

Oil Shocks and the U.S. Macroeconomy: Recent Evidence

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Abstract

This paper examines the impact of oil price shocks on the U.S. GDP growth rate by applying multivariate vector autoregression (VAR) analysis and Granger causality tests on quarterly time series data from 1960 Q1 to 2014 Q3. The findings suggest that the linear relationship between oil prices and output is inconsistent with observed macroeconomic performance, validating the result of [Hooker, 1996]. The impulse response functions further indicate that the impacts of oil shocks on output have reduced over time, especially for the post-1973 era. Additionally, consistent with [Hooker, 1997] and [Hamilton, 1996], this paper finds that asymmetric specifications of oil price shocks yield a stronger Granger causality relationship between oil price shocks and economic output, but cannot revert the breakdown of oil price - macroeconomy relationship post-1980s.

1 Introduction

The 1970s energy crisis, during which major industrial countries experienced substantial oil supply shortages as well as significant run-ups in price levels, has led to a number of influential studies that attempt to determine the causality relationships between oil shocks and macroeconomic activities. Earlier empirical studies ([Hamilton, 1983]; [Mork, 1989]) credited oil price changes with a great deal of responsibility for the ensuing recessions of the U.S. economy. [Hamilton, 1988] argued that on the demand side, oil shocks affect the macroeconomy primarily by depressing demand for key consumption and investment goods. On the supply side, increased crude oil price results in a run-up in production costs and thus leads to a decrease of output, which is further aggravated by irreversible investment decisions. Indeed, oil price changes have been viewed as an important source of economic fluctuations by macroeconomists.

However, [Hooker, 1996] concluded that the oil price's impact on the economic output significantly decreased after 1973 by demonstrating that oil price no longer Granger caused many of the U.S. macroeconomic indicators like GDP growth rates. He further argued that the continuing shifts of the U.S. economy towards energy efficiency and increased services industry contribution to GDP might cause a gradual lessening of oil prices' impacts. [Blanchard and Gali, 2007] confirmed that the effects of a given change in the price of oil have changed substantially over time. Their VAR estimates implied much larger effects of oil

price shocks on macroeconomic activity in the early (pre-OPEC shocks) sample. Similarly, [Hamilton, 2005], [Blanchard and Gali, 2007], and [Kliesen, 2008] have also found that the U.S. economy has become much less sensitive to large changes in oil prices.

In fact, since the late 1990s, the U.S. economy has experienced two oil shocks comparable to those of the 1970s, but in contrast with what happened in 1970s, namely high inflation and low growth, GDP growth and inflation have remained relatively stable during the 1990s oil shocks episodes. The goal of this paper is to provide more recent evidence on the impact of oil shocks on output growth, particularly the changes over time in the magnitude of those impacts. In order to do so, we estimate the effects of oil price shocks on macroeconomy using structural VAR techniques and compare the estimates for different sample periods to first validate [Hooker, 1996] and [Hooker, 1997]’s finding of a weakening relationship based on data up to 1997 and then derive insights from post-1997 data.

I then explore potential explanations for the oil price’s weakening impacts over time. A popular explanation for differential response of the macroeconomy to the oil shocks is the changes in the way monetary policy is conducted; that is, the stronger commitment of the central bank to maintaining low inflation. [Bernanke et al., 1997] used structural models and found that it was the tighter monetary policy subsequent to oil shocks that mainly led to the recessions. [Rogoff, 2006] added that deeper financial markets and more flexible labor markets have furthered weakened the effects of oil shocks.

Second, as the U.S. reduced its dependence on imported energy and diversified the economy away from energy-intensive industries, the share of oil in economic output has declined significantly, which may account for the weakened role of oil shocks.

Structural breaks might also explain the weakening role of oil shocks; therefore we will also break down the data into episodes according to identified structural breaks.

More importantly, the mis-specification of the functional form of the basic linear model was proposed by [Hamilton, 1996], [Lee et al., 2001], and [Mork, 1989] as another explanation. They proposed transformations of oil prices that emphasize oil price increases and volatility and demonstrated using re-specified oil shocks can improve the significance of oil price - macroeconomy relationship. In particular, positive oil shocks have bigger impacts compared with negative oil shocks based on the investment uncertainty theories from [Hamilton, 1983].

The rest of the paper is structured as follows. Section 2 provides a description of the data and baseline VAR model, then documents the evidence for the weakening causal relationship between oil price shock and macroeconomic indicators, with emphasis on several structural breakpoints. Section 3 further investigates alternative specifications of oil price shocks that can better reflect the oil price-macroeconomy relationship. Even though the re-specifications work better than the basic linear model, VAR models using these oil price transformations still can’t refute the weakening relationship suggested by the baseline model. Section 4 concludes.

2 Oil Price - Macroeconomy Relationship

2.1 Data

Consistent with the literature, the baseline quarterly VAR model includes the following endogenous variables: real GDP, inflation (GDP deflator), nominal oil price (crude oil: West Texas Intermediate), import goods inflation (import price deflator), and short-term interest rate. Instead of using real oil price, we use the nominal price of oil, along with the inflation variable to avoid dividing by an endogenous variable. This specification is consistent with the seminal papers [Hamilton, 1996] and [Hooker, 1996]. As argued by [Hooker, 1996], the paper uses Federal Funds rate rather than the 3-month Treasury bill rate in order to more closely associate money market conditions with monetary policy since the Federal Funds rate is directly specified by the Federal Reserve rather than determined through open market. See Appendix A for detailed description of the data and the transformations.

2.2 Oil Price Shocks

Figure 1 demonstrates the evolution of oil prices since the 1960s. The shaded areas indicate the oil price shock episodes described below. A long period of stability from the 1960s was ended by a sharp increase during OPEC shock in 1973, which was immediately followed by the second OPEC shock in 1979. Following the 1970s Energy Crisis, a serious surplus of crude oil caused the 1986 Oil Bust. Then the economy experienced an extended period of wild oil price fluctuations until the late 1990s, when oil prices started to rise consistently. Around 2002, OPEC oil production cuts and rising tension in the Middle East contributed jointly to a significant increase in oil price. Continued oil supply disruptions in Iraq and Nigeria coupled with strong demand drove the price higher until the reversal movement during 2008 due to worries over the recession. Oil price recovered along with the economy after late 2009. Since late 2014 however, the oil price has suddenly collapsed and lost almost half of its 2008 value due to U.S. shale gas production run up and weakening demand from China and Europe.

