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The Impact of Oil Prices on the U.S. Economy

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Contents

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Abstract

Nine of the ten recessions since WWII have been preceded by relatively large and sudden increases in the price of oil. In this paper, I use time series analysis to forecast GDP growth using oil prices. I use the methodology from Hamilton (2009), and extend the dataset through 2010. Impulse response functions are used to analyze the historical performance of the model's one-year-ahead forecasts. In April, 2011, the International Monetary Fund changed its forecast of 2011 GDP growth in the U.S. from 3.0% to 2.8% largely due to persistently high oil prices. My model suggests that the price increase in 2011Q1 will lead to growth of 2% in 2011. Furthermore, my model predicts that a 54% increase in crude oil prices during the second quarter of 2011 will lead the U.S. into a double dip recession

1. Introduction

The last time you pulled up to a red light and made a right turn, you probably were not thinking about oil shocks—but if not for the 1973 oil crisis, some states might still require you to wait for a green light to turn right. When the Organization of Petroleum Exporting Countries (OPEC) instituted an embargo on oil to countries deemed to be pro-Israel, the global oil supply fell 7.5% (Hamilton 2010). The effects of the 1973 Oil Crisis were incredibly far reaching. The U.S., led by Richard Nixon at the time, set the goal of reducing energy consumption by 25% (Forrester 1984). Congress passed a temporary nation-wide speed limit of 55 miles per hour which lasted until 1987 (Frum 2010). The State of Oregon banned the use of Christmas lights and some commercial lighting (Frum 2010). Major developed countries such as the UK, Germany, Switzerland, Norway and Italy prohibited flying, boating or driving on Sundays and some countries including Italy experimented with an even-odd scheme where only those with odd license plate numbers could buy gasoline on odd numbered days (Frum 2010). Thousands of U.S. gas stations were closed due to lack of supply, with many more deciding whether to ration the gasoline or sell the supply as fast as possible to minimize arguments with angry customers (Hamilton 2010). The hours of waiting in lines and the fear of the American lifestyle being threatened by instability in the Middle East, had a strong effect on Americans. In 1975, Congress passed the Energy Policy and Savings Act to establish a strategic reserve of petroleum to better prepare for oil supply shocks (Zador 1983). The

Act also required states to develop energy conservation plans[1], and required legalization of the gasoline-saving right turn on red.[2]

In April 2011, crude oil prices reached a two and a half year high because of political turmoil in Libya.[3] President Obama addressed the issue of oil prices in a March 11, 2011 news conference.[4] He pointed out that though we use 7% less oil than we did in 2005, we are still very dependent on foreign oil, controlling 2% of the world's oil but using over 25%.[5] The U.S. imports over 50% of the crude oil it uses[6]. Though none comes directly from Libya, European countries import crude oil from Libya which is shipped to the U.S., refined and then shipped back to Europe.[7] On April 11, the International Monetary Fund changed its forecast for 2011 growth in the U.S. from 3.0% to 2.8%, largely due to oil price increases.[8] On April 21, with prices still rising, the Justice Department announced an investigation into fraud in the setting of gasoline prices.[9] There was no reason to suspect fraud, and the notion that the U.S. Government could lower the short term price of oil is unrealistic.[10] Nevertheless, with consumers angry over rising costs, the government has found itself desperate to pursue anything which would appease consumers.

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[1] An additional Federal Regulation in 1992 required legalization of right turns on red in order for a state to receive funding for energy conservation plans. Source: http://www.law.cornell.edu/uscode/42/6322.html

[2] Analysis from Zador (1983) suggests that the adoption of right-turn laws increased right turn crashes by 18%.

[3] Source: http://www.bloomberg.com/news/2011-04-11/imf-cuts-2011-u-s-growth-forecast-on-oil-lackluster-pace-of-job-gains.html

[4] Source: http://www.whitehouse.gov/the-press-office/2011/03/11/news-conference-president

[5] Source: http://www.whitehouse.gov/the-press-office/2011/03/11/news-conference-president

[6] Source: http://www.eia.gov/energy_in_brief/foreign_oil_dependence.cfm

[7] Source: http://money.msn.com/how-to-budget/article.aspx?post=df31d82d-ff74-4a56-9cdc-1302039b3a02

[8] Source: http://www.bloomberg.com/news/2011-04-11/imf-cuts-2011-u-s-growth-forecast-on-oil-lackluster-pace-of-job-gains.html

[9] Source: http://www.reuters.com/article/2011/04/21/us-usa-energy-fraud-idUSTRE73K5FS20110421

[10] Source: http://www.washingtonpost.com/blogs/post-partisan/post/obamas-gas-price-charade/2011/04/22/AFJLFGQE_blog.html

While oil prices are clearly important, frequently making front page news, there is a large amount of disagreement in the literature about the effects of oil prices on the U.S. GDP. The instances where oil prices rise significantly in a short period of time, called oil shocks, are of particular interest. The purpose of this paper is to examine how past oil shocks have impacted the economy and predict how the economy will fare in light of recent oil prices. Using the Hamilton (2008) methodology of forecasting with time series analysis, I use the impulse response functions from oil price shocks to predict the response of real GDP. The paper proceeds as follows: In the literature review, I describe how oil became an integral part of the economy, and how oil shocks and recessions have coincided since WWII. I highlight the disagreements in the literature about the effect of oil shocks on the economy and the asymmetry of price increases and decreases. Extending Hamilton's sample, I build a similar forecasting model to predict the impact of oil prices on real GDP. I compare the one-year-ahead forecasts of the model for different oil shocks, and estimate the path of GDP given the oil shock in the first quarter of 2011.

2. Literature Review

In this section, I review the literature on oil shocks. I examine the history of oil before and after WWII, and then explain the theories of how oil prices impact the economy. I examine the issue of exogeneity of oil shocks, and show the construction of the model I use in the rest of the paper.

2.1 Oil Shocks

An oil shock refers to any time that oil prices rise significantly in a short period of time. The causes and consequences of oil shocks have been shown to have generally similar effects on industrialized countries. Kilian (2007) found that across G7 countries, all of which except Canada are net oil importers,[11] oil price increases are generally followed by a hit to real GDP in the second year after the shock. He also noted a spike in inflation peaking three to four quarters after the oil price shock. There is a branch of literature that studies the effects of oil shocks on inflation, but this paper focuses on the relationship between oil prices and real U.S. GDP.

There is substantial disagreement in the literature over how much oil prices affect the U.S. economy and through which mechanisms the effects are realized. Blanchard and Gali (2007) argued that the economy today is better able to adapt than in the past, so shocks have less effect now. The Blanchard and Gali argument made sense in light of the significant price increases from 2002-2007, with no commensurate recession. Nordhaus (2007) too argued that the effects were small for 2002-2007 because they were gradual. Figure 1 shows that the energy intensity in the U.S. economy, measured the share of energy purchases in total expenditures, has been cut in half since the 1970s (Blinder 2009). Edelstein and Kilian (2007) found a declining effect of energy price shocks on the aggregate measures of consumption—in a sample from 1970-2006, a 1% increase in energy prices was found to lead to a 0.30% decline in real consumption one year later for the first half of the sample, but only 0.08% for the second half. Blanchard and Gali (2007) attributed the lack of recession to the above reasons, in combination with an

[11] The UK exported oil until 2006 when the country became a net importer. Source: U.S. Energy Information Agency: http://www.eia.doe.gov/emeu/international/oiltrade.html

automobile industry which had decreased in size since the previous shocks, and a Federal Reserve that established credibility in keeping inflation low.

Unfortunately, the recession of 2007-2008 presented a challenge to the story that the economy was now relatively immune to energy price socks. Although the energy intensity had fallen significantly since the 1970s, Kilian (2009) notes it began increasing again after 2000, as displayed in Figure 1.[12] The energy intensity was 8% in 1970 and steadily rose to a high of 13.7% in 1981. It declined to its low of 5.9% in 1999 but by 2007 the value was back up to 8.8% and Hamilton (2009) argues that this increasing energy intensity amplified the effect of the oil price shock. He argues that with the earlier increases people could afford to keep buying energy, but then by the end of 2007, they could no longer afford to and a threshold was reached which set in motion the impending collapse of the housing market and the financial crisis. Hamilton (2009) argues that there would not have been a recession in 2007-2008 in the absence of oil price increases.

The Hamilton claim, however, does not belittle the housing bubble and the collapse of the financial industry as the cause for the Great Recession. His argument is as follows: Demand was rising globally from 2002-2007 and due to the supply increases in 2004-2006, the price effects of the increasing demand weren't realized until the production slowed in 2007-2008. Since the housing market had already been creating a drag on the economy, the rapid oil prices tipped the economy into the housing crisis[13] and

[12] The shaded areas on this graph correspond to recessions.
[13] Hamilton (2009) notes the interaction between oil prices and housing: home prices in suburbs fell far more in suburbs that require long commutes via automobile, than in neighborhoods closer to cities.

Figure 1. Energy Intensity in the U.S. Economy from 1970-2010 measured as Energy Expenditures as Share of GDP

