CRUDE OIL PRICE SHOCKS AND GROSS DOMESTIC PRODUCT

A Thesis

Presented to

The Faculty of the Department

of Economics

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Jordan Hernandez

August, 2012

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Jordan Hernandez

APPROVED:

_____
Ed Hirs, CFA; MA, MBA.

_____
Rebecca Thornton, Ph.D.

_____
Brett Jiu, Ph.D.

_____
John W. Roberts, Ph.D.
Dean, College of Liberal Arts and Social Sciences
Department of English

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ABSTRACT

This study uses ordinary least squares estimation to test multivariate models in order to find out whether or not crude oil price shocks are contractionary and negatively impact the macroeconomy. Variables are annual and pertain to different aspects of crude oil and how they affect real gross domestic product (GDP). It is predicted that increases in domestic and imported crude oil prices negatively affect real GDP by decreasing not only energy consumption but the consumption of other goods and services as well. It is found that the initial hypothesis is partially correct. While increases in imported oil prices do decrease real GDP, increases in domestic oil prices actually increase real GDP. Additionally, as predicted, consumption other than energy is affected by crude oil price shocks and causes real GDP to contract.

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Section 1

INTRODUCTION

The relationship between the price of crude oil and GDP has been one of constant change. It arguably had everything to do with the economic downturn during the late 1970's and mid 1980's and possibly nothing to do with the most recent recession. There is a possibility that energy price shocks are exogenous to the United States' macroeconomic well-being.[1] One reason for this is that consumers are known to smooth their consumption across commodities in order to gain maximum utility over all their goods and services, implying that a correlation exists between increases in the price of crude oil and macroeconomic aggregates, but may not necessarily infer causation.[2] This could be a possible answer as to why recessionary characteristics were not seen during the recent spike in oil prices. According to Killian (2008), ten of the last recessions were preceded by oil price spikes which might suggest that higher oil prices do in fact cause recessions. When this does in fact take place and higher oil prices are followed by a recession, it is likely due to unemployment and inflation levels being affected. However, when the tenth post war United States recession began in 2001, from 2001 to 2003 unemployment rose almost 28%. Then in 2003 the United States experienced an energy crisis. What is interesting about this is that once the energy crisis began, it is thought that it would be followed by typical recessionary characteristics. Surprisingly enough, macroeconomic variables such as output and unemployment moved in unexpected

[1] Shocks refer to price increases.
[2] Goods and services here refer to goods and services less energy.

directions.[3] Output went up by a little more than 5% from 2003 to 2006. During the same time, unemployment decreased by more than 23%.[4] An explanation for this could be that in the short run, the positive effects outweigh the negative due to global commodity prices being sticky (Killian 2008).

It is in fact possible that crude oil energy prices are endogenous, with respect to the macroeconomic condition of the United States.[5] However, it depends on which aspect of the macroeconomy one is referring to. For example, it may be the case that increased energy prices will produce macroeconomic externalities due to consumers and firms altering their expenditures on durable and non-durable goods and decreasing their consumption of energy, bringing down overall consumption and negatively impacting GDP.

In an attempt to answer whether or not crude oil energy prices have a causal effect on the GDP of the United States, ordinary least squares (OLS) will be used in order to figure out which factors of the oil industry are most significant to the domestic macroeconomy and in turn have the most effect on GDP. Do spikes in the import price of crude oil decrease consumption patterns and make it a demand side problem? Or does it affect the prevalence of capital, labor and production making it detrimental to the supply side of the macroeconomy?

[3] Output refers to Business Sector Output per hour of all persons indexed at 2005=100. The Unemployment rate is the Civilian Unemployment Rate that is a percentage of the labor force. Both variables are annual, and seasonally adjusted.
[4] See www.bls.gov/data
[5] Endogeneity here refers to a possibility of reverse causality between energy prices and macroeconomic aggregates.

