economy. It is believed that since the SPR are not used on daily basis and are kept for the crisis, they do not affect the world crude oil prices much. We see from Table 7 that the SPR during the 1982-2002 period did not led reducing oil prices and this is because they were not as important at that time as they have been since the early 2000s.

Looking at the post 2002 period, we observe that the increasing SPRs did play huge role in reducing oil prices. This is because the inventory knowledge to the analyst and the general public and there is a view that since there is plenty oil in the storage, any oil supply or demand disruption in the long run could be handled by it. It is known from literature that the SPR stocks have been increasing quite rapidly in the past because US wants its future to be secure and doesn't want to face another oil shock. Thus to maintain the stability in the economy, US has been focusing on making its SPR strong and this belief has been

known to the market through the records which leads to drop in oil prices in the near past. Due to the decreased oil price volatility from the inventories angle, there is less volatile impact of the oil prices on the output and thus the economy.

Conclusion and Further Improvements

There is no doubt in saying that oil prices are dynamic. Oil shocks have played an important role in the history of US economic growth as well as downturns. Though the relationship between oil prices and the macroeconomic variables are still the same it is to be accepted that the intensity of the relationship is not the same. It has been theoretically and statistically proven that oil prices do not affect the output the same way as it used to before the 1970s. The impact of oil has reduced since the World War II and it is diminishing with time.

It is also seen that it not only affects the economy directly through the GNP but also price transmission mechanism and not only producers but consumers are also affected by any oil price change that takes place. Therefore, it can be said that the relationship between the two has weakened with time and oil prices no more effectively explain the variation in the output of US economy.

The reasons for reduced oil dependency are plenty. Both technological and political and strategic factors are responsible for this downturn. The introduction of shale oil has changed the import patterns of the US as they are now becoming self-reliant for the oil production and this has affected the world crude oil prices to some extent. The oil prices have also stagnated or rather say reduced in the current past due to availability of oil substitutes. This has resulted in the changing demand patterns since the 1980s. There has been greater awareness about the environment than 25 years ago and thus the demand is being shifted more towards the consumption of renewable energy than the traditional energy. This has not only led to reduced demand of oil but the data for the consumption patterns depicts that the impact of oil consumption on

the output of an economy will deteriorate even further. The contribution of oil prices to explain the impact on GDP has reduced and the traditional oil volatility has also been stabilized. Due to this, the output volatility explained by oil prices is losing its impact.

One of the limitations of the paper is that the impact of oil shocks on industrial production has not been studied. The industrial sector being highly sensitive to the demand, responds rather instantly to any oil shock. This study can be extended to understand which industries are highly affected by the shock and whether they show linear or non-linear relation. Further, as a large literature has shown that different types of structural oil shocks have very different macroeconomic effects, attempts could be made to understand the role of different compositions of oil price shocks in changing oil dependence over time.

APPENDIX

CUSUM Test

The samples from a process y_n are assigned with weights w_n and summed as follows:

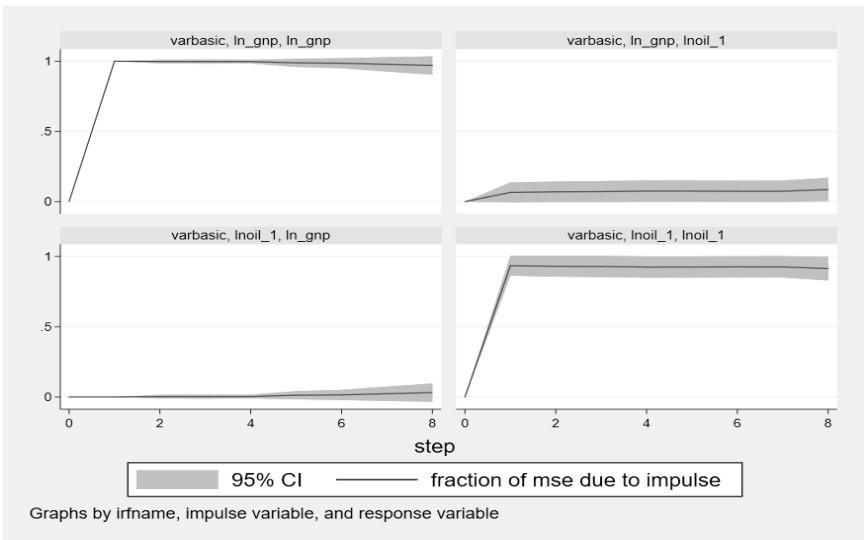
$$S_0 = 0$$

$$S_{n+1} = \max(0, S_n + x_n - w_n)$$

When a certain threshold value has been exceeded by the calculated value of S then, there is a change detected in the value. When the min operation is used instead of the max operation then, the values below the threshold value, represented by the negative values are found.

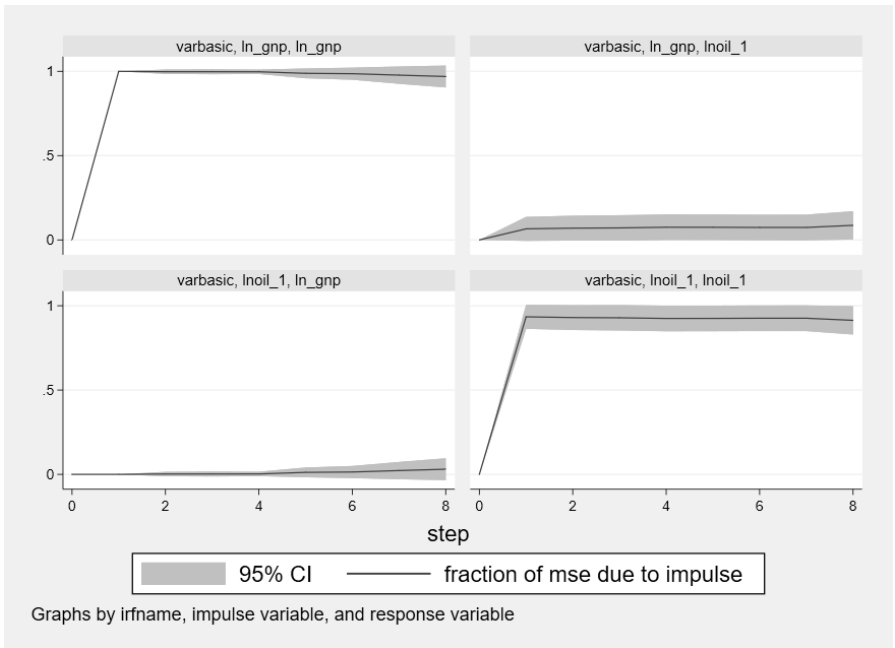
Error Variance Decomposition Graph

Figure 4: Forecast Error Variance Decomposition of GNP 1948:1972



Source: Authors' Calculations

Figure 5: Forecast Error Variance Decomposition of GNP 1973:2018



Source: Authors' Calculations

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