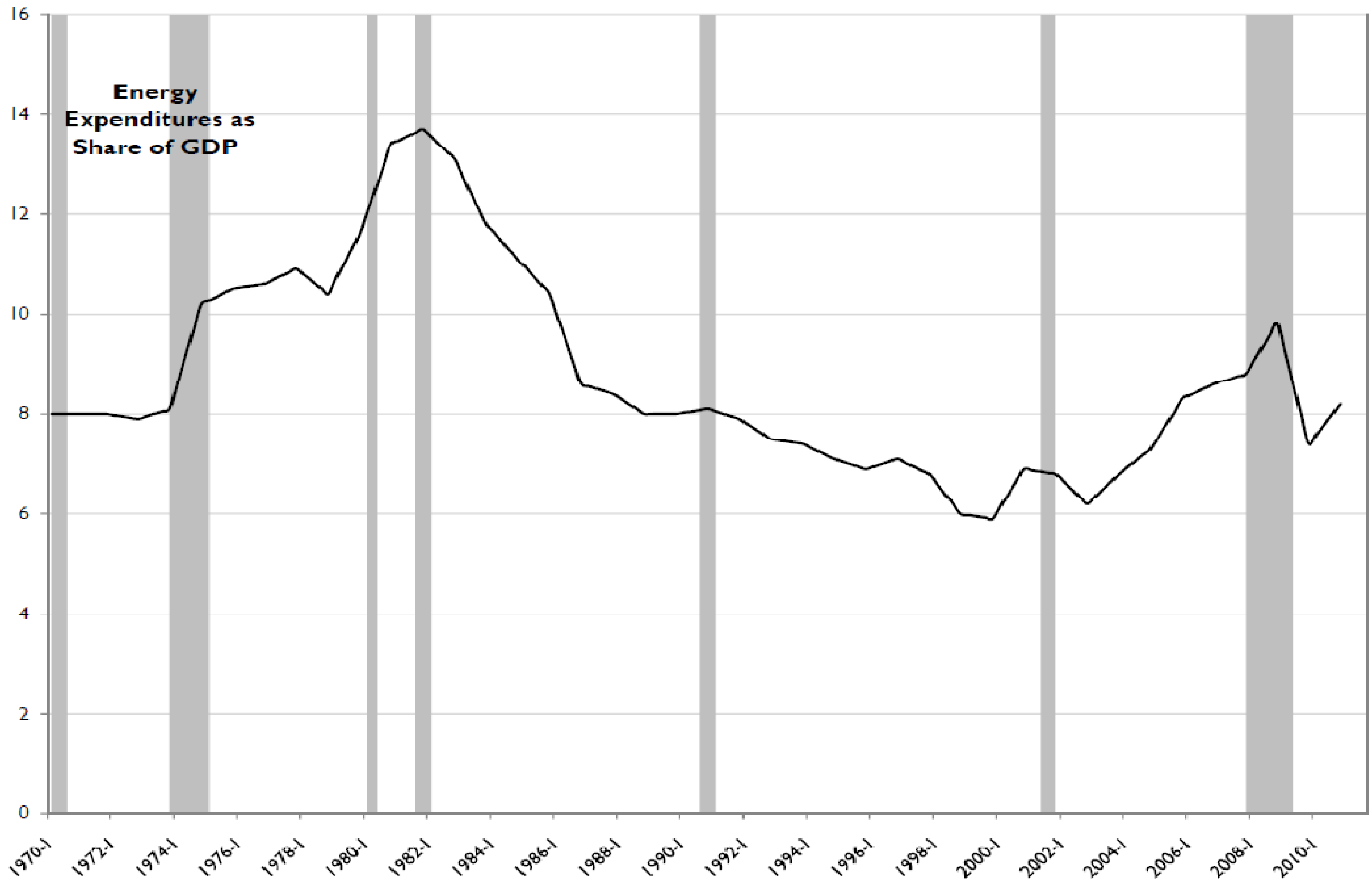
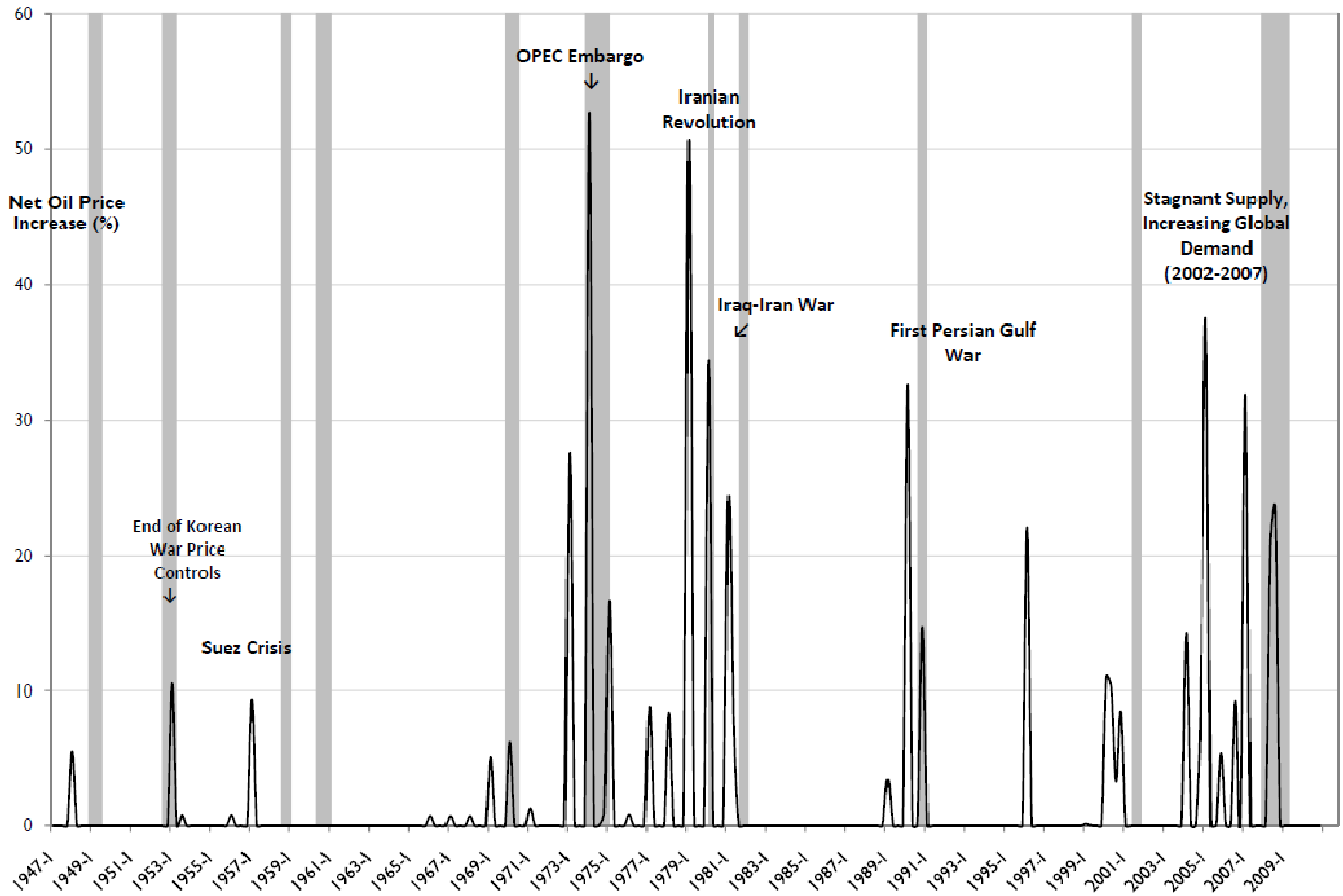


Figure 2. Oil Price Shocks from 1947-2010 measured as Quarterly Percentage Change from Previous Three-Year High



financial meltdown. I now take a step back to examine how oil became such an integral part of the U.S. economy that a respected economist could claim that oil prices caused the largest economic recession since the Great Depression.

2.2 History of Oil before WWII

In 1859, Edwin Drake produced the first commercially available crude oil in the U.S. (Hamilton 2010). A tax on alcohol added in 1862 made alcohol-derived illuminants too expensive to produce. Consequently, alternative illuminants made with petroleum became the norm. After the civil war, the oil industry expanded but still only accounted for 0.4% of GNP in 1900.

In the early twentieth century, the use of petroleum evolved, and petroleum products became more integrated into various parts of the economy. Though petroleum based illuminants were largely replaced with electric lighting, oil became widely used for commercial and industrial heating. Additionally, oil was used to power trains and, later on, for motor vehicles.

After the Great Depression, the oil industry changed in two distinct ways: it was more regulated, and it became largely controlled by Texas. With the discovery of the enormous East Texas field, which started producing oil in 1930, Texas became a major part of the oil industry. The state would produce 40% of the crude in the U.S. from 1935-1960 (Hamilton 2010). The Texas Railroad Commission (TRC), the state agency governing petroleum use in Texas, initiated regulations which both mandated proper field management and restricted supply to keep prices high. The TRC had a widespread influence—in the post World War II era, global crude oil prices were quoted based on prices in the Gulf of Mexico. The TRC would keep nominal prices constant and raise them in response to external supply disruptions.

2.3 Behavior of oil prices after WWII

From 1948-1972, the TRC would forecast demand for the upcoming month and set production levels to meet the demand (Hamilton 2010). After 1973, the Organization of Petroleum Exporting Countries became the major player in the world oil market, changing production levels in response to fluctuations in demand.

Hamilton (2008) notes that nine of the ten U.S. recessions since WWII have occurred after increases in oil prices. A recession is typically two consecutive quarters of negative GDP growth, but the National Bureau of Economic Research (NBER) has flexibility in setting the dates. The NBER defines a recession as:

> A significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales.[14]

Figure 2 displays the oil shocks.[15] The following events are responsible for the large oil shocks:

Korean War: Oil prices were frozen by order of the Office of Price Stabilization from January 25, 1950 to February 13, 1953.

1956-1957 Suez Crisis: Israel, Britain and France invaded the Suez Canal, preventing transportation of oil through the canal and movement of Iraqi oil transportation through

[14] Source: http://www.nber.org/cycles.html

[15] Shaded areas in this graph correspond to recessions.

Syria. The global production fell by 10.1%, the largest percentage drop of any oil shock (Hamilton 2010).

OPEC embargo: Syria and Egypt attacked Israel on October 6, 1973 and the U.S. provided weapons and supplies to assist Israel. On October 17, the Arab members of OPEC announced an embargo to pro-Israel countries. The overall decrease in global production was 7.5% from September to November.

Iranian Revolution: There were large scale protests in Iran, including oil sector employees. The result was a drop of 7% of world production from October 1978 to January 1979. Saudi Arabia was able to increase production which made up for a third of the lost production in Iran.

1980-1981 Iran-Iraq war. When Iraq invaded Iran in September 1980, the lost production from both countries caused a 7.2% drop in global production.

First Gulf War: When Iraq invaded Kuwait, production from both countries dropped. The two countries accounted for 9% of world supply, and the disruption caused prices to double. There were no long lines or rationing of oil in the U.S., because Saudi Arabia was able to increase production to bring back levels back to the pre-war levels within a few months.

The Iraq War beginning in 2003 and the instability in Venezuela in 2002 did not coincide with subsequent recessions. This led Blanchard and Gali (2007) to believe that the country had improved its ability to respond to oil shocks. In the following section, I take a closer look at the mechanism through which oil shocks are believed to affect GDP.

2.4 Mechanism of effects

Demand for oil is largely determined by income; as an economy grows, more oil is needed to fuel growth. The natural log of oil consumption plotted against the log of real GDP has a slope of 1.2 from 1949-1961 and 1.04 from 1961-1973 (Hamilton, 2009). This slope is the income elasticity of demand, in other words if income increases by 1%, from 1949-1961, on average oil consumption increased by 1.2%[16]. The elasticity falls to 0.47 for the period from 1985-1997, which Hamilton (2009) attributes to either the "delayed consequences of increased energy conservation following the 1970s oil shocks" or the natural process of the income elasticity falling as a country gets more developed.

The price elasticity of demand, which measures how much demand will fall for a 1% increase in price, is also an important metric. Since individuals and firms are relatively unable or unwilling to change consumption of oil, the price elasticity of demand for oil is low. Hamilton (2009) estimates the short-run price elasticity of demand for gasoline to be 0.21-0.34 from 1975-1980 but only 0.034-0.077 in 2001-2006, reflecting an even greater lack of adjustment to price changes.

The energy intensity in the U.S. economy has been falling since the 1970s. With an income elasticity below 1, when income increases oil, consumption increases by a smaller percentage, so the energy intensity falls. However, with low short-run price elasticity, when the price of oil goes up the demand falls by less than the price increase and the energy intensity rises (Hamilton 2009).

[16] These percentages are calculated as the difference in the natural log of consumption.

One argument for the mechanism of supply disruptions affecting the economy is the factor share argument. A firm's production function Y can be expressed in terms of labor (N), capital (K) and energy (E), with the following formula:

$$Y = F(N, K, E).$$

If P is the nominal price, W is wages, Q is the price of energy, and r is the nominal interest rate, profits are given by:

$$PY - WN - rK - QE.$$

Firms will use energy up to the point where marginal product of energy equals the price of energy. The partial derivative of F with respect to energy is given by QE/PY. Therefore, the elasticity of output for a change in energy use can be predicted by the energy intensity.[17] The factor share framework is useful for conceptualizing the macroeconomic effects of oil price fluctuations on firms. However, based on a survey of the literature, Hamilton (2008) asserts that

> The key mechanism whereby oil shocks affect the economy is through a disruption in spending by consumers and firms on other goods [and] if this disruption fails to occur, the effects on the economy are indeed governed by the factor share argument.

Edelstein and Kilian (2007) break down the effects of energy price changes on consumption behavior into four components and test the contribution from each. The first component measures the effect of a decrease in spending of discretionary income. Due to the low price elasticity of demand for oil, consumers will continue to spend on oil when

[17] This is a modified version of the factor share argument layed out in Hamilton (2008)

prices rise and have less left over for other spending. This effect is bounded by the energy intensity, because even if the elasticity of demand is zero, one still only needs to spend a certain amount on energy. The second effect is the "uncertainty effect" (Edelstein and Kilian 2007) of consumers putting off decisions about purchases of durable goods, which may be difficult to reverse, until there is more certainty about oil prices. Hamilton (2003) points out that a change in oil prices leads to hesitation in consumption:

> How energy-efficient should your appliances, windows and insulation be?...When energy prices and availability are as uncertain as they were in early 1974, it is rational to postpone such commitments until better information is available.

The response to consumption of durable goods is five times larger than that predicted by the energy share argument (Hamilton 2009). However, Edelstein and Kilian find no evidence of the uncertainty effect directly. The third effect is the decrease in overall spending which goes instead towards "precautionary saving" as consumers worry about uncertain oil prices. The fourth effect is the "operating cost effect" which is the decrease in spending on durable goods that require energy used as a compliment, such as automobiles. Edelstein and Kilian (2007) also tested for indirect "allocative effects" due to changing composition in the sectors of the economy. For example, if automobiles become more costly to produce, industry specific capital and labor may be unused. They were unable to find evidence for this reallocation effect, but are not surprised because of the diminishing role of the U.S. automobile industry. Other studies, such as Lee and Ni (2002) however, find that the reallocation amplifies the negative effect on the economy.