[Blanchard and Gali, 2007] visually illustrated that the oil shock episodes are associated with different macroeconomic performances despite their similar magnitudes. In their early sample periods including the 1973 and 1979 shocks, both inflation and unemployment peaked a few quarters after the oil prices peaked but the patterns become less obvious for recent episodes (post-1984). They also found impulse responses of (log) GDP and (log) CPI to a fixed 10% change in oil price became more muted for the post-1984 sample compared with the earlier sample.

The evidence presented above leads us to frame the hypothesis that the impacts of oil price shocks on macroeconomic indicators have decreased over time. It also suggests structural breaks regarding the relationship. To further explore the weakening oil price-macroeconomy relationship, we apply VAR techniques in the following section.

2.3 Baseline VAR Model

As a first step of the VAR analysis, we test the stationarity of the time series by analyzing their order of integration on the basis of unit root test. Table 1 shows the results of Augmented Dickey-Fuller (ADF) tests for unit roots and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests for level and trend stationarity. The ADF tests indicate that the null hypothesis for existence of unit roots can be rejected at conventional significance levels for Federal Funds rate (variable FEDFUNDS) and unemployment rate (variable UNRATE), while all the other variables exhibit a unit root. Therefore we take the first difference of the logarithmic form for all the other $I(1)$ variables to get stationary series (intuitively the growth rates). The KPSS tests further confirm that the variables after transformation are stationary. Since variables have different levels of integration, we do not need to conduct Johansens Cointegration Test to investigate cointegration. Therefore we can construct the baseline VAR model that includes oil price (log-differenced), real GDP (log-differenced), GDP deflator (log-differenced), import deflator (log-differenced), and Federal Funds rate to analyze how the oil price - GDP relationship evolve. The oil price - unemployment rate relationship will also be investigated following a similar procedure.

Then we employ both the Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (SIC) to select the optimal number of lags to be included in the VAR since the models are non-nested. The lag-length criteria including Likelihood-Ratio, AIC, and SIC all suggest a lag order of 4. Henceforth, the VAR models will include 4 lags.

2.4 Structural Stability and Granger Causality Tests

We discuss various breakpoints in the 1960 Q1 - 2014 Q3 U.S. macroeconomy data series and apply Granger causality tests to provide evidence for the declining role of oil price in the linear model. Failing to account for structural breakpoints would lead to mismeasurement of the impact of oil price shocks. We will then use the subsamples divided by the identified breakpoint, 1973 Q3/Q4 to explore how the estimates of the coefficients for the oil price shock vary over time.

There are several breakpoint candidates for the GDP and unemployment equation of the baseline VAR model: 1973 when OPEC first dominated the market, 1979 when the second OPEC shock happened, 1986 when market collapsed and experienced a free-fall, late 1999 when the commodities boom started, and possibly late 2009 when price rose again after concerns over credit crunch and recession were alleviated.

Some of the breakpoints have been shown by the literature. [Hooker, 1997] validated [Hamilton, 1983]'s finding of a structural break of the GDP equation at 1973 Q3/Q4 through conducting Chow stability tests on VAR models that contain oil price, 3 month T-bill rate, GDP deflator, and real GDP. The evidence for structural breaks of the unemployment equation is weak. [Mork, 1989] used the modified definition of oil shock and tested the stability of the GNP equation to argue for a structural break point at 1986 Q1/Q2. More recent results from [Jiménez-Rodríguez* and Sánchez, 2005] suggested 1999 Q4/2000 Q1 as an important oil shock episode although didn't claim it to be a breakpoint. The multi break points test (Bai-Perron test of sequentially determined breaks) and the Chow breakpoint test are applied here to identify and confirm structural breakpoints.

The multi break points test identifies two structural breakpoint candidates for the GDP equation: 1973 Q3/Q4 and 1986 Q1/Q2, a result consistent with the literature. Regarding the unemployment equation, the multi break points test identifies 1980 Q3/Q4 and 1986 Q1/Q2 as breakpoint candidates.

The Chow breakpoint test divides the data into separate subsamples at the candidate break points then estimates the equations separately to determine whether there are significant differences in the estimated coefficients. The top section of Table 2 presents F-statistics and p-values for the null hypothesis of structural stability across the various breakpoints for both the GDP and Unemployment equations in the VAR models. At 1973 Q3/Q4, the GDP equation strongly rejects structural stability. While at 1980 Q3/Q4 and 1986 Q1/Q2, the Unemployment equation fails to stay stable. As summarized in [Hooker, 1997], multiple bodies of evidence show that the year 1973 is linked with many important, structural changes in the economy, including the slowdown of post-war productivity growth, the adoption of a floating exchange rate, and a completely different institutional regime as indicated by [Hamilton, 1983]. Interestingly, 1973 is the only structural breakpoint we find for the GDP equation over the entire sample from 1960 - 2014, implying that episodes like the 1979 OPEC shock (coupled with the Feds response of directly targeting money supply to break inflation), the dot-com bubble in 1999 (coupled with commodities boom), the shale gas boom since 2005, and the recent financial crisis in 2008 all fail to change the structural relationship between oil price and economic output.

To further investigate the relationship between oil price shocks and macroeconomic variables, we perform the Granger causality tests. The Granger causality test is a widely-applied statistical test to determine whether one time series (e.g. oil price shock) is useful in predicting another series (e.g. GDP growth, or unemployment rate). By definition, X Granger-causes Y if past lagged values of X contain information that helps improve the prediction of Y using lagged values of Y alone. The Granger causality test computes the Wald test statistic on the hypothesis that the estimated coefficients of the lagged values of the endogenous variables X in the $X - Y$ equation are jointly zero.