The hypothesis is that domestic price and production as well as imported price and quantity will have significant effects on real GDP. More specifically the prediction is that increases in domestic and imported crude oil prices will decrease real GDP. This is due to the belief that increases in these prices will decrease the demand for all products (not just crude oil and petroleum commodities). As consumers attempt to smooth their consumption, they will consume less of goods and services excluding energy in order to maintain their initial consumption of crude oil and petroleum products. This will then cause overall consumption to drop and eventually bring down GDP. If this happens to be the case, crude oil price shocks should then be considered a demand side problem that causes contractionary characteristics on the domestic macroeconomy. Based on the obtained results, recommendations will be made to guide energy policies in such a way as to avoid macro externalities.

Section 2

HISTORY OF OIL PRICE SHOCKS

Prior to 1970 crude oil was abundant and had stable price behavior (Nordhaus 2007). Domestic oil production peaked in 1972 and then started declining. This led to a higher import share of crude oil. The price of crude oil then began to rapidly increase over the next decade. Aside from that, during the early 1970's the United States no longer allowed foreign central banks to convert dollars to gold. The end of the Bretton Woods system then caused a depreciation of the dollar.[6] Once the dollar had less purchasing power on the international market, the dollar price increased for many internationally traded commodities, including oil. Prices increased and real interest rates fell. Furthermore, in 1971 President Nixon implemented wage and price controls in an attempt to hinder climbing inflation rates. This was a complete failure. These events, along with the OPEC embargo during 1973 and 1974 led to massive increases in the price of crude oil.[7] In 1973, Syria and Egypt attacked Israel and Arab members of OPEC announced an embargo on countries that were thought to be supporters of Israel (Hamilton 2011). This of course led to a significant decrease in OPEC's oil production. From 1974 to 1978, the producer price index (PPI) for crude energy materials increased by over 60%.[8] During this time the consumer price index (CPI) for all items grew by 32% while the CPI for gasoline alone increased by 23%.[9]

[6] This system established financial rules and regulations among the world's top industrial states.
[7] OPEC is the Organization of the Petroleum Exporting Countries
[8] See http://research.stlouisfed.org/fred2/series/PPICEM
[9] See http://research.stlouisfed.org/fred2/series/CPIAUCSL; http://research.stlouisfed.org/fred2/series/CUUR0000SETB01

In 1978, Iran's oil sector began protesting and without labor the amount of Iranian oil production decreased substantially. The decrease was about 7% of the world's production (Hamilton 2011). By 1979 levels were about back to normal. Then in 1980 Iraq declared war on Iran, halting production in both countries. This led to another world production decrease of about 6% (Hamilton 2011). By looking at the PPI for crude oil and the CPI for gasoline, there can be seen two distinct spikes separating the oil price shock of 1978 from that of 1980.[10] From 1979 to 1981 the average imported price of crude oil rose by 37%.[11] Through the mid 1980's total petroleum consumption steadily declined. Figure B shows the relationship between the average import price of crude oil, CPI for gasoline and PPI for finished energy goods. It is worth noting that the CPI for gasoline and the PPI for finished goods are nearly identical except that the PPI line is slightly under the CPI line. This makes sense because firms must raise prices in order to push as much cost onto the consumer as they can. Then, looking at the average import price of crude oil line, you can see that from 1978 to 1980 it is the same as the CPI for gasoline line. There is definitely correlation and this could possibly suggest causation between the two. Furthermore, Iraqi oil production resumed and was back to normal levels by the late 1980's. Then, 1990 was the start of the Gulf War when Iraq invaded Kuwait. The price spike in oil proved to be of very short duration. The Saudis took excess capacity they had been storing and used it to replenish the world's oil supply (Hamilton 2011).