The ability to understand the relative contributions of each effect is critical for extending the model into the future. For example, if the relative contribution from automobile spending is known, then it can be scaled by the size of the automobile industry when applied to predicting future consequences. Edelstein and Kilian (2007) find that a 1% increase in energy prices leads to a decrease of 0.15% in real consumption one year later.

2.5 The Exogeneity of Oil Shocks Issue

If oil shocks and GDP growth are found to have a statistically significant relationship in the subsequent periods, then there is a historical correlation between the sets of values. In order to say that oil shocks actually cause the change in growth rate of GDP, it is necessary to say that oil shocks are determined exogenously, that is, by external forces outside of the model.

Due to the Texas Railroad Commission's setting of prices to meet forecasted demand, Hamilton (2003) argues that only supply disruptions changed price from 1948 to 1972. Since these supply disruptions are caused by political activity in the Middle East, Hamilton argues that oil prices were exogenous during this period. Hamilton (2003) notes that the argument about exogeneity from 1948-1972 cannot be made about post 1973 data when global forces of supply and demand determine prices.

As long as the political events in the Middle East that cause supply shocks are not determined by the business cycle fluctuations in the U.S., the correlation should be interpreted as causal (Hamilton 2010). Hamilton (1983) performs a test for Granger Causality of oil prices on GDP. Since there may still be a third variable causing both the oil prices and the recessions, Hamilton (1983) tests if lagged values of six macro aggregate variables in a Sims VAR system Granger cause oil prices. He argues that if Granger Causality is shown and no other macro variables can be proven to predict oil price changes, then there is a strong case for causality. The six variables tested were real GNP, unemployment rate, U.S. prices, U.S. wages, inflation, and import prices. The only statistically significant variable was import prices, but the portion of oil prices driving GDP could not be predicted by oil prices. Since there is no evidence of an omitted variable driving both oil prices and GDP, the causal view is supported. Kilian (2009) disagrees, arguing that real global demand may be driving both U.S. business cycle dynamics and oil prices, violating the *ceteris paribus* condition, . Kilian (2009) also cautions against the causal interpretation of Hamilton's model in the case of 2007-2008 because the price changes were gradual from 2002-2007 and Hamilton's model captures the effect on average of the sudden shocks.

2.6 Constructing the model

Using the Hamilton (1983) finding that none of the macroeconomic variables in the Sims system Granger cause oil prices, the functional form of the equation can use simply lagged values of change in GDP and change in oil prices. The "feedback-free reduced-form equation" (Hamilton 1983) is

$$\begin{aligned} y_t &= a_0 + a_1 y_{t-1} + a_2 y_{t-2} + a_3 y_{t-3} + a_4 y_{t-4} \\ &\quad + b_1 o_{t-1} + b_2 o_{t-2} + b_3 o_{t-3} + b_4 o_{t-4} + u_t \end{aligned} \tag{1}$$

2.7 Asymmetry

Hooker (1996) argues that after 1973, oil price changes no longer Granger cause GDP growth, even when only price increases are used. Mork (1989) ran Hamilton's equation with different coefficients for price increases and price decreases, with the former but not the latter showing statistical significance. Hooker, however, using a post-1973 sample found a Granger test p-value of 0.42 leading to rejection of Granger Causality for oil price increases. The Hooker article, called "What happened to the oil price-macroeconomy relationship?" was received for publication with the Journal of Monetary Economics in March of 1996. In April of 1996, the final version of James Hamilton's article was received for publication. Hamilton's title was "This is what happened to the oil price-macroeconomy relationship". In only 5 pages, compared with Hooker's 18, Hamilton refuted Hooker's claim and suggested a new form of asymmetry to solve the discrepancy. Hamilton plotted the change in nominal oil prices over time and saw that increases often follow even larger decreases. He proposed instead using the percent increase over the one year high, since these increases are more likely to affect firms and consumers decisions. He calls this value the "net oil price increase," and if the value in period t is not a new one year high, the series is said to be zero. An F-test on the null hypothesis that none of the lagged oil values changed after 1973 using the net oil price increase, and the F-statistic was 1.71 leading to failure to reject the null hypothesis.

Lee, Ni and Ratti (1995) used a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model of oil price changes on GDP. The theoretical backing for expecting conditional heteroskedasticity is that the shocks will matter more when prices have been steady than when they have been volatile. When recent prices are volatile an increase is often seen as correcting a previous decrease, but if prices are steady, the increase may be taken more seriously by consumers and firms. The model essentially divides the oil shock by the recent volatility.

There was clearly some sort of asymmetry, but the exact nature was unclear. Hamilton (2003) used a flexible approach to determine the correct nonlinear specification to explain the asymmetry. He found strong evidence supporting the method of Lee, Ni and Ratti (1995). He also found strong evidence for a method which uses “net oil price increase” as in Hamilton (1996) but instead with only values that exceed the previous three-year high. An instrumental variables approach that isolated the five major military conflicts in the Middle East performed very similarly to the “net oil price increase” model because taking the three-year high filters out almost everything except these events. The number of non-zero observations in the 1947Q1-2010Q4 sample drops from 143 to 39.

The asymmetry remains a disputed issue in the literature. Edelstein and Kilian (2007) found no evidence of asymmetry in response of consumer spending, aggregrate unemployment rate, or consumer expectations. Hamilton (2008) believes that the significant oil price decreases in 1985-1986 did not cause the subsequent economic expansion. Edelstein and Kilian (2007) found symmetrical consumer behavior in response to the 1979 oil shock and the 1986 oil price reductions.

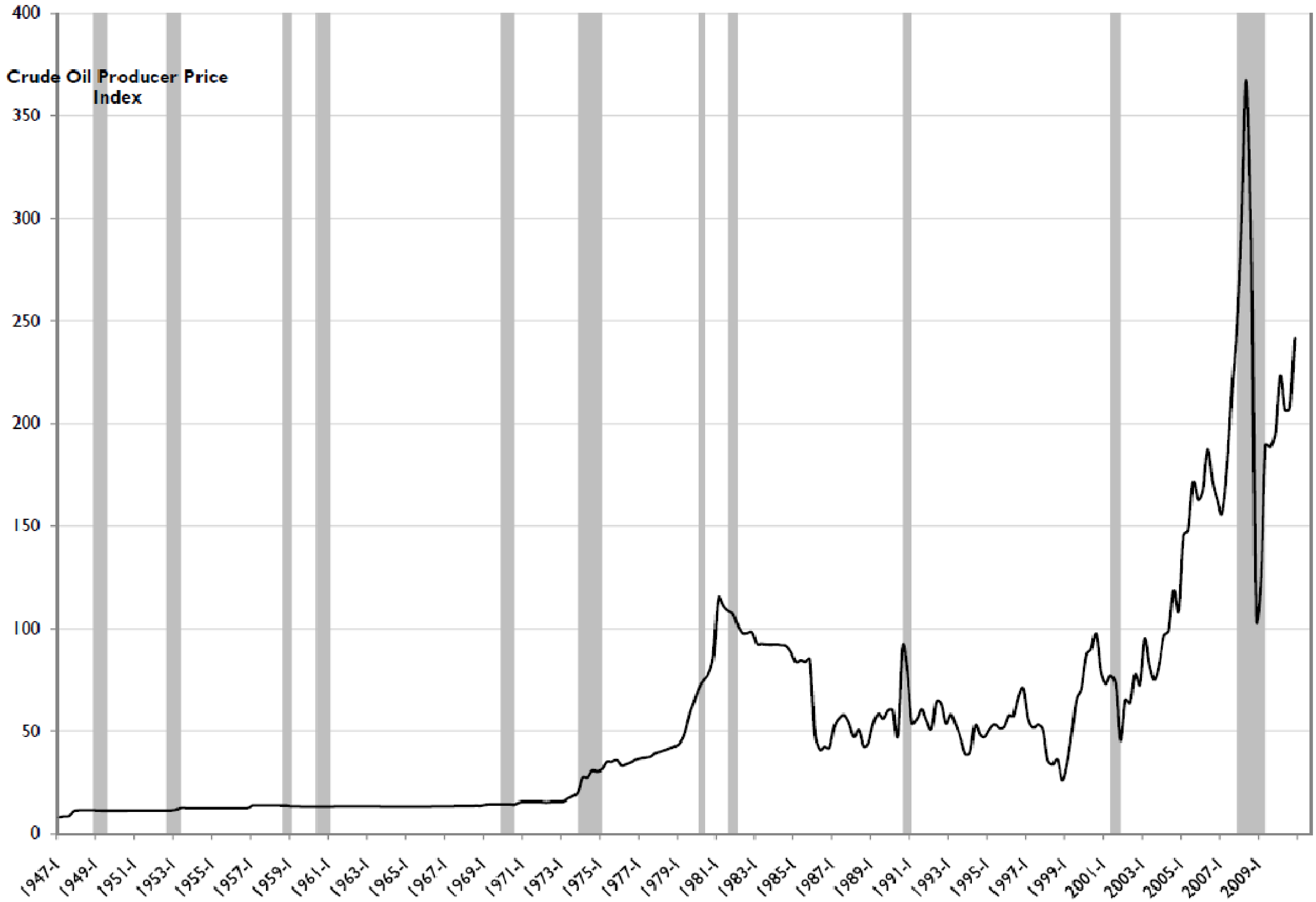
3. Methodology

3.1 Data

The dataset consist of real GDP and crude oil prices from the first quarter of 1947 to the fourth quarter of 2010. My data for Gross Domestic Product used was in real values, using 2005 as the base year.[18] The measure of oil prices used was the crude oil Producer Price Index (PPI) for domestically produced oil, plotted in Figure 3. The monthly values are averages of what oil refiners pay for crude oil produced domestically during that month. Since the U.S. imports 51% of the crude oil and refined petroleum products it uses[19], and prices are set by forces of global supply and demand, the PPI for domestic crude oil is still an appropriate measure to use. There are many different measures of oil prices and the choice can have a profound impact on results. For example, Blanchard and Gali (2007) predict that the economic growth in 1980-81 would have been worse if oil prices had not risen. Hamilton (2008) points out that their measure of oil prices was the price of West Texas Intermediate crude oil which fell during that period, while oil prices increased according to all other measures. The crude oil PPI is a nominal value, so inflation is not taken into account. Since inflation and GDP growth are related through related macroeconomic factors, including inflation weakens the case for oil shocks being exogenous. The crude oil PPI values are recorded monthly, so I converted it to a quarterly dataset by taking the end values of each quarter. For example, the first quarter value for 2011 is the crude oil PPI for March. Oil shocks are measured as in Hamilton (2008). Still using the monthly data, the previous three year high at each quarter is recorded. Then, if the value in quarter t is greater than the three year high, the oil shock is the percentage increase from the previous three-year high. This value will hereafter be referred to as the net oil price increase. The oil shock is said to be zero if no new three-year high is reached

[18] Source: http://research.stlouisfed.org/fred2/categories/106
[19] Source: http://www.eia.gov/energy_in_brief/foreign_oil_dependence.cfm

Figure 3. Crude Oil Producer Price Index for Domestically Produced Oil from 1947-2010



during the period. This method is used to focus on the major oil shocks. The drawback of using this methodology is that there are only 39 quarters in which an oil shock occurs, so the sample size is small. The summary statistics for the 39 shocks are shown in Table 1. All of the net oil price increases are shown in the Appendix.

3.2 Stationarity

In order to make a dependable forecast using time series data, it is often better to look at changes rather than levels. If the levels have a trend, then the values before and after a given time will have a different joint distribution that depends on the time.[20] Such a time series is said to be nonstationary, and forecasts will be skewed. A variable must be stationary for time series analysis and the Augmented Dickey-Fuller (ADF) test is used to test for stationary. I conducted ADF tests on both real GDP and crude oil PPI, finding both to be nonstationary. However, tests on the difference in natural log of real GDP and net oil price increase showed both to be stationary with p-values <0.00001[21]. The variables are now considered to be integrated of order one, or I(1).[22]

3.3 Cointegration

Even though the two variables y and o are stationary when integrated of order one, there is still a chance that the variables share a common trend. If $y - \beta o$ is stationary, when β is some coefficient, then y and o are cointegrated. I used the EG-ADF test[23] for cointegration. First I regressed y on o and calculated the residuals. Then I ran an ADF test

[20] Keil's 2008 Lecture Notes
[21] Resuts of test are shown in Appendix
[22] Keil's 2008 Lecture Notes
[23] Stock and Watson Textbook, Chapter 16

on the residuals. The p value of the test statistic for the EG-ADF test was <0.00001, leading to rejection of the null hypothesis of cointegration.[24] Intuitively, this result makes sense because it would be surprising to find that GDP growth at time t had a common trend with the same period's net oil price increase which as is largely determined by political instability in the Middle East.