The bottom section of Table 2 reports the Chi-square (Wald statistics) and p-values of the multivariate Granger causality test (block-exogeneity type) on the oil price - GDP equation and the oil price - unemployment equation of the VAR models. A high p-value of the oil price variable in the GDP equation means that the variable does not have a significant direct impact on the GDP (growth), at least according to the basic linear specification. Thus based on Granger causality test on the entire sample, we conclude that oil price shocks do not directly impact economic output in a linear way. Moreover, the impact weakens over time as the pre-1973 sample has a low p-value of 0.147 (borderline of the 10% threshold) while the post-1973 sample has an extremely high p-value of 0.968. The results for the post-1973 period are consistent with [Hooker, 1997]. However, unlike [Hooker, 1996], [Hooker, 1997], or [Hamilton, 1996], the paper finds that oil price shock also fails to Granger cause GDP during pre-1973 period, which may be explained by the usage of shorter data series (1960s - 1973 rather than [Hooker, 1997]'s 1940s - 1973) and a different proxy for oil price (West Texas Intermediate instead of World Producer Production Index). A possible explanation for the insignificance of the oil price's measured role is that linear specifications may not accurately capture the way in which oil prices affect the macroeconomy; that is, the functional form of the model is mis-specified.

Applying Likelihood-Ratio (LR) test for the null hypothesis that all of the oil price coefficients are jointly zero in all equations of the VAR model, we find the null hypothesis is rejected for the 1960 - 2014 period, which indicates that the oil price is likely to impact GDP indirectly through other variables. In particular, a popular explanation is that the oil price affects GDP (growth) through the interest rate (monetary policy) channel.

2.5 Impulse Responses

Impulse response functions can reflect the dynamic responses of macroeconomic variables to oil shocks in the VAR models. Figure 2 displays the impulse response functions that trace the impacts of a positive one-standard deviation oil price shock on the current and future values of GDP (growth), inflation, and unemployment rate.

For the GDP (growth) variable, the negative response lasts for 6 quarters after the shock and the maximum negative effect occurs during the 5th quarter and reaches the magnitude of around 0.4 percentage points, implying that a 1-S.D. oil price shock could reduce the growth rate by as much as 0.4 percentage points. Around 6 quarters after the initial shock, the impact of the shock reverses and fades away eventually. This pattern aligns with the economic intuition that oil price spikes slow down the economy. As for the Federal Funds rate, the response to an oil price spike is at first positive, but only lasts for around a year before following a prolonged negative trend for around 6 quarters and finally dying out in two years. A similar pattern fits the response of the inflation measure GDP deflator: the response peaks after around 3 quarters to a maximum of 0.25 percentage point, before it mutes away. The response stays positive over the entire 10 quarters in consideration. The final graph computes how the unemployment rate evolve in response to the oil shock. Interestingly, the response of the unemployment rate is initially negative but in 3 quarters it reverses the direction and becomes significantly greater in magnitude.

Then we compare the impulse response patterns across the samples to evaluate the weakening impact implied by the Granger causality tests. Based on results from Section 2.4, we break down the sample at 1973 Q3/Q4 for GDP-related analysis, and at 1980 Q3/Q4 for unemployment-related analysis. The left-hand graphs in Figure 3 display the responses using the earlier samples, and the right-hand graphs display the corresponding responses using the more recent samples. Figure 3 clearly implies that the impulse responses of both GDP growth and unemployment to oil shocks tend to be more muted and dampen faster in the more recent samples. The response of GDP to oil shock in the post-1973 period is only a third of the response in the pre-1973 period in terms of magnitude. Moreover, the responses of the post-1973 sample reach the maximum negative level in 5 quarters, much longer than 3 quarters of the pre-1973 sample. A similar pattern can be obtained through the cross-sample comparison of impulse response of unemployment rate to oil shocks. As shown in the bottom of Figure 3, the unemployment response in the pre-1980 period can achieve a maximum magnitude almost five times bigger than that in post-1980 period, given the same magnitude of oil price shocks.

3 Asymmetric Re-specifications of Oil Shocks

3.1 Re-specifications

In response to [Hooker, 1996]’s finding of the breakdown of the oil - macroeconomy relationship, a number of studies have proposed alternative specifications and tested whether the standard linear specification of oil price used above fails to accurately capture the non-linear way that oil prices affect the macroeconomy. [Mork, 1989] and [Lee et al., 2001] found that specifications emphasizing only on positive oil price shocks tend to produce stronger causality and therefore suggested non-linear re-specifications. In order to test for asymmetries we use the following non-linear specifications of oil shocks based on previous empirical literature.

[Mork, 1989] constructed an asymmetric specification that distinguishes between the positive rate of change and the negative rate of change. He showed that when the effects from oil price increases and decreases were separately evaluated, the oil price increases Granger cause output changes while decreases don’t. Let $O_t = \log(P_t) - \log(P_{t-1})$ denote the rate of change of real oil price P_t . Then the positive shock and negative shock series are defined respectively by:

$$MORKI_t = \begin{cases} O_t & \text{if } O_t > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$MORKD_t = \begin{cases} O_t & \text{if } O_t < 0 \\ 0 & \text{otherwise} \end{cases}$$