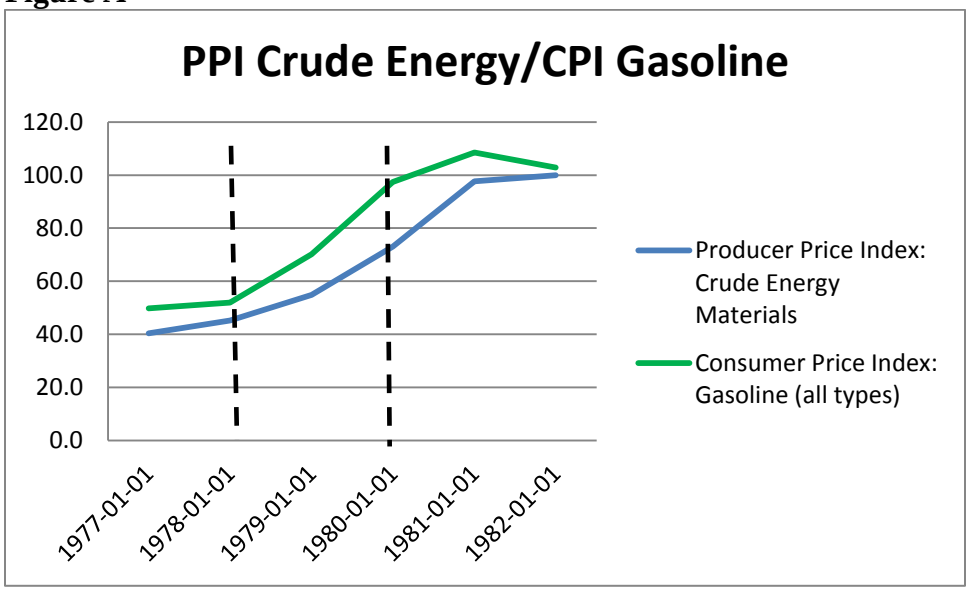
The most recent energy crisis the United States has experienced began with the invasion of Iraq in 2003. The effect on global supply was much smaller than any crisis

[10] See Figure A
[11] See http://www.eia.gov/petroleum/

before. From 2003 to 2008 the average imported price of crude oil rose dramatically. From 2003 to 2008 PPI for crude energy materials rose nearly 40% while the CPI for gasoline increased over 110%.[12] However, many believe that the post war recession felt by the United States in 2007 was largely due to the financial crisis rather than oil related problems and exogenous geopolitical events (Hamilton 2011).

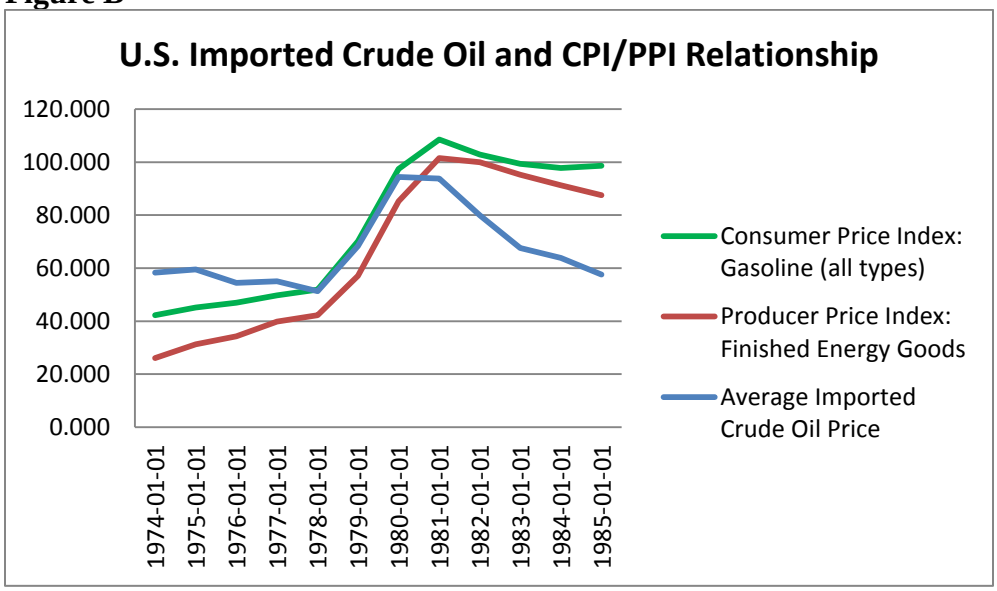
[12] See http://research.stlouisfed.org/fred2/series/PPICEM; http://research.stlouisfed.org/fred2/series/CUUR0000SETB01

Figure A



Source: http://research.stlouisfed.org/fred2/series/PPICEM; http://research.stlouisfed.org/fred2/series/CUUR0000SETB01. The producer price index (PPI) for crude energy materials is collected annually, not seasonally adjusted and indexed at 1982=100. The CPI for gasoline is for all types of gasoline, seasonally adjusted and indexed at 1982-84=100.