3.4 Lag Selection

In the regressions I am essentially using the lagged values of real GDP growth and net oil price increase to forecast real GDP growth. The values of real GDP growth are calculated as the difference in natural log between real GDP in period t and t-1, and will hereafter be referred to as GDP growth. Equation 1 shows the form of the regression used by Hamilton (2008).

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + a_3 y_{t-3} + a_4 y_{t-4} + b_1 o_{t-1} + b_2 o_{t-2} + b_3 o_{t-3} + b_4 o_{t-4} + u_t \quad (1)$$

Where y is GDP growth, and o is the net oil price increase. The dependent variable is GDP growth in quarter t, and the eight explanatory variables are the values of GDP growth in the previous four periods and the net oil price increase in the previous four periods. To decide the optimal number of lagged values to use, I used the Bayes-Schwartz Information Criterion (BIC) and the Akaike Information Criterion (AIC).[25] If too few lags are used, an important explanatory variable may be left out, and if too many are used then unnecessary explanatory variables will increase the inaccuracy of the

[24] Resuts of test are shown in Appendix
[25] Keil's 2008 Lecture Notes

forecast. Both of these information criteria give information that balance these factors. Both the BIC and the AIC suggest a lag length of four.[26] The results of the regression, shown in Figure 3, show that the fourth lag of oil prices is significant at the 5% level for the full sample. Using four lags is consistent with the equation used by Hamilton (2008).

3.5 Standard Errors

I use Newey-West Standard Errors for the regressions. A White noise Q test tests the null hypothesis of no serial correlation. Both net oil price increase and GDP growth have a Portmanteau (Q) statistic p-value of <0.00001, leading to a rejection of the null. Since there is serial correlation and no reason to assume homoskedasticity, I use Newey West errors which are consistent for autocorrelation and heteroskedasticity.

3.6 Breaks in the Data

Hamilton found that the relationship from 1948-1972 was a poor predictor of the effects from the price increases of 1973-1974, because the price increases were roughly three times larger than the largest during the 1948-1972 sample. The results for the entire sample consequently show much smaller coefficients than the second sample. Hamilton (1983) hypothesizes that "changes in expected inflation, the response of monetary policy to oil shocks, or the regime in which oil prices are determined" could create the structural break. I conducted a Chow test for a structural break starting in 1973Q1 and with a p value of 0.0000 rejected the null hypothesis of no break.

[26] Resuts of test are shown in Appendix

4. Results

4.1 Regression

As in Hamilton, I estimate the regression beginning in 1949Q2, because during 1947 and 1948 the post war transition to automobile usage led to an 80% increase in the price of crude oil, but this is not the type of oil price variation we are interested in examining.[27] Figure 4 shows the results of the regression. Column 1 is from the full sample from 1949Q2-2010Q4. Column 2 shows the same results for the early sample period from 1949Q2-1972Q4, the point at which Hamilton (1983) finds a structural break. I ran a Chow test for a structural break at 1973Q1. With the null hypothesis of no break, I found an F-stat of 8.49 with a p value of 0.0000 leading to rejection of the null. Column 3 shows the results for the late sample period from 1973Q1-2010Q4. The form of the regression from column 1 is displayed in equation 2 with Newey-West standard errors in brackets.

$$\begin{aligned} y_t = \underset{(0.10)}{0.825} + \underset{(0.06)}{0.25}y_{t-1} + \underset{(0.07)}{0.12}y_{t-2} - \underset{(0.06)}{0.10}y_{t-3} - \underset{(0.07)}{0.09}y_{t-4} \\ - \underset{(0.01)}{0.02}o_{t-1} - \underset{(0.008)}{0.02}o_{t-2} - \underset{(0.007)}{0.02}o_{t-3} - \underset{(0.008)}{0.02}o_{t-4} \end{aligned}$$

The R-squared is 0.23 meaning that 23% of the variation in GDP growth is explained by the model. When the four lagged values of GDP growth are taken out, the model with only four lagged values of net oil price increase has an R-squared of 0.14. The Results with only the net oil price increase are shown in columns 4-6 of Figure 4.

[27] Hamilton (2010)

4.2 Granger Causality

The Granger Causality test is applied to determine if a variable's lagged values have predictive power of another variable. The name "Granger causality" is a misnomer in the sense that the test does not determine if the dependent variable *causes* the independent variable. Stock and Watson note that a more appropriate name would be "Granger predictability" [28] because though it may be useful in forecasting, additional assumptions need to be made in order to make a causal interpretation. Namely, the assumption of exogeneity needs to be satisfied. Since the net oil price increase is considered fairly exogenous, the results of the Granger Causality test can be interpreted roughly as a test of one variable causing the other.

In the Granger Causality test, the null hypothesis of the F-test is that all four lagged values of net oil price increase are insignificant explanatory variables when regressed on GDP growth. The F-test p-value is 0.0001 leading to rejection of the null. This establishes that net oil price increase Granger causes GDP growth.

To test whether GDP growth Granger causes net oil price increase, I regressed GDP growth on net oil price increase. The null hypothesis that all four lagged values of GDP growth are insignificant explanatory variables has an F-Test p-value of 0.55, so the null cannot be rejected. Hence, GDP growth does not Granger cause net oil price increase.[29]

4.3 Impulse Response Functions

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[28] Stock and Watson Textbook, Chapter 15

[29] The results of both Granger Causality tests can be found in the Appendix Sections 6 and 7

Table 1. Values of Net Oil Price Increase in During Oil Shocks

Date	Net Oil Price Increase
1974q1	52.8%
1979q1	50.7%
1980q1	34.4%
1990q1	32.6%
2007q1	31.8%
1981q1	24.3%
2008q3	23.5%

A first step for interpreting the above regression is to look at the impulse response function for a one standard deviation net oil price increase (Kilian 2009). The standard Deviation of net oil price increase is 13.86. For a 13.86% increase in oil prices, the model predicts a 1.1% decrease in GDP four quarters later. The actual values of net oil price increase during oil shocks are far higher, See Table 1.[30] Since we care most about the large values, consider that roughly 2 standard deviation net oil price increase of 25% yields a 2.0% drop in GDP four quarters later.

Take for example the largest oil shock in the dataset which resulted from the OPEC Embargo in October of 1973. The Crude Oil PPI increased from 19.9 to 24.3 from December 1973 to January 1974. In March the figure was 27.5. In my dataset this translates to a net oil price increase in 1974Q1 of 52.8%. Figure 4 shows what the model from 1949Q1-2010Q4 would predict for the one-year-ahead forecast, compared with the actual result. Figures 5-9 show the same results for the other major oil shocks. In each graph, the forecast

[30] All values are shown in the Appendix.

Figure 4. Regression of Net Oil Price Increase and GDP Growth on GDP Growth

VARIABLES	(1) y_t (1949Q2-2010Q4)	(2) y_t (1949Q2-1972Q4)	(3) y_t (1973Q1-20104)	(1) y_t (1949Q2-2010Q4)	(2) y_t (1949Q2-1972Q4)	(3) y_t (1973Q1-20104)
y_{t-1}	0.250***	0.149**	0.221**			
	(0.0641)	(0.0726)	(0.0856)			
y_{t-2}	0.118	0.135	0.0913			
	(0.0714)	(0.0944)	(0.0945)			
y_{t-3}	-0.0972	-0.127*	-0.0505			
	(0.0628)	(0.0721)	(0.0926)			
y_{t-4}	-0.0879	-0.169*	0.0141			
	(0.0714)	(0.0976)	(0.109)			
o_{t-1}	-0.0207**	-0.148***	-0.0185*	-0.024**	-0.127***	-0.0213**
	(0.00969)	(0.0276)	(0.00952)	(0.0093)	(0.0394)	(0.00922)
o_{t-2}	-0.0192**	-0.103**	-0.0175**	-0.026***	-0.117***	-0.0235***
	(0.00765)	(0.0444)	(0.00760)	(0.0074)	(0.0437)	(0.00754)
o_{t-3}	-0.0186***	-0.248***	-0.0142**	-0.026***	-0.291***	-0.0203***
	(0.00704)	(0.0430)	(0.00665)	(0.0074)	(0.0290)	(0.00680)
o_{t-4}	-0.0202**	-0.155	-0.0166**	-0.026***	-0.198*	-0.0223**
	(0.00795)	(0.118)	(0.00828)	(0.0092)	(0.106)	(0.00913)
Constant	0.825***	1.251***	0.706***	1.02***	1.277***	0.963***
	(0.0979)	(0.157)	(0.115)	(0.079)	(0.133)	(0.0773)
Observations	247	95	152	247	95	152
R^2	0.230	0.358	0.248	0.139	0.270	0.193
Root MSE	0.881	0.979	0.746	.924	1.02	.763

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

is given along with dotted lines for the 95% confidence interval.[31]

How accurate is the model at forecasting GDP? The R^2 of 0.24 shows the limitations of the model. If the oil shocks are determined exogenously, it provides an

[31] Calculated as the projection +/- 1.96 Newey-West Standard Errors.

Figure 5. Regression of Net Oil Price Increase and GDP Growth on GDP Growth at the Time of Each Oil Shock

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	y_t	y_t	y_t	y_t	y_t	y_t
	(1949Q2-1974Q1)	(1949Q2-1979Q1)	(1949Q2-1980Q1)	(1949Q2-1990Q1)	(1949Q2-1981Q1)	(1949Q2-2008Q2)
y_{t-1}	0.219**	0.215***	0.224***	0.228***	0.244***	0.234***
	(0.0861)	(0.0759)	(0.0775)	(0.0695)	(0.0771)	(0.0637)
y_{t-2}	0.136	0.0813	0.0892	0.0969	0.0726	0.113
	(0.108)	(0.0958)	(0.0928)	(0.0786)	(0.0889)	(0.0727)
y_{t-3}	-0.0886	-0.0901	-0.0986	-0.103	-0.136*	-0.0978
	(0.0858)	(0.0823)	(0.0799)	(0.0731)	(0.0755)	(0.0643)
y_{t-4}	-0.157	-0.184**	-0.165*	-0.122	-0.129	-0.0994
	(0.0986)	(0.0905)	(0.0873)	(0.0813)	(0.0913)	(0.0735)
o_{t-1}	-0.0413	-0.00852	-0.00782	-0.0256*	-0.0211	-0.0167*
	(0.0303)	(0.00891)	(0.00621)	(0.0144)	(0.0132)	(0.00947)
o_{t-2}	0.0725***	-0.0423***	-0.0259*	-0.0210*	-0.0242**	-0.0168**
	(0.0151)	(0.00827)	(0.0136)	(0.0112)	(0.0121)	(0.00741)
o_{t-3}	-0.0508	-0.0319**	-0.0246***	-0.0208**	-0.0168*	-0.0189**
	(0.0574)	(0.0140)	(0.00817)	(0.00988)	(0.00922)	(0.00747)
o_{t-4}	-0.0727**	-0.0469***	-0.0342***	-0.0292***	-0.0273**	-0.0219**
	(0.0365)	(0.0108)	(0.0109)	(0.0107)	(0.0114)	(0.00845)
Constant	1.027***	1.096***	1.047***	0.969***	1.045***	0.863***
	(0.152)	(0.149)	(0.153)	(0.126)	(0.154)	(0.102)
Observations	100	120	124	164	128	237
	0.253	0.242	0.223	0.214	0.209	0.201

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

estimate, all else equal, for the path of GDP growth. And since the fourth lagged value of net oil price increase is significant at the one percent level, the one-year-ahead forecasts could be useful. Figure 5 shows the forecasts of the model up to the time of each oil shock. Whereas Figures 6-11 show the impulse response using the model using the information known in 2011, Figures 12-17 show the impulse response functions using the information known at time t. Table 2 compares the two sets.