[Lee et al., 2001], on the other hand, focused on volatility and argued that oil shocks should have a more significant impact on an economy where oil prices have been stable than on an economy where oil prices have fluctuated wildly since price movements in a volatile economy are more likely to be reversed. They estimated a GARCH (1, 1) model and used the residuals divided by the square root of the variance series to construct the ratio, scaled oil price increases (SOPI):

$$O_t = \beta_0 + \sum_{i=1}^4 \beta_i O_{t-i} + \epsilon_t$$

$$\epsilon_t \sim N(0, \sigma_t^2)$$

$$\sigma_t^2 = \gamma_0 + \gamma_1 \sigma_{t-1}^2 + \gamma_2 \sigma_{t-2}^2$$

$$SOPI_t = \max\left(0, \frac{\epsilon_t}{\sigma_t}\right)$$

$$SOPD_t = \min\left(0, \frac{\epsilon_t}{\sigma_t}\right).$$

The net oil price increase (NOPI) measure was first proposed by [Hamilton, 1996]. It compares the price of oil each quarter with the past four quarters maximum value and plots the percentage change in oil price levels if that is positive and equals to zero otherwise. This transformation is based on the investment-uncertainty transmission mechanism (i.e. oil shocks affect economy through affecting consumption and investment decisions), thus current oil prices should be compared with prices over a year rather than the previous quarter:

$$NOPI_t = \max[0, (O_t - \max(O_{t-1}, \dots, O_{t-4}))].$$

Assuming that depressing demand for key consumption and investment goods is indeed the main mechanism, then oil price changes should have asymmetric effects on the economy as decreases in oil prices would not boost the investment as significantly as increases in oil prices depress it.

If the above re-specifications can better capture the oil price macroeconomy relationship than the standard log-difference specification, then they should better Granger cause macroeconomic indicators and render the VARs structurally stable across oil shock episodes. As in the case using the standard log-differenced oil shock measure, we test the unit root and stationarity of the alternative measures of oil price shock using ADF and KPSS tests. The ADF tests presented in Table 3 indicate that none of the measures has any unit root while KPSS tests indicate that among the measures, only MORKD and MORKI are borderline stationary. Overall, we conclude the oil shock specifications can be included directly in the model without further transformations.

3.2 Granger Causality and Structural Stability Tests Using Re-specified Oil Shocks

We assess the relative performance of the different models. A specification that successfully represents the oil price - macroeconomy relationship has to pass structural stability tests and improve the Granger causality results of output and unemployment equations. Table 4 evaluates how well the proposed oil price shock re-specifications perform in such tests. The result shows that all the re-specified oil shocks produce significant improvements in predicting GDP growth, confirming the hypothesis that oil price shocks affect the macroeconomy in an asymmetric way. Particularly, for MORKI ([Mork, 1989]s asymmetric increase) and MORKD ([Mork, 1989]’s asymmetric decrease), Granger causality is achieved for the 1960 Q1 - 2014 Q3 period at 5% significance level. However, the results imply that re-specified oil shocks’ improvements in affecting GDP are not sufficient to yield Granger causality at conventional significance levels for post-1973 period (1973 Q4 - 2014 Q3).

Overall, we can conclude that re-specifications like MORKI and MORKD can capture the oil price - GDP relationship in a significantly better way, but still fail to justify Granger causality for post-1973 data. This conclusion is consistent with the [Hooker, 1997]’s claim that re-specified oil shocks still fail to Granger cause GDP post-1973. However, we find [Mork, 1989]’s MORKI series, instead of [Hamilton, 1996]’s NOPI, outperforms other measures in improving Granger causality results for the output.

The Granger causality results for the unemployment equation in the bottom of Table 4 are stronger than in the GDP case, no matter what oil shock measure is used. Also, the re-specifications show significantly improved performance over the standard log-differenced measure. In the pre-1980 sample, all re-specifications Granger cause unemployment at 1% significance level while the standard measure is only significant at 5% level. In the post-1980 sample, although the Granger causality results are stronger using re-specifications, none of the measures can restore the strong Granger causality relationship observed in the pre-1980 sample. In addition, unlike in the output case, [Hamilton, 1996]’s NOPI series emerges as the predictor of unemployment.

In addition, the paper has argued that correct re-specifications should render the VARs

structurally stable across potential structural breakpoints. Table 5 shows the maximum Wald statistics of the Quandt-Andrews unknown breakpoint test on GDP and unemployment equations using various oil shock re-specifications. The tests using MORKI, MORD, SOPI and NOPI accept null hypothesis of structural stability for the GDP equation with strong confidence. In comparison, the standard oil shock specification and SOPD specification reject stability of GDP equation at the 5% level.

Unlike in the output case, the unemployment equations are quite stable at 5% or even 1% significance levels. The oil price re-specifications that incorporate measures of asymmetry or volatility improve the stability of the equations. These results indicate that the oil price re-specifications have contributed in explaining the breakdown of the oil price-unemployment relationship but still failed to resolve it.

3.3 Impulse Responses to Re-specified Oil Shocks

Figure 4 plots the impulse-response functions that relate GDP growth to different oil price shocks. In the case of positive oil shock specifications MOKI, SOPI and NOPI, the results indicate that impulse response patterns of GDP (growth) are similar in terms of both magnitudes and trends to those of the standard specification. In particular, the response to NOPI shock looks exactly like that of the standard shock. For the MORKI specification, the response of GDP achieves the maximum magnitude faster than the standard case. Finally, the SOPI specification shows smoother response patterns with more immediate changes. Regarding the magnitude of the response, the non-linear re-specifications yield larger negative impacts on GDP growth than in the linear case, with the impact of $SOPI > NOPI > MORKI > \text{Standard measure}$.

Comparing the responses to negative shocks with that of positive shocks, we find that oil price changes indeed have an asymmetric effect of growth rates, as widely shown in the literature ([Hamilton, 1996], [Hooker, 1997]). In fact, while oil price increases have a negative and significant accumulated effect on GDP (growth), the opposite result is less clear for oil price decreases, the responses to negative oil shock specification vanish faster and tend to be more muted. For example, the response to the negative MORKD shock achieves only half of the magnitude as the response to positive MORKI shock. As another example, the response to negative SOPD shock dies out faster than that of the positive SOPI shock.

To summarize, as implied by the distinct impulse response patterns of GDP to positive and negative oil shocks, asymmetric specifications of oil shocks are intuitively better than the standard linear specification. Moreover, the MORKI and MORKD series tend to improve both the structural stability and the Granger causality results of the oil price - GDP relationship. However, the asymmetric transformations still fail to restore the robustness of the oil shock - macroeconomy causal relationship for the post-1973 period. Therefore we evaluate in the next section another explanation for the broken relationship: the interest rate channel.