Figure B



Source: http://research.stlouisfed.org/fred2/series/CUUR0000SETB01; http://research.stlouisfed.org/fred2/series/PPIFEG; http://www.eia.gov/petroleum/. The CPI for gasoline is for all types of gasoline, seasonally adjusted and indexed at 1982-84=100. PPI for finished energy goods is collected annually, seasonally adjusted and indexed at 1982=100. The annual average imported crude oil price is in 2012 dollars and in units of real dollars per barrel.

Section 3

LITERATURE REVIEW

The United States has experienced fluctuations in crude oil prices since the 1970's. During 1973, 1978, 1980 and 1990 oil prices spiked and the country experienced a time of economic downturn. However, from 2001 to 2006 real oil prices more than tripled and the country did not see recessionary characteristics. Output grew, unemployment decreased and inflation was moderate (Nordhaus 2007). Oil price shocks are thought to be contractionary because of the effects on productivity and aggregate demand. For example, productivity could be affected due to the substitution of labor for energy. If crude oil prices increase, firms may have to cut costs. This could mean employing fewer workers. Despite crude oil price shocks historically having adverse effects on GDP in the past, recently they have not had as much of an inverse relationship and are more or less random than compared to previous decades. Thus, Nordhaus (2007) does not feel that the recent oil price shock had any significant macroeconomic outcomes like the other shocks and claims that people have begun to think of these price increases like they would a permanent tax increase. The marginal propensity to consume is a lot higher for the buyers than it is for the sellers. This suggests that consumers are not viewing shocks to the price of crude oil as short term fluctuations. People now see oil prices as being more volatile over longer time periods and are not so quick to alter their energy consumption patterns. People therefore attempt to smooth their consumption by purchasing less of other goods in order to spend the same amount on energy that they normally would. Nordhaus also argues that policies should be made based on the "world oil market" and not the amount that is imported into the country, conjecturing that macro

externalities would arise due to the total domestic expenditure on oil and not based on how much is imported (Nordhaus 2009). This is because crude oil imports are categorized as domestic gross output as opposed to domestic value added. Therefore, holding capital and labor fixed, oil price shocks do not increase value added and cannot be considered productivity shocks to GDP (Killian 2008).

Many economists believe that energy price increases are completely different from any other goods. This is mainly due to the fact that energy price increases occur at much different times that are considered unusual than those of other goods. It is possible that energy price shocks are much more important and should be followed closer than other price increases because of the inelastic nature of things such as crude oil. Another reason that energy prices are viewed differently than other commodities is because of situations where things tend to manipulate their prices that are completely exogenous to our nation's economy. This would be referring to natural disasters, war and other political problems in foreign countries. Natural disasters such as Hurricane Rita and Katrina did not affect the supply of crude oil as much as it did the supply of gasoline. This made for a huge spike in gasoline prices. Killian (2008) explains that crude oil supply shocks have little effect on prices and that the effects are better measured by peoples' expectations (of future crude oil production) and demand for crude oil. Therefore, he feels that it is better to focus on retail energy prices, such as gasoline, when determining how energy price shocks will affect the U.S. economy (opposed to primary energy/crude oil).

With this being said, it is also widely accepted that crude oil prices do affect the United States' economy. The supply and demand for energy "depend on global

macroeconomic aggregates such as global economic activity and interest rates" (Killian 2008). This is why the increased oil prices are most likely correlated with the United States' macroeconomic situation but not necessarily imply that there is causation.

Section 4

DATA

All of the data has been collected annually by different sources. The data collected in order to test how crude oil price shocks affect GDP only dates back to 1968 in order to avoid as much irrelevant and/or omitted variable bias as possible. Each observation has been collected from the first quarter of 1968 until the first quarter of 2011.

The dependent variable is real GDP, which is the inflation adjusted value of goods and services produced in the United States. This information has been obtained from the Bureau of Economic Analysis' (BEA) website.[13] It is collected annually and is seasonally adjusted. Since the value of the dollar changes over time, it has been chained to billions of 2005 dollars.