Figure 6. Forecasted and Actual Response of GDP Growth to Oil Shock of 1974Q1

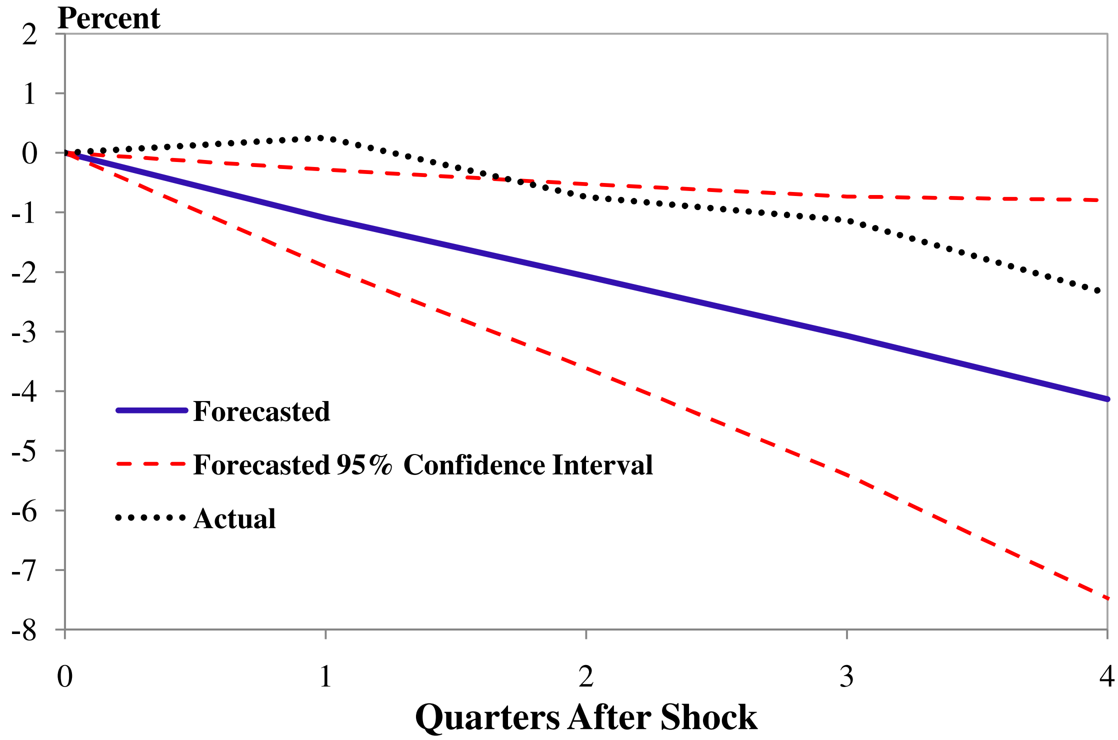

Figure 7. Forecasted and Actual Response of GDP Growth to Oil Shock of 1979Q1

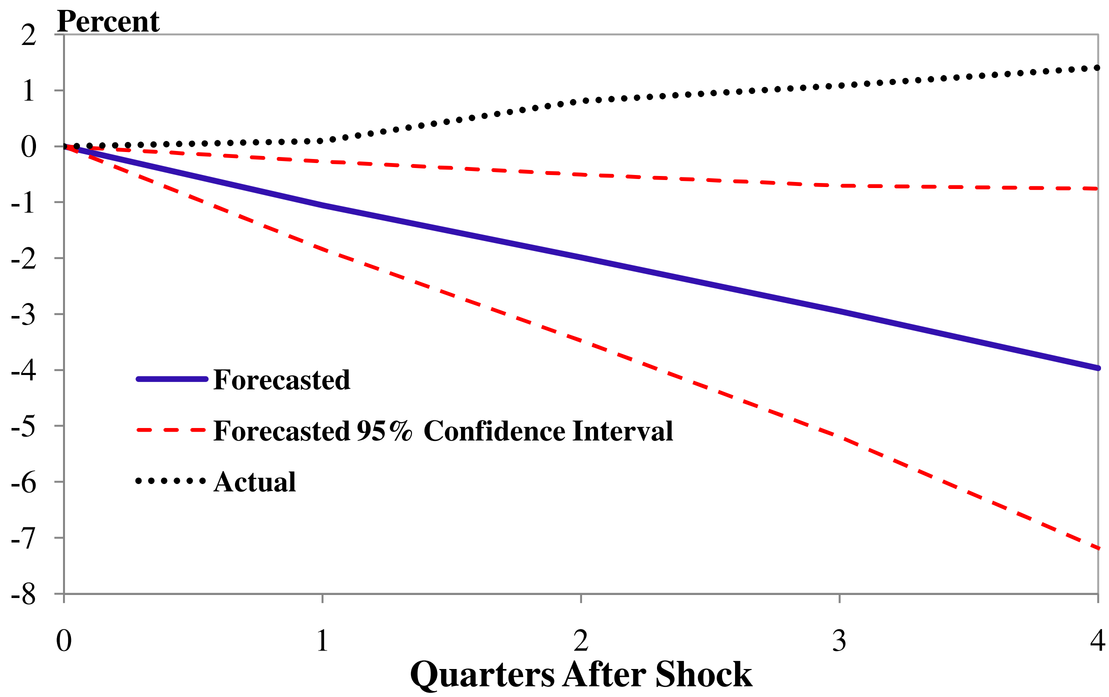

Figure 8. Forecasted and Actual Response of GDP Growth to Oil Shock of 1980Q1

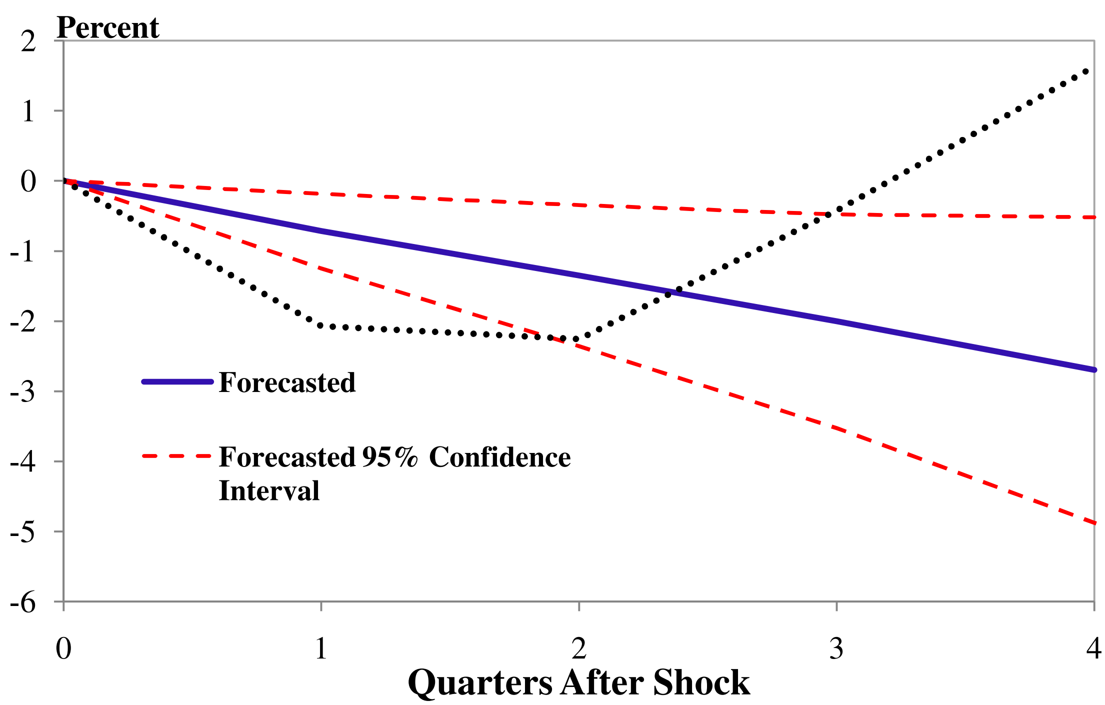

Figure 9. Forecasted and Actual Response of GDP Growth to Oil Shock of 1990Q4

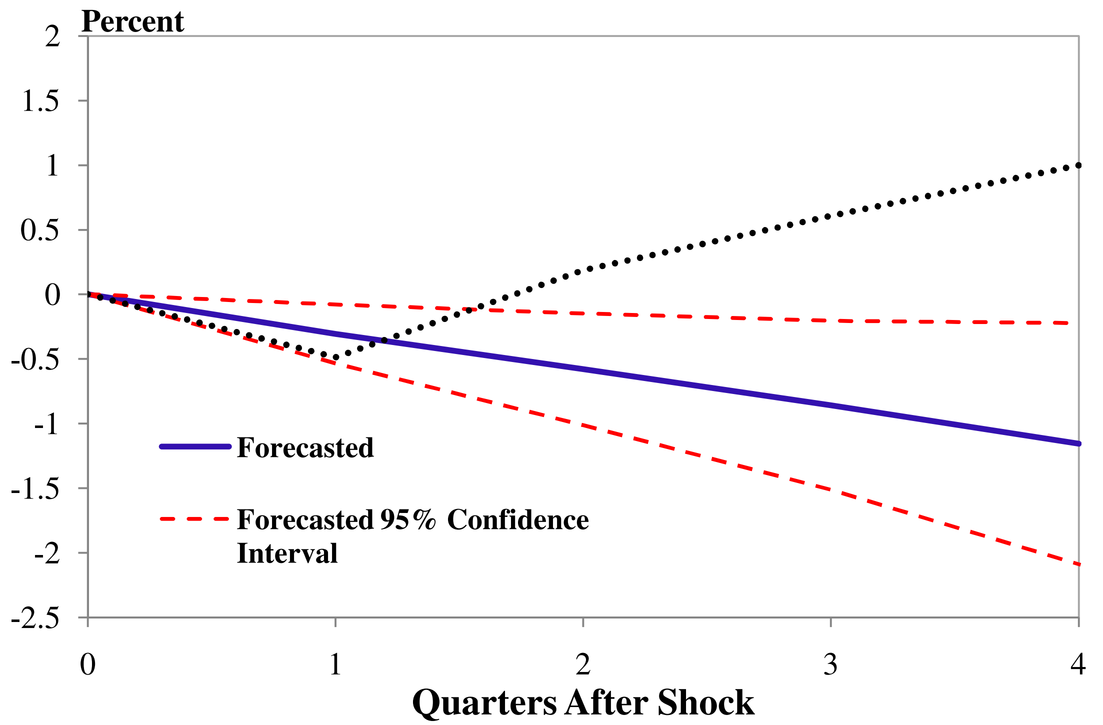

Figure 10. Forecasted and Actual Response of GDP Growth to Consecutive Oil Shocks of 1981Q1 and Q2

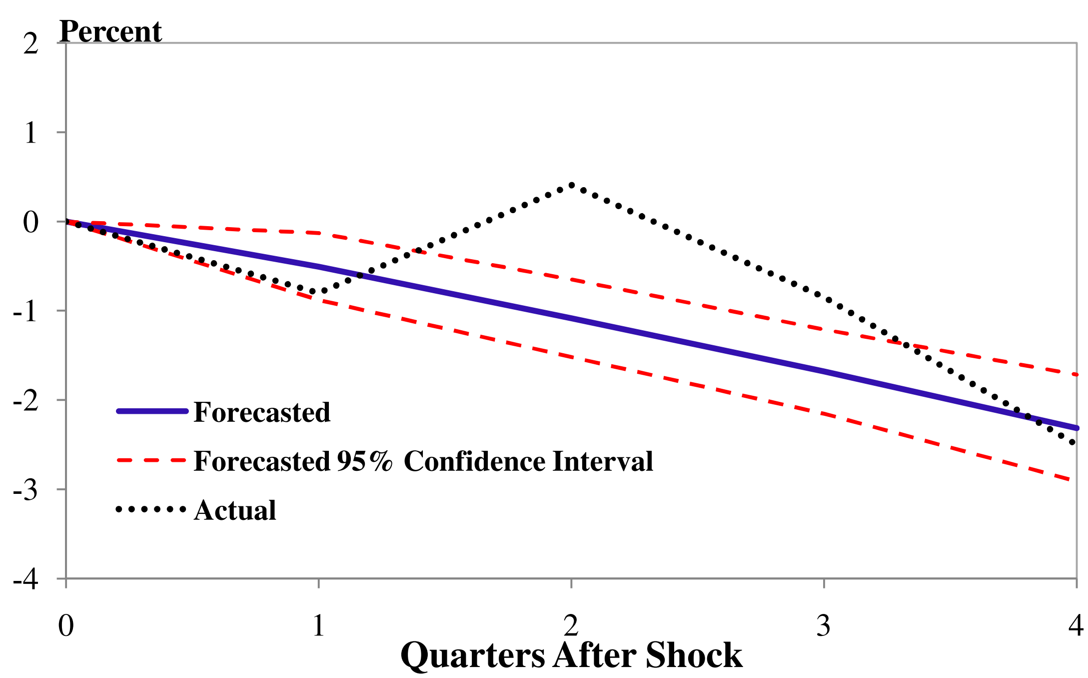

Figure 11. Forecasted and Actual Response of GDP Growth to Consecutive Oil Shocks of 2008Q2 and Q3