4 Conclusions

This paper investigates the relationship between oil price shocks and the U.S. macroeconomic activities using VAR models. Based on results of impulse response functions and Granger causality tests, I find that the standard log-difference specification of oil shocks does not significantly affect GDP growth post-1973 or unemployment post-1980 in a linear way.

The paper then re-analyzes the relationships by re-specifying the oil price shocks to take into account of the asymmetry and volatility concerns. Although re-specifications suggested by [Mork, 1989]'s positive oil surprises (MORK) and [Hamilton, 1996]'s net oil price increase (NOPI) manage to significantly improve the Granger causality results, they still fail to resolve either the structural breakdown instability or the breakdown of Granger causality of the oil - macroeconomy relationship for the post-1980s period, the start of which was marked by the formation of OPEC and the economy's dwindling emphasis on energy use. The instability of the model can be mainly attributed to that a linear relationship would break down as oil price drops fail to produce an economic boom. Still, the paper agrees with the literature that mis-specification concerns remains and it is possible that certain new specification may better capture the oil shock's non-linear relationship with the macroeconomy can restore the Granger causality relationship for the post-1980s period.

Overall, the Granger causality and structural stability results for the unemployment equation are stronger than those for the GDP equation. The oil - unemployment relationship is also more stable than the oil - GDP relationship. It requires further investigation for this discrepancy between oil prices' impact on the output and the impacts on the labor market.

Finally, it's worthy to mention that the literature finds strong support for the explanation that oil prices affect the economy indirectly through inducing monetary policy responses. In fact, in response to the second OPEC shock in 1979, the Federal Reserve started to directly target money supply to control inflation and ever since monetary policy has immediately responded to large oil price shocks. [Hooker, 1997] argued that after the 1980s, oil prices affected GDP indirectly through monetary policies by inducing simultaneous changes in Federal Funds rate responses; as a result multicollinearity would reduce the significance of oil prices in the regression. Similarly, [Daniel, 1997] obtained statistically significant causal effects of oil price shocks after taking out the effects of interest rates. [Bernanke et al., 1997] also investigated the role of monetary policy in the oil-price GDP relationship through executing a counter-factual analysis of the consequences of the Federal Reserve maintaining federal funds rates at a constant level. They concluded that most of the GDP decreases should be attributed to monetary policy rather than oil price shocks. A dynamic general equilibrium model may provide further insights on channels through which oil prices affect macroeconomic activities.

A Data Appendix

The data used in this paper is from the Federal Reserve Economic Data (FRED), aggregated from monthly to quarterly using the mean.

Oil Price, log-differenced: Crude Oil Prices: West Texas Intermediate, dollars per barrel, seasonally adjusted.

Real GDP, log-differenced: Real Gross Domestic Product, billions of chained 2009 dollars, seasonally adjusted.

Inflation, log-differenced: GDP Deflator, seasonally adjusted.

Import Goods Inflation, log-differenced: Import Goods Price Deflator, seasonally adjusted.

Interest rate: Effective Federal Funds rate, percent.

Unemployment rate: Civilian Unemployment rate, percent, seasonally adjusted.

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Variables	Levels		First Log-difference	
	ADF test	KPSS test	ADF test	KPSS test
RGDP	1.78	1.9***	- 7.26***	0.41*
OILPRICE	- 0.35	1.33***	- 12.23***	0.06
GDPDEF	0.22	1.92***	- 2.15	0.57
IMPORTDEF	- 0.79	1.64***	- 5.57***	0.28
FEDFUNDS	- 2.24*	0.36	- 9.13***	0.253
UNRATE	- 3.47***	0.21	- 6.77***	0.03

Table 1: Unit Root Tests¹

I. Structural stability tests	GDP growth eqn.	Breakpoints	Unemployment eqn.
1973 Q3 / Q4	1.75 (0.028**)	1973 Q3 / Q4	0.86 (0.637)
1980 Q3 / Q4	0.82 (0.683)	1980 Q3 / Q4	3.01 (0.000***)
1986 Q1 / Q2	0.65 (0.87)	1986 Q1 / Q2	1.93 (0.013**)
II. Granger causality tests	Oil -/->GDP growth	Samples	Oil -/->Unemployment
1960 Q1 - 2014 Q3	1.27 (0.865)	1960 Q1 - 2014 Q3	4.72 (0.317)
1960 Q1 - 1973 Q3	6.78 (0.147)	1960 Q1 - 1980 Q3	12.72 (0.013**)
1973 Q4 - 2014 Q3	0.55 (0.968)	1980 Q4 - 2014 Q3	2.94 (0.568)

Table 2: Chow Structural Stability and Granger causality Tests²

¹ADF Test Null Hypothesis: series has a unit root. KPSS Test Null Hypothesis: series is stationary. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.

²The Chow structural stability test has the null hypothesis of structural stability. The Granger causality test has the null hypothesis that lags of oil price (first difference of logarithmic value) have jointly zero coefficients in the regression of the dependent variable (GDP growth or unemployment) on lags of its own, oil price, Federal Funds rate, GDP deflator, and Import deflator.

*, ** and *** denote significance at 10%, 5% and 1% levels, respectively.

The values for Chow tests are F-statistics and values in () are p-values. The values for Granger tests are Chi-square (Wald) statics and values in () are p-values.