Each independent variable can be found on the U.S. Energy Information Administration's (EIA) website.[14] The first independent variable will be the domestic crude oil first purchase price.[15] It will be abbreviated as *DOP* and its units are in dollars per barrel. Next will be the amount of domestic crude oil production, which will be abbreviated as *DOProd*.[16] Here the EIA measures production in thousands of barrels.

It is not unusual for many economists to focus strictly on the price of imported oil in order to determine if crude oil price shocks cause contractions in our domestic economy. This is because they believe that it effects production decisions of firms who

[13] See http://www.bea.gov/national/index.htm#gdp
[14] See http://www.eia.gov/
[15] See http://www.eia.gov/dnav/pet/pet_pri_dfp1_k_a.htm
[16] See http://www.eia.gov/petroleum/

have expectations of future contractions in the demand for their goods and/or services (Killian 2008). Therefore the price of imported oil will be included in the regression analysis as well as the quantity that is imported into the country. These variables will be abbreviated as *IOP* and *IOQ* respectively. The imported oil price (*IOP*) is defined as the annual average imported crude oil price and is measured in real 2012 dollars per barrel. The quantity of crude oil imported is recorded in thousands of barrels.[17]

Additionally an oil shock independent variable is constructed. A standard way to implement an oil shock variable is to use real or nominal dollars. A model for this variable is used that is similar to one created by Killian (2008). However, in Killian's oil shock variable, he takes the natural log of the nominal price of oil divided by the previous period's price and then multiples this by the lagged nominal price of oil times lagged consumption and divided by lagged nominal GDP. Basing this study's variable off of this, nominal values are substituted for real domestic oil price and real GDP. Further the current period's price, consumption and GDP level is used for the second half of the equation:

- $LnOilShock = [\ln (DOP/DOP_{t-1})]*[(DOP_t*DPETCON_t)/GDP_t]$

Where *DOP* is the domestic oil price and *DPETCON* is defined as domestic petroleum consumption and its units are in quadrillion BTU's.[18] The variable GDP is used as the denominator in order to give an idea of the value of oil consumption as a share of GDP. This equation for an oil price shock should help indicate when one is occurring. However there are some problems with it. The main problem is that it does not take

[17] http://www.eia.gov/petroleum/
[18] BTU refers to the traditional British Thermal Unit

consumers' elasticity of demand for crude oil or petroleum products into account. This way we are unaware of their spending patterns regardless of what the domestic price may be in period t.

Killian (2008) asserts that energy price shocks have a sure effect on the economy because these shocks disrupt consumers' spending on goods and services other than energy. Hence the belief that firms see oil price shocks as a shock to the demand for their product rather than a shock to how much it is going to cost them to be able to produce whatever their energy dependent product may be. People will tend to smooth their consumption as much as possible on other commodities in order to not suffer losses in their consumption of energy. The hypothesis made agrees with this and predicts this to be true and therefore the same regression that is run on GDP will be applied to personal consumption patterns as well. However, the personal consumption that will be used as a dependent variable is less food and energy in order to see if commodities other than energy are affected by oil price shocks.

Section 5

METHADOLOGY

The model chosen in order to estimate the effect crude oil prices and price shocks have on real GDP contains five independent variables. The following equation has been constructed:

1) $GDP_t = \beta_0 - \beta_1 DOP_t + \beta_2 DOProd_t - \beta_3 IOP_t + \beta_4 IOQ_t - \beta_5 LnOilShock_t + \varepsilon$

In the first model, one can see that it is predicted that some variables will have contractionary effects, decreasing GDP, while others are expected to increase it. The regression will then be run using OLS estimation and robust standard errors in order to correct for any heteroskedasticity.

The second model estimated has the same dependent and independent variables. However, each of the independent variables will be lagged one period behind. If Model 1 does not produce logical results explaining the relationship between domestic crude oil price shocks and GDP, this second model should:

2) $GDP_t = \beta_0 - \beta_1 DOP_{t-1} + \beta_2 DOProd_{t-1} - \beta_3 IOP_{t-1} + \beta_4 IOQ_{t-1} - \beta_5 LnOilShock_{t-1} + \varepsilon$

Model 2 may be a better equation for the estimation because it can give a better idea of how the price, quantity and production of oil in the previous period help to explain GDP in the next.