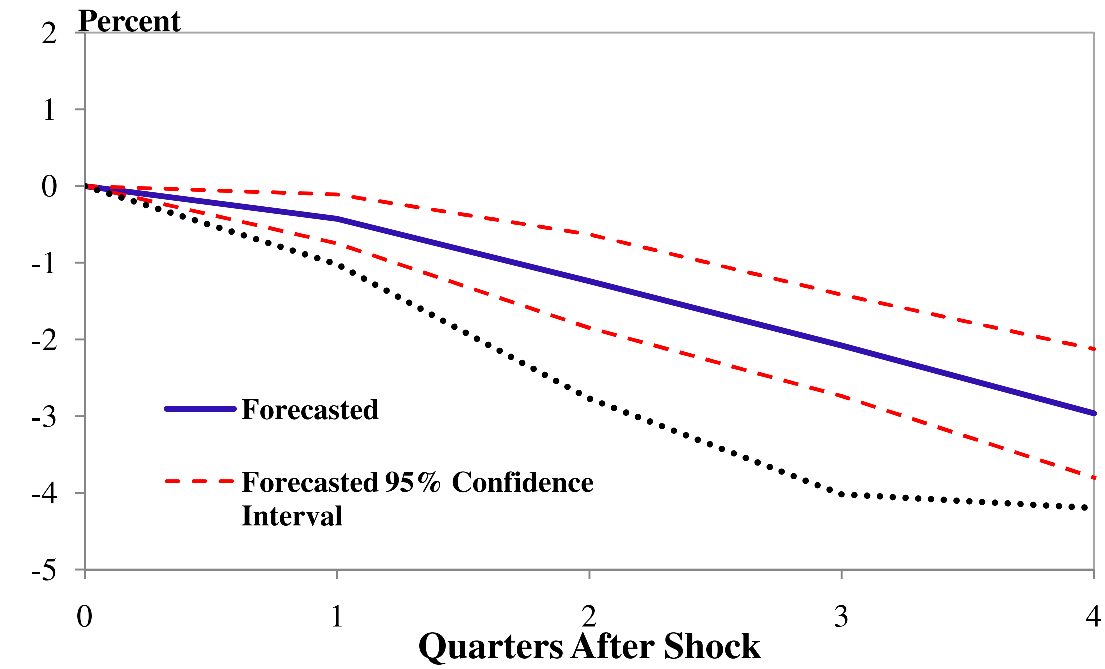

Figure 12. Forecasted and Actual Response of GDP Growth to Oil Shock of 1974Q1 with model as of 1974

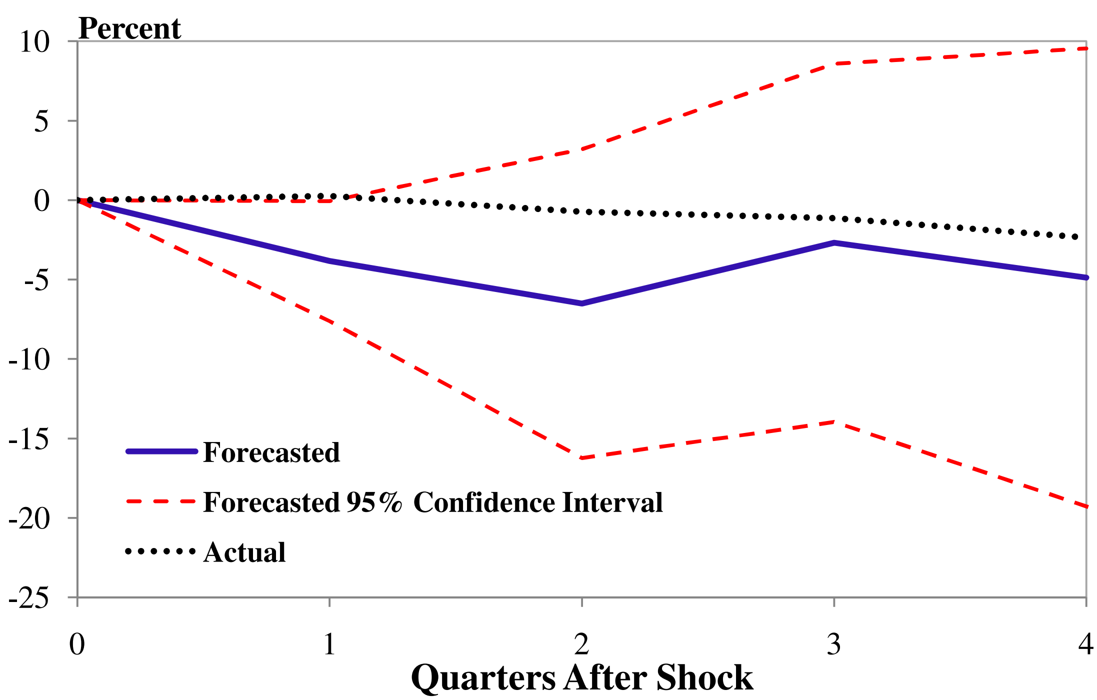

Figure 13. Forecasted and Actual Response of GDP Growth to Oil Shock of 1979Q1 with model as of 1979

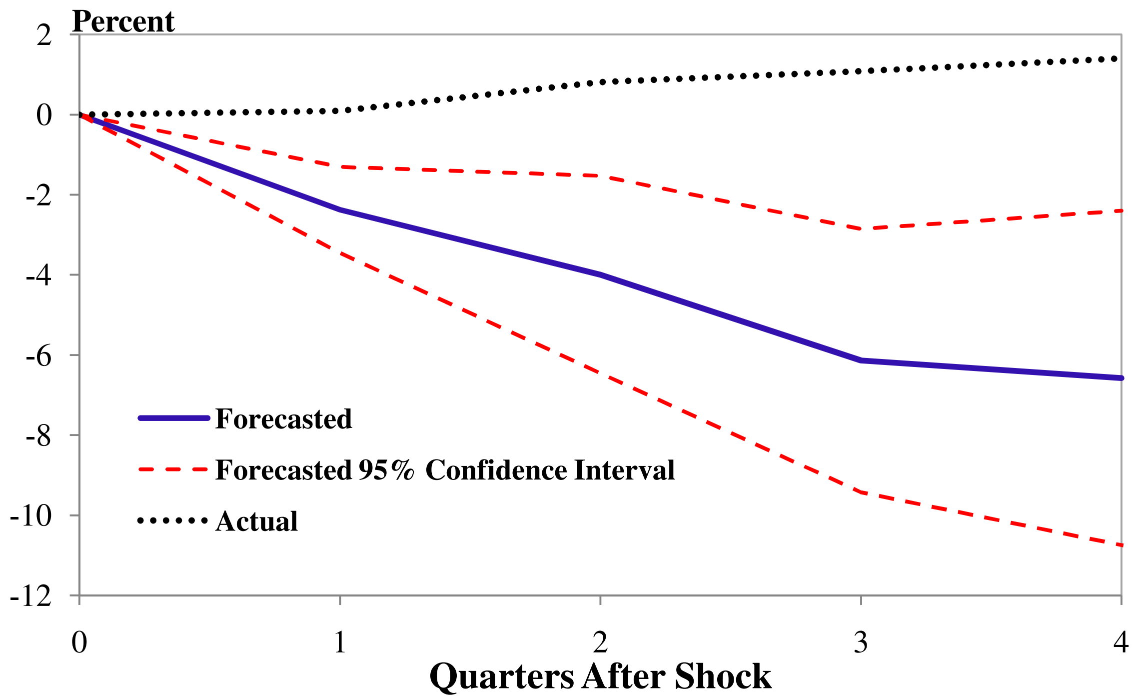

Figure 14. Forecasted and Actual Response of GDP Growth to Oil Shock of 1980Q1 with model as of 1980

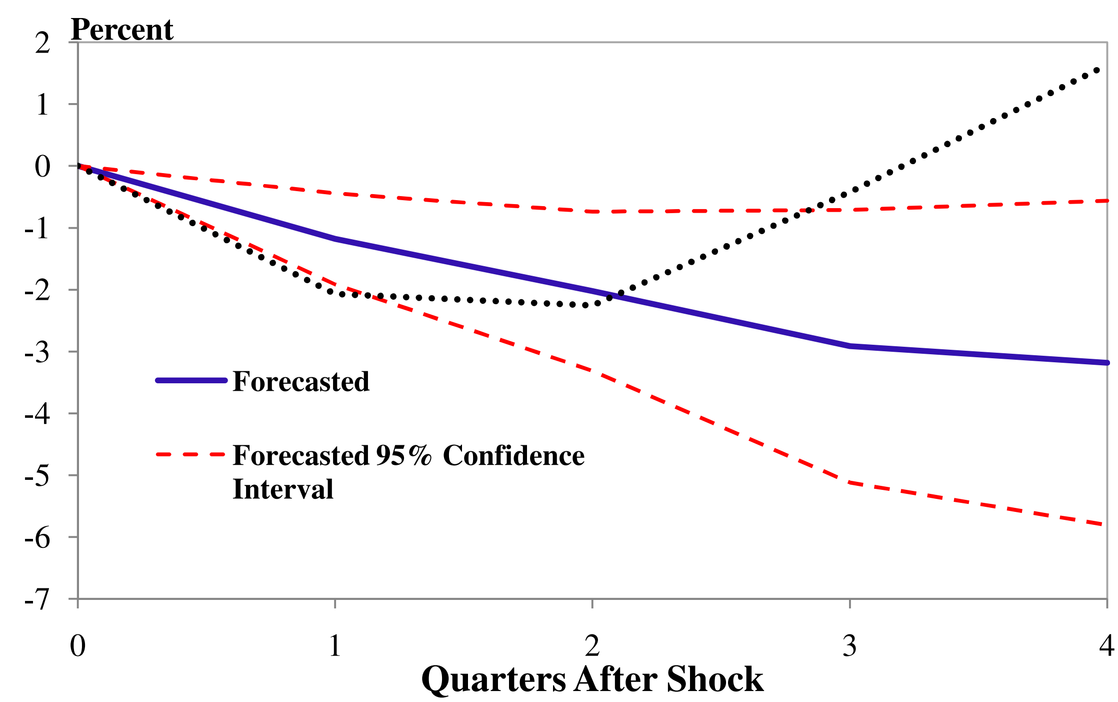

Figure 15. Forecasted and Actual Response of GDP Growth to Oil Shock of 1990Q1 with model as of 1990Q1