Variables	ADF test	KPSS test
MORKI	- 11.99***	0.59**
MORKD	-11.62***	0.87**
SOPI	-12.63***	0.75
SOPD	-13.84***	0.76
NOPI	-11.80***	0.17

Table 3: Unit Root Tests of Oil Shock Re-specifications ³

Oil Shock -/->GDP Growth			
Oil Shock Specification	1960 - 2014	1960 - 1973	1974 - 2014
LOGDIF (Standard)	1.27 (0.865)	6.78 (0.147)	0.55 (0.968)
MORKI	10.10 (0.039**)	14.02 (0.0072***)	2.03 (0.730)
MORKD	9.69 (0.046**)	18.25 (0.001***)	1.27 (0.865)
SOPI	2.05 (0.726)	1.76 (0.779)	2.92 (0.571)
SOPD	1.92 (0.749)	7.86 (0.096*)	0.66 (0.955)
NOPI	4.64 (0.326)	4.23 (0.375)	3.19 (0.527)
Oil Shock -/->Unemployment			
Oil Shock Specification	1960 - 2014	1960 - 1980	1981 - 2014
LOGDIF (Standard)	4.72 (0.317)	12.72 (0.013**)	2.94 (0.568)
MORKI	11.26 (0.024**)	13.35 (0.010***)	2.64 (0.620)
MORKD	11.64 (0.020**)	17.42 (0.002***)	1.64 (0.802)
SOPI	5.76 (0.218)	17.25 (0.002***)	1.73 (0.784)
SOPD	11.76 (0.019**)	23.6 (0.000***)	2.11 (0.715)
NOPI	12.14 (0.016**)	27.93 (0.000***)	4.52 (0.340)

Table 4: Summary of Granger Causality Tests for Re-specified Oil Shocks ⁴

	Standard	MORKI	MORKD	SOPI	SOPD	NOPI
GDP	44.9 (0.02**)	34.1 (0.30)	37.9 (0.14)	34.4 (0.28)	47.3 (0.01**)	34.9 (0.26)
Unrate	40.2 (0.12)	49.6 (0.01***)	41.3 (0.03**)	65.2 (0.00***)	69.4 (0.00***)	63.3 (0.00***)

Table 5: Quandt-Andrews Unknown Breakpoint Tests for Re-specified Oil Shocks ⁵

³ADF Test Null Hypothesis: series has a unit root. KPSS Test Null Hypothesis: series is stationary. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.

⁴The values are Chi-square (Wald) statics and values in () are p-values. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.

⁵The values are maximum Wald test statistics for structural stability and values in () are p-values. *, ** and *** denote significance at 10%, 5% and 1% levels, respectively.

Crude Oil Prices: West Texas Intermediate (\$ per barrel)

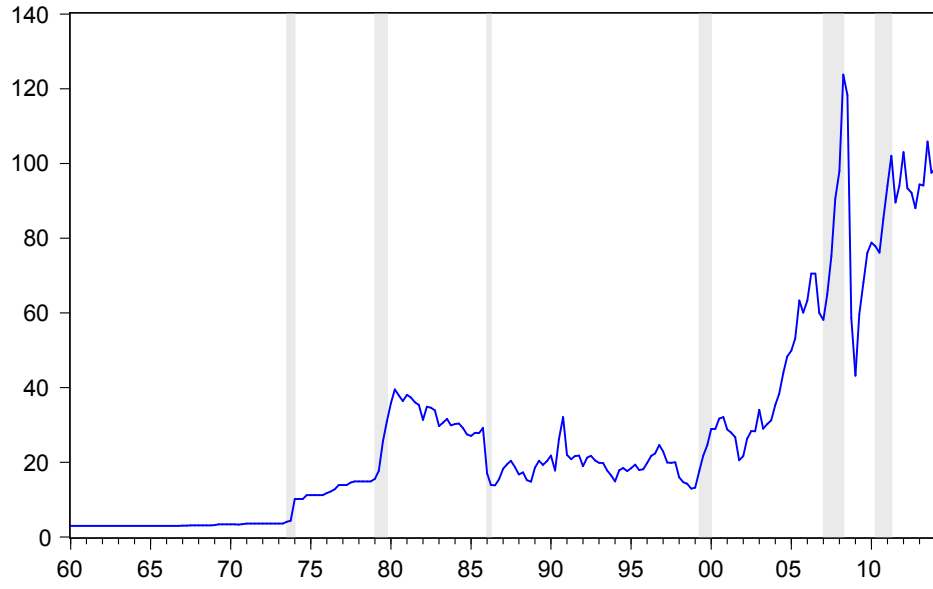
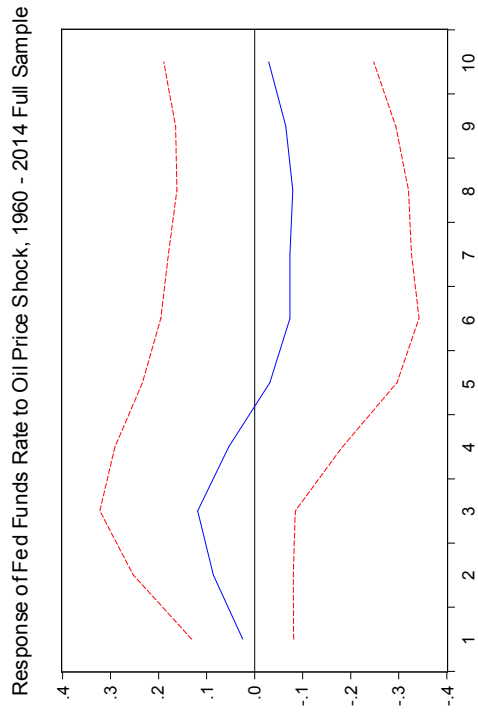
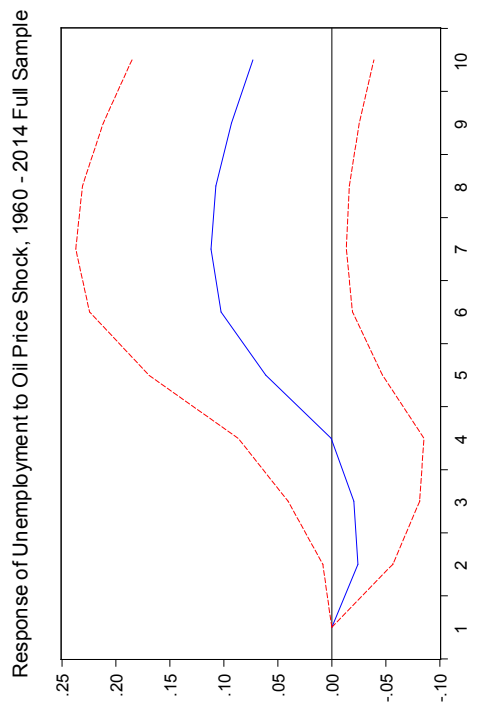