DOP is the domestic crude oil first purchase price and believed to have a negative coefficient. Once domestic prices increase the price shock will hurt producers and decrease the demand for their products. Once consumers decrease consumption, GDP will then decline. Next is the independent variable *DOProd*. This variable represents the amount of crude oil produced domestically. This variable's coefficient is expected to be

positive and increase GDP as production increases. With increased domestic oil production, there is more work coupled with more products on the market. With more work available, producers do not have to substitute labor for capital in order to produce the same amount. Therefore, if unemployment decreases GDP will increase. Next there is *IOP*, which stands for the average imported oil price. *IOP* is hypothesized to have a negative coefficient. This is due to the fact that if the price for imported oil continues to rise, so will the PPI and then the CPI. This will cause a chain reaction resulting in a decrease in consumption and then contractionary effects on real GDP. On the other hand *IOQ*, which stands for the quantity of imported oil, is anticipated to have the opposite result that the price of imported oil has on the macroeconomy and will produce positive effects on GDP. Once the United States has demand up and is meeting this increased demand for energy with an increased supply of imported oil, consumers should then increase consumption and inject the macroeconomy with currency. Finally, there is the natural log of an oil price shock variable denoted as *LnOilShock*. During times of a crude oil energy price shock, this will inflate the price of our oil and petroleum commodities severely increasing CPI and hence decreasing the demand for energy as well as energy complimented goods. This could increase unemployment, and inflation while decreasing consumption across markets. If things such as unemployment and inflation do rise and consumption falls, real GDP will decline.

Then, a third model is created and a regression will be run using personal consumption expenditures (excluding food and energy) as the dependent variable. The same independent variables will be used in order to answer whether or not these crude oil

characteristics affect consumer consumption patterns of commodities other than crude oil (or other petroleum products). This third equation is modeled as follows:

3) $PCLFE_t = \beta_0 - \beta_1 DOP_t + \beta_2 DOProd_t - \beta_3 IOP_t + \beta_4 IOQ_t - \beta_5 LnOilShock_t + \varepsilon$

Here the dependent variable, PCLFE, is an abbreviation for personal consumption less food and energy. If Model 1 and 2 fail to produce any results that allow the conclusion that crude oil energy price shocks can and will affect GDP, then this model might be able to help explain why. If the results seem more accurate for model 3, then this would help support what Hamilton (2011) says about oil price increases being exogenous of GDP and only has correlation.

This study hypothesizes that people do tend to smooth their consumption and energy consumption will not change near as much as other goods and services. Therefore the independent variables should have the same coefficients as they did on real GDP. When crude oil prices increase, it will decrease expenditures on products other than food and energy. Inversely, when production and quantity of crude oil are increased, the price of energy related goods will fall, thus allowing consumers to resume their normal spending habits and increase consumption of goods and services less energy.

Section 6

RESULTS AND DISCUSSION

The results obtained after running the OLS estimation on Model 1 can be seen in Table 1. Based on the hypothesis for Model 1, all the variables have the correct signs on their coefficients except for the domestic oil price and the domestic oil production. This first model obtained an R-squared value of 0.9771. Aside from the oil price shock variable, all the independent variables demonstrate statistical significance.

The results from Model 1 show that for every dollar per barrel increase in the domestic price of crude oil, there will be an increase of 64.58 billion dollars in real GDP. This was unexpected, but based off of the t-statistic and p-value, this variable demonstrates strong statistical significance. Although the sign of the coefficient was unexpected, it may be following the reverse causality that Killian (2008) speaks of when he says that it is actually when GDP increases that there will be an increase in the price of crude oil. The next variable for domestic oil production also gave me an unexpected sign. The results for this variable says that for every thousand barrels the United States increases in domestic production, real GDP will decrease by 0.0022 billion dollars. This variable is also highly significant and could be right. This is most likely due to the production cost of constructing drills and rigs in order to obtain the oil and then having to pay people to maintain the operation. There is a possibility that in order to achieve the correct estimates for this coefficient, one would have to hold capital and labor fixed.