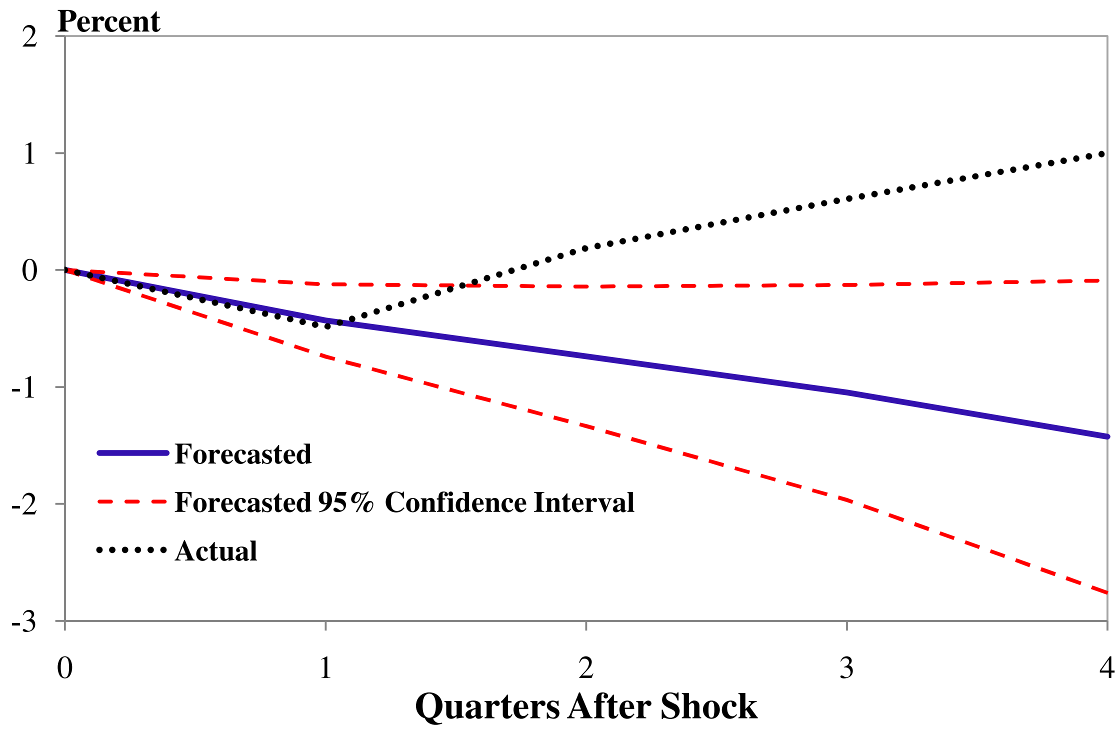

Figure 16. Forecasted and Actual Response of GDP Growth to Consecutive Oil Shocks of 1981Q1 and 1981Q2 with model as of 1981Q1

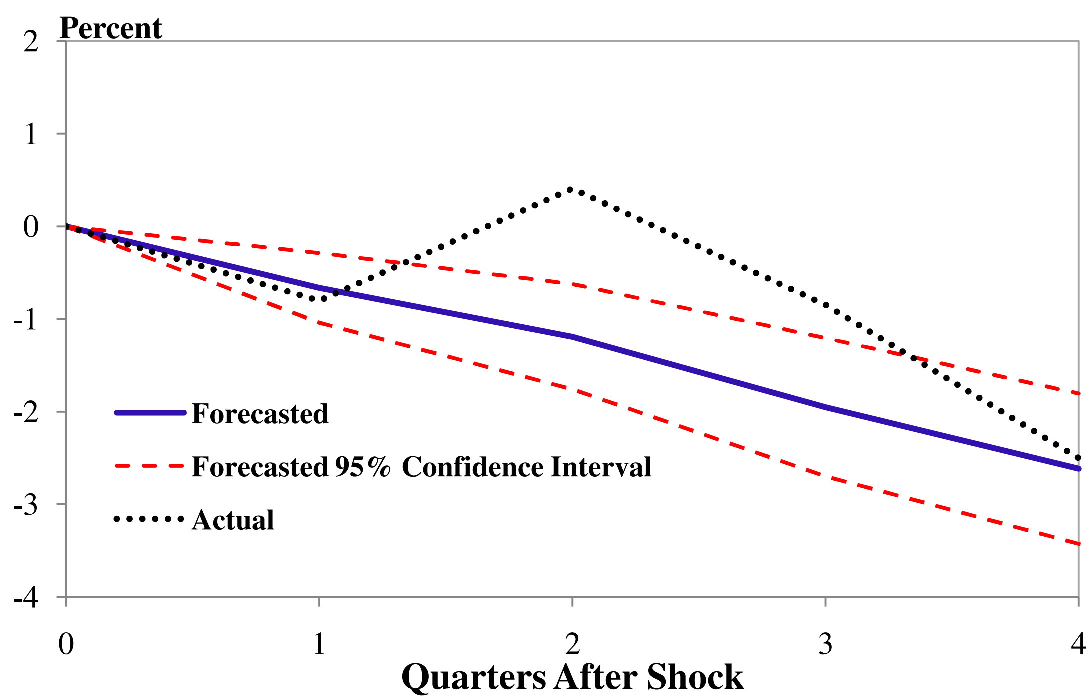

Figure 17. Forecasted and Actual Response of GDP Growth to Consecutive Oil Shocks of 1981Q1 and 1981Q2 with model as of 1981Q1

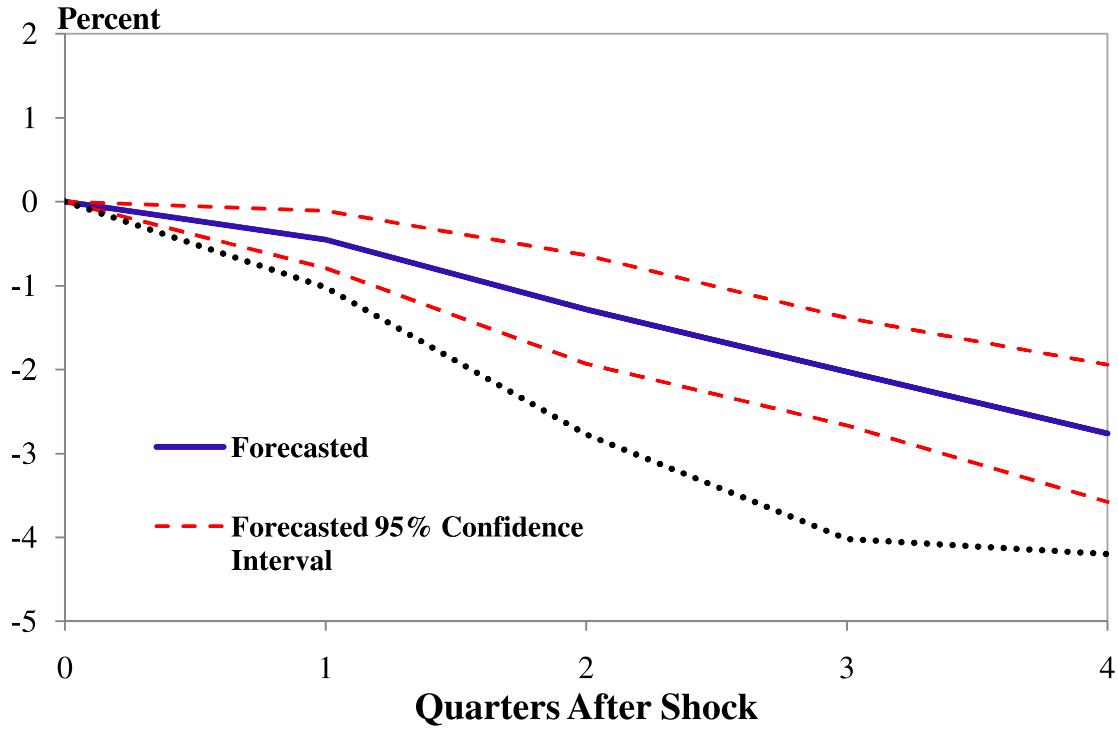

Table 2. One-Year-Ahead Forecasts of Past Oil Shocks: Comparison of Performance of the Equation Known in 2011 with the Model known at time of Oil Shock

Date of Shocks	Size of Shock	One-Year Ahead Result	One-Year Ahead Forecast With Model from 1949Q2-2010Q4 (Cumulative Percentage Change in real GDP)	Forecast Error (Percentage Points)	One-Year Ahead Forecast With Model from 1949Q2-Time of Shock (Cumulative Percentage Change in real GDP)	Forecast Error (Percentage Points)
1974 Q1	52.7 %	-2.36%	-4.13%	1.8	-4.87%	2.5
1979 Q1	50.7 %	1.4%	-4.0%	5.4	-6.6%	8.0
1980 Q1	34.4 %	1.6%	-2.7%	4.3	-3.2%	4.8
1981 Q1 1981 Q2	24.3 % 7.1%	-2.5%	-2.3%	0.2	-2.6	0.1
1990 Q4	14.8 %	1.0%	-1.2%	2.2	-1.4%	2.4
2008 Q2 2008 Q3	20.6 % 23.4 %	4.2%	-3.0%	1.2	-2.8%	1.4
Average				**2.5**		**3.2**
Average Excluding 1979 and 1980				**1.4**		**1.6**

5. Discussion

5.1 Extension to 2011 Oil Shock

On April 11, 2011 the International Monetary Fund (IMF) lowered its forecast for 2011 U.S. nominal GDP growth from 3.0% to 2.8%, largely due to the increasing price of oil.[32] The PPI for December 2010 (the fourth quarter value in my sample) is 242.0, and the value increases 17% to 283.5 in March 2011 (the third quarter value in my sample). Figure 18 shows the cumulative change in real GDP following a 17% net oil price increase. Using the model with Hamilton's definition of an oil shock, there will be no shock until prices reach 384.3, the July 2008 value. However, this definition was created so that only large oil shocks are examined. Since prices dropped so drastically after July 2008, the March 2011 value is only a two and a half year high. I include the shock nonetheless. Three quarters after the shock represents the end of 2011. All else equal, given that the oil price rose 17% from 2010Q4 to 2011Q1, we expect to see real GDP lower by almost a percent. The 95% confidence interval runs from -0.26% to -2.4%. The IMF projected decline of expected GDP growth, therefore, is outside the upper bound of the predicted effect based on my model. If there is a subsequent 10% spike in the second quarter, the model predicts a 1.3% decline corresponding to 1.7% GDP growth for 2011.

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[32] Source: http://www.bloomberg.com/news/2011-04-11/imf-cuts-2011-u-s-growth-forecast-on-oil-lackluster-pace-of-job-gains.html