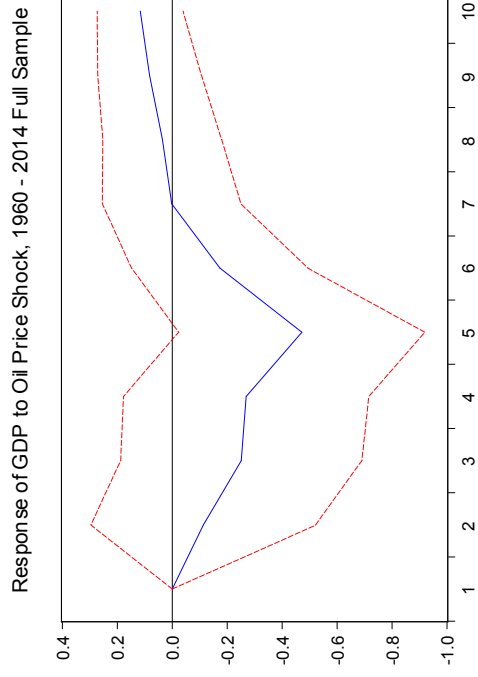
Figure 1: Oil Price Shocks, 1960 - 2014



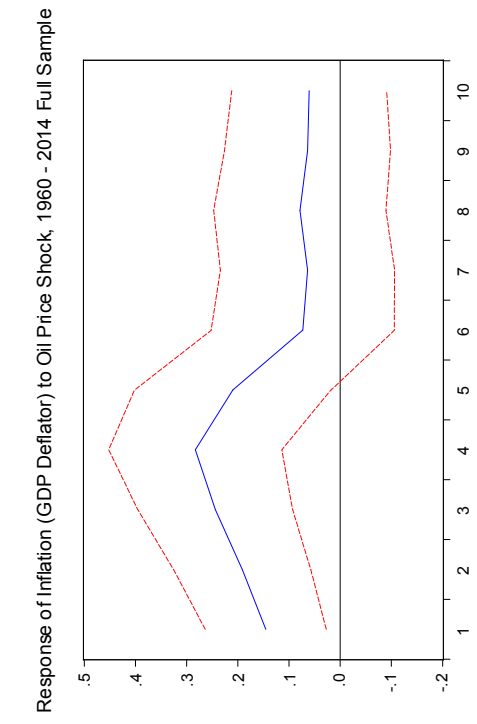
(a)



(b)

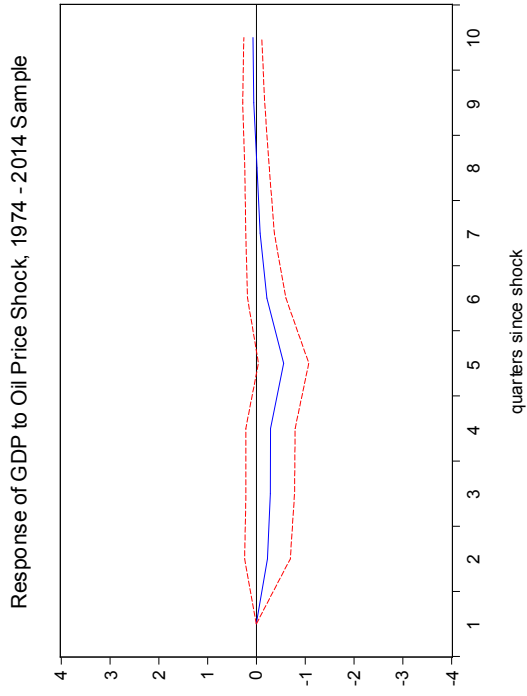


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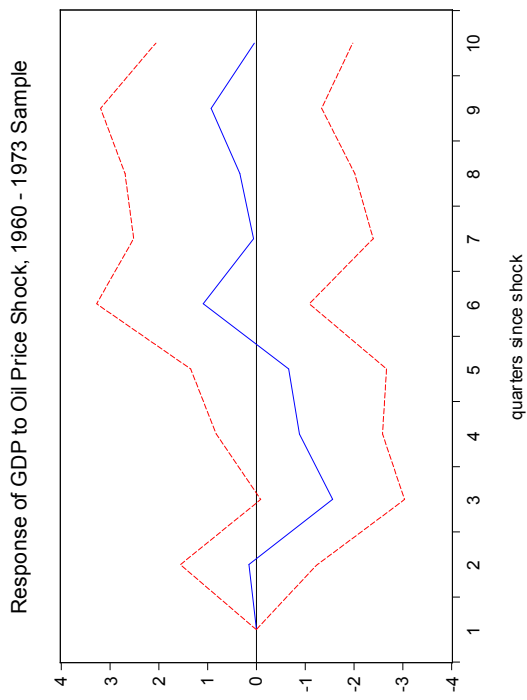


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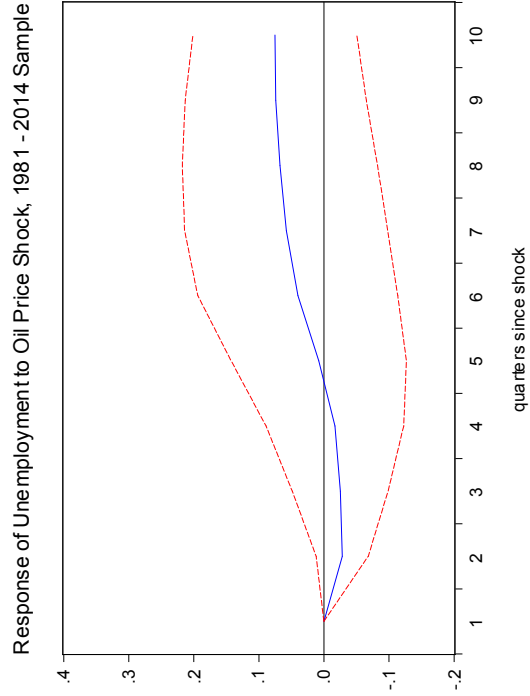
Figure 2: Impulse Responses of Macroeconomic Indicators to Oil Price Shocks, 1960 - 2014