Looking at the imported oil price variable, expected results were obtained and it is statistically significant. Model 1 depicts that for every dollar per barrel the price for imported crude oil increases, GDP will decrease by 28.01 billion dollars. If firms have to

pay more to obtain a product they are going to naturally raise the price. This was seen in Figure B when the CPI and PPI line followed the same path but the PPI line was always just below that of the CPI line. This is in support of the argument that shocks to the price of imported crude oil could affect demand enough to cause contractionary economic events, and decrease GDP. Then, the results for imported crude oil quantity say that if the amount of imported crude oil increases by one thousand barrels, GDP should rise by 0.00096 billion dollars. Although this variable has the correct sign and is statistically significant, the effect it has on GDP is relatively small. This could be due to Killian's point that crude oil imports are categorized as domestic gross output rather than value added and cannot be considered a productivity shock to GDP (Killian 2008).

Finally there is the oil price shock variable. This variable is only statistically significant against a two-sided test at the 10% level of significance. Each of the other variables turned out to all portray significance against a two-sided test at the 5% level. Because of this, it is enough to say that the oil shock variable is not significant in explaining how real GDP behaves and is therefore insignificant to this model.

For Model 1, it is best to try and run the sort of regression that will correct for any heteroskedasticity bias. Therefore the residuals were plotted to further examine the possible presence of this bias.[19] From this I can see that there is probably the presence of heteroskedasticity. In order to correct this problem, the regression was run using robust standard errors. The results in Table 1 are presented with these results. A correlation table was then created along with the implementation of a variance inflation factors (VIF) test to get an idea of how much each independent variable is correlated with each other

[19] The plotted residuals for Model 1 can be seen on Table 2.

and if there are any signs of multicollinearity.[20] Based on the correlation table it can be seen that the imported oil quantity variable is highly correlated with the amount of domestic oil production. Also, based on the VIF table, *DOProd* and *IOQ* both have high degrees of multicollinearity.[21] It is likely that there is one of two problems. First, it could be an irrelevant variable bias and the heteroskedasticity and multicollinearity problem will be fixed by dropping either *IOQ* or *DOProd*. Or it could be an omitted variable bias and there is some variable that is essential to the equation and is being left out.

Although the hypothesis for the domestic variables' coefficients was wrong, the broader hypothesis was not. Domestic and imported oil prices were significant in explaining the behavior of real GDP. Given the information from Model 1, it appears that both the domestic oil price and the imported oil price have an effect on real GDP with the unexpected result that an increase in the imported price of crude oil is the only one that has contractionary effects (not including the oil price shock variable).

Model 2 contains the same dependent and independent variables as Model 1. The difference is that in Model 2 all the independent variables are lagged one period behind in order to try and capture how they explain real GDP in the following period. From this OLS estimation it is found that all the resulting signs on the coefficients for the lagged independent variables are the same as they were in Model 1.[22] On the other hand, unlike Model 1, Model 2's results show that all the lagged independent variables are statistically significant against a two-sided test at the 5% significance level.

[20] Correlation and VIF tables for Model 1 can be seen on Table 3.
[21] Any variables with a VIF score greater than 10.0, is thought to have severe multicollinearity problems. 1/VIF is the Tolerance. Tolerance ranges from 0.0 to 1.0, with 1.0 signifying no multicollinearity.
[22] The OLS estimation results for Model 2 can be found on Table 4.

Also different from Model 1, in Model 2 the lagged oil price shock variable (*lagLnOilShock*) is statistically significant. It explains that for every period that there is an increase in the price of oil consumption as a share of GDP in period t, real GDP should decrease by 7778.552 billion dollars in year t + 1. This supports the hypothesis that during times of an oil shock, contractionary effects are seen on GDP.

Before running the regression with robust standard errors, to test the reliability of Model 2, the residuals were plotted in order to try and eyeball whether there is the presence of heteroskedasticity or not.[23] Looking at Table 6 it seems as though there is more of a constant variance in Model 2 than there was in Model 1 but it is possible that there is still the presence of heteroskedasticity. Therefore the regression was run using robust standard errors and the results shown in Table 4 depict this. A correlation and VIF table was made to see if this model has any issues with multicollinearity.[24] According to the correlation table, as well as the VIF table, the lagged domestic oil production and imported oil quantity variables have strong indications of multicollinearity.