Figure 18. Forecasted Response of GDP Growth to Oil Shocks of 2011Q1

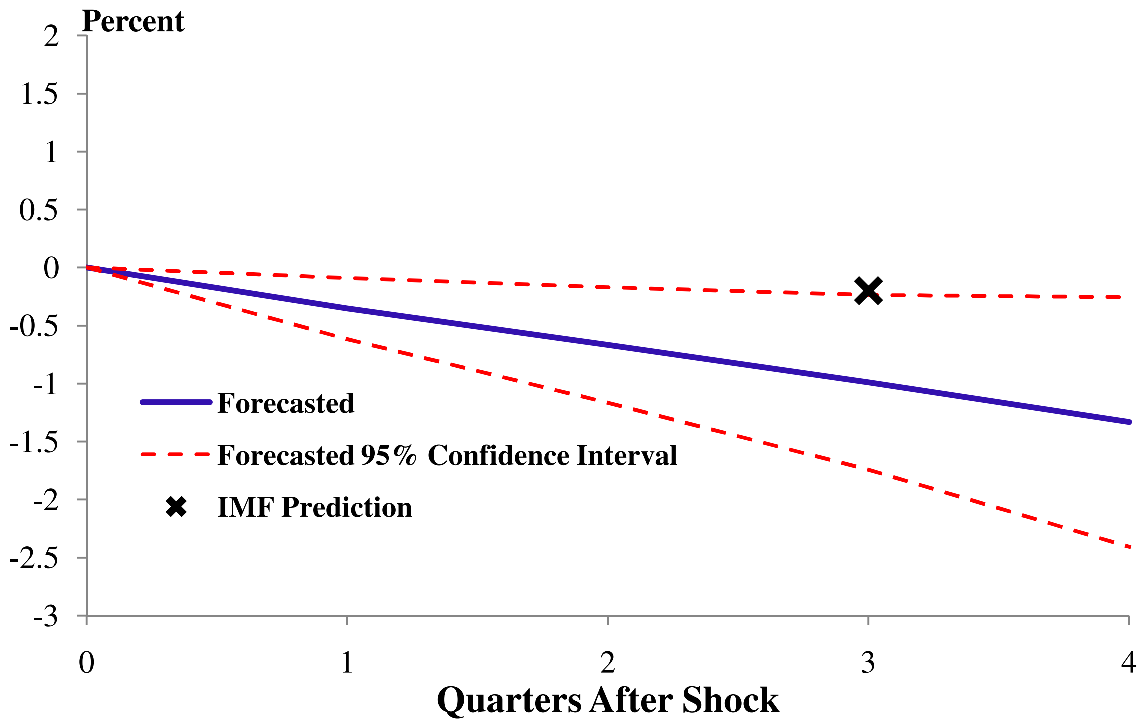
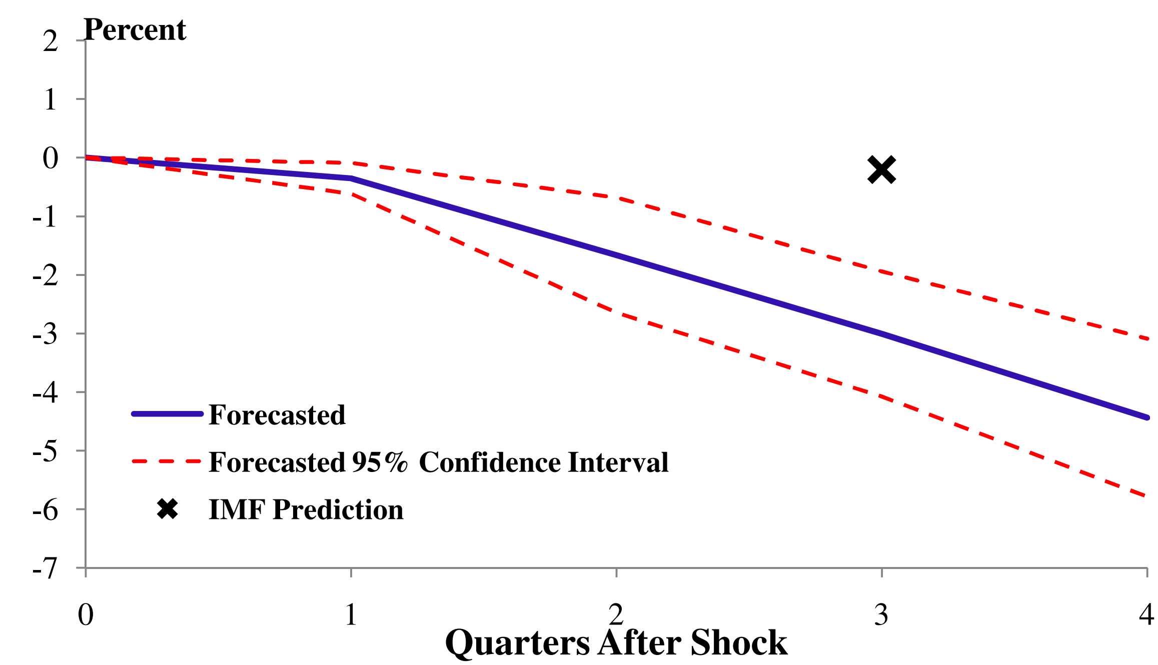
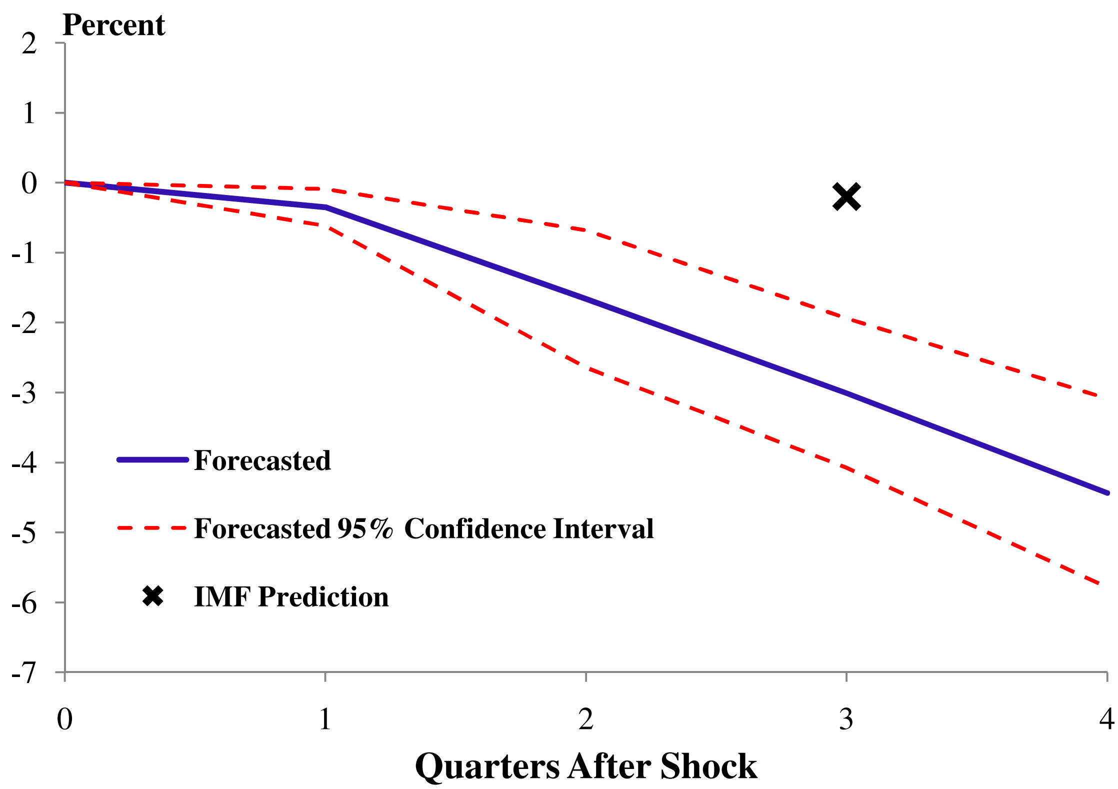


Figure 19. Forecasted Response of GDP Growth to Oil Shocks of 2011Q1 Followed by Hypothetical 10% Shock in 2011Q2



Retail gas prices have continued to rise up to the publication date. Since the U.S. is coming out of a recession it is reasonable to expect demand to continue to rise, and the falling dollar makes it even more probable that prices will continue to rise for Americans.[33] If crude oil PPI rises 54% this quarter, the model predicts growth will decline by 3 percentage points, see Figure 20. Using the IMF forecast of 3% as of 2011Q1, this translates to zero growth. Since the fourth lag of the second shock would take effect in the first quarter of 2012, the model would predict a second quarter with negative growth, constituting a recession.

Figure 20. Forecasted Response of GDP Growth to Oil Shocks of 2011Q1 Followed by Hypothetical 57% Shock in 2011Q2



[33] Source: http://money.msn.com/how-to-budget/article.aspx?post=df31d82d-ff74-4a56-9cdc-1302039b3a02

5.2 Limitations of the Methods

There are several significant limitations to the methods used in this paper. First, there are only five major oil exogenous shocks in the sample and the net oil price increase above the three year high only has 39 non-zero observations. There may be important variables omitted such as energy intensity (Kilian 2008) and wage flexibility (Blinder 2009). The end of an expansionary period may cause higher demand for oil, raising prices. Then the oil prices and output decline are simultaneous, but both caused by a third factor. (Hamilton 2008). One of those potential factors that Kilian (2008) proposes is global real activity. This variable is of particular interest for the debate about the causes of the 1973-4 oil shock. Hamilton (2003) argues that the price increases were mostly driven by the calculated political decisions of the Arab members of OPEC. Kilian (2008), however, constructs a measure of global real demand, based on shipping rates of cargo and claims that the price increases had to do in large part with an economic calculation.[34]

6. Conclusion

In this paper I have looked at the one-year-ahead forecasts of GDP growth based on oil shocks. For the sample period 1949Q2-2010Q4, four previous quarter's values of the net oil price increases explain 14% of the variation in GDP growth during time t. Considering that many factors influence GDP growth, this value is economically

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[34] Hamilton's response comes in three parts. First the price of a barrel of oil went from \$3.01 to \$11.65 from October to January as OPEC instituted the embargo. It is unlikely that the calculation would lead to such a large price increase at exactly that time. Second, it is unlikely that the Arab members of OPEC and nonArab members reached different calculations of demand. And lastly, the embargo was fueled largely by Egypt and Syria who were not oil producing nations, but rather just the most vehemently anti-Israel nations.

significant. The forecast error of the model was 8 percentage points and 4.8 percentage points for 1979 and 1980 respectively. For the other three shocks, the model was off by 1.6 percentage points on average. What gives the results strength is that the fourth lag is significant at the 5% level for all specifications, and the standard errors are relatively small as most of the lagged variables are significant. Therefore, the model gives a prediction of, all else equal, what the likely path of GDP growth will be.

The results in this paper have significant implications for monetary policy makers. In 2008Q1, the Federal Reserve rapidly decreased interest rates, concerned about a weakening economy. Frankel (2008) argues that low real interest rates are correlated with high real commodity prices. He asserts that when real interest rates are low, the opportunity cost of keeping large inventories of commodities goes down. The increased demand will then cause the price to be artificially high until the market realizes that the commodities are overvalued. Hamilton (2009) points out that Fed Chairman Ben Bernanke was focused on the longer term picture that the U.S. economy needed demand stimulated, and that commodity prices would decline once global demand slowed. However, if Frankel (2008) is right, than the monetary policy reaction increased the oil prices. My model then, predicts that high oil prices contributed to the severity of the recession in the subsequent four quarters. Hamilton (2009) and Frankel (2008) note that the Federal Reserve then may have decreased the severity of the recession, had it more strongly considered the effects of short term oil price increases. If the economy goes into another recession as my model predicts following a 54% net oil price increase in 2011Q2, monetary policymakers may pay more attention to controlling oil prices this time around.

Appendix

1.Oil Shocks from 1949-2010 with the Major Oil Shocks Highlighted

Quarter	Net Oil Price Increase
1948-I	5.5
1953-I	10.5
1956-I	0.8
1957-I	9.4
1966-I	0.7
1967-I	0.7
1968-I	0.7
1969-I	5.1
1970-I	6.2
1971-I	1.3
1973-I	27.6
1974-I	52.8
1974-IV	1.0
1975-I	16.6
1976-I	0.8
1977-I	8.9
1978-I	8.4
1979-I	50.7
1980-I	34.4
1981-I	24.3
1981-II	7.1
1989-I	3.5
1990-I	32.6
1990-IV	14.8
1996-I	22.0
1999-I	0.1
2000-I	11.0
2000-II	10.3
2000-III	3.3
2000-IV	8.5
2004-I	14.3
2004-IV	8.8
2005-I	37.4
2005-IV	5.4
2006-III	9.3

2007-I	31.8
2008-II	20.6
2008-III	23.4
2011-1	17.1

2.Oil shock Summary Statistics

Observations: 39
Mean: 13.6
Standard Deviation: 13.9
Min: 0.1
Max: 52.8

3.Variable Definition

GDP Growth: difference in natural log of GDP between t and t-1 (referred to in paper as GDP growth)
Net Oil Price Increase: Percentage increase above previous three year high. If no new three year high is set, value is zero.
Crude oil PPI: Quarter end value of crude oil PPI
Natural log of real GDP: Natural log of real GDP in 2005 years at time t

4. Results of EG-ADF test for cointegration between GDP Growth and Net Oil Price Increase

Test Statistic for test of Cointegration: -7.8	Mackinnon approximate p-value for Z(t): 0.0000

5. Augmented Dickey-Fuller test results for natural log of real GDP and GDP growth

Test Statistic for Natural log of GDP: -1.1	Mackinnon approximate p-value for Z(t): 0.72
Test Statistic for Net Oil Price Increase: -10.8	Mackinnon approximate p-value for Z(t): 0.0000

6. Augmented Dickey-Fuller test results for crude oil PPI and the net oil price increase

Test Statistic for Crude Oil PPI: -2.6	Mackinnon approximate p-value for Z(t): 0.09
Test Statistic for Net Oil Price Increase: -15.8	Mackinnon approximate p-value for Z(t): 0.0000

7. Lag Selection Test Leading to Selection of 4 Lags

Lag Length	AIC	BIC
2	676.69	694.38
3	668.94	693.68
4	661.51	693.28
5	660.2077	698.9877

8. Granger Causality Test for Null Hypothesis that net oil price increase does not cause GDP Growth

F-Statistic: 8.03
Prob > F: 0.0001

9. Granger Causality Test for Null Hypothesis that GDP Growth does not cause Net Oil Price Increase

F-Statistic: 1.60
Prob > F: 0.55

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