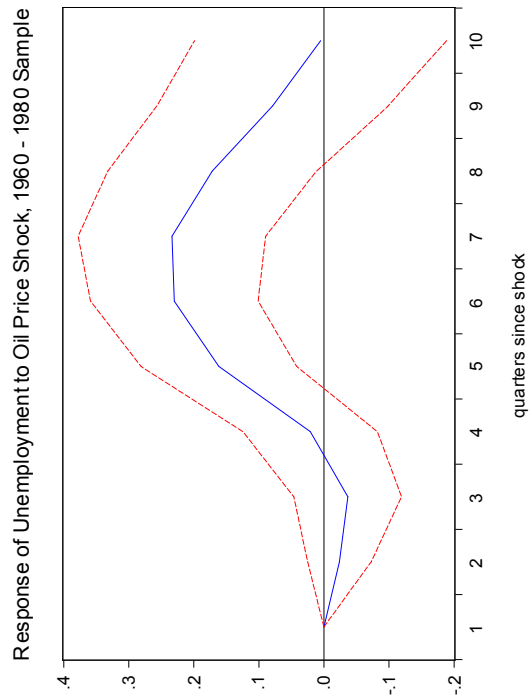
(a)



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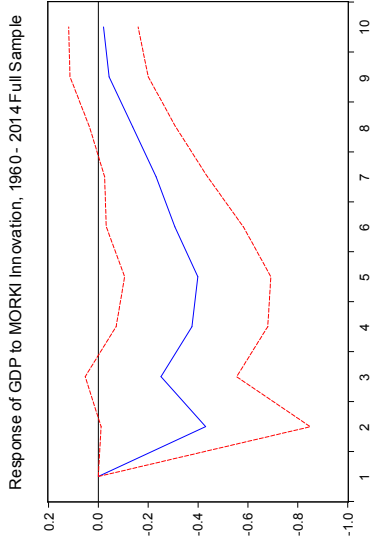


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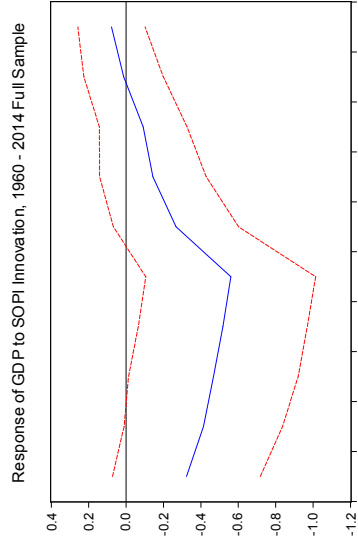


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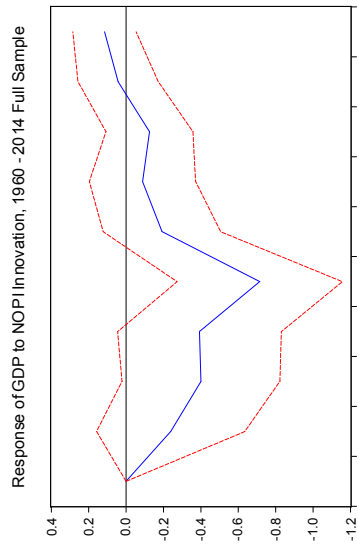
Figure 3: The Change of Impulse Responses Patterns



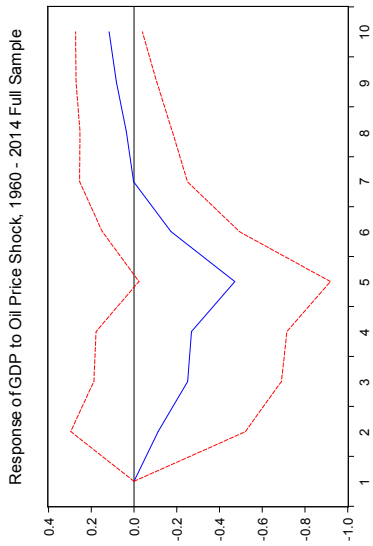
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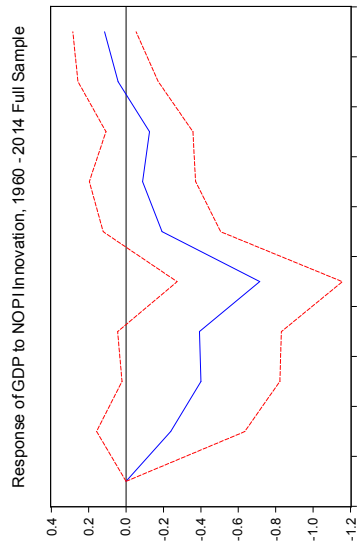
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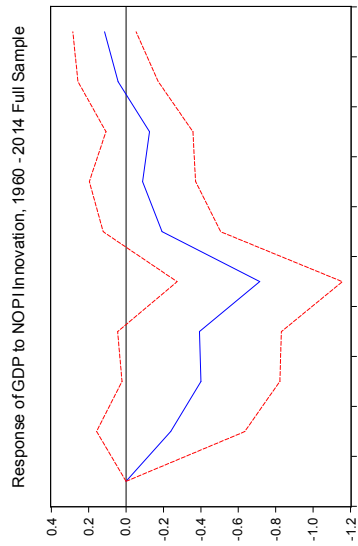
(c)



(d)



(e)



(f)

Figure 4: Impulse Responses of GDP (Growth) to Re-specified Oil Shocks, 1960 - 2014