Then, with Model 2, in an attempt to fix the problem of multicollinearity one of the variables with a high VIF score was dropped. In the new estimation (Model 2.1) lagged variable for imported oil quantity was dropped. Once *lagIOQ* was dropped from the estimation, the variable *lagLnOilShock* immediately became insignificant. In addition to that, *lagIOP* was borderline insignificant with a p-value of 0.049.[25]

Instead of going any further with more testing on this revised model, the variable *lagIOQ* was replaced back into the model and instead *lagDOProd* was dropped from the estimation to see if I could obtain all significant variables (Model 2.2). This did in fact

[23] The plot of Model 2's residuals can be found on Table 5.
[24] Model 2's correlation and VIF table can be found on Table 6.
[25] The results for Model 2.1 (excluding *lagIOQ*) are on Table 7.

result in all the current independent variables showing statistical significance at the 5% level.[26] Furthermore, a new correlation table and VIF test reveal that there are no more multicollinearity possibilities among these independent variables. The VIF table also displays the lowest mean value VIF out of all the estimated models.[27] Therefore this seems to be the most accurate model out of the ones that have been estimated. According to Model 2.2, when domestic oil price increases, so does GDP. Once again we see that when imported oil prices increase this has contractionary effects on real GDP.

Finally, I ran a supplementary regression to see if these same independent variables are affecting the consumption patterns of goods and services besides energy. This is to help try and decipher if oil price shocks are a demand or supply side problem. Since Model 2.2 worked out so well without the presence of *lagDOProd*, I went ahead and left the un-lagged variable *DOProd* out of Model 3's estimation:

3) $PCLFE_t = \beta_0 - \beta_1 DOP_t - \beta_2 IOP_t + \beta_3 IOQ_t - \beta_4 LnOilShock_t + \varepsilon$

All of the independent variables included in Model 3 came out significant at the 5% level. Robust standard errors are used and there appears to be no presence of multicollinearity based on the VIF test.[28] The results from this are nearly identical to those found in Model 2.2 in the sense that the signs of the coefficients are the same. The only difference is that the effect these variables have on consumption (less food and energy) is much smaller than the effect they have shown to have on GDP. Nonetheless the relationship is still there.

In Model 2.2 we obtained results saying that the lagged value of domestic oil production was not significant to the equation. However, to test further whether or not

[26] The results for Model 2.2 (excluding *lagDOProd*) are on Table 8.
[27] The Correlation Table and VIF test for Model 2.2 are on Table 9.
[28] The OLS results and VIF test for Model 3 can be found on Tables 10 and 11 respectively.

lagDOProd is significant, a fourth model was created. This model instead drops the domestic and imported oil price variables. Suspecting that the price of domestic crude oil is dependent upon the price of imported crude oil, a weighted average variable was created in their place. This resulted in the following equation:

4) $GDP_t = \beta_0 + \beta_1 DOProd_{t-1} + \beta_2 IOQ_{t-1} - \beta_3 WAPC_{t-1} - \beta_4 LnOilShock_{t-1} + \varepsilon$

In Model 4, all the independent variables are lagged. The independent variable WAPC is defined as the weighted average of the price of crude oil. This was derived as follows:

- $WAPC = \frac{[(DOP * DOProd) + (IOP * IOQ)]}{(DOProd + IOQ)}$

Here the domestic crude oil price is multiplied by domestic crude oil production and is added to the value of the imported crude oil price multiplied by the imported crude oil quantity. The value of the numerator is then dived by domestic crude oil production plus the quantity of imported oil.

The regression using Model 4 gives an R-squared value of 0.9515.[29] From the results it is found that now that *lagDOProd* is significant along with all the other values against a two sided test at the 5% significance level except for *lagIOQ*. The variable *lagIOQ* is now highly insignificant with a p-value of 0.957. None of the hypothesized signs of the coefficients were correct except for the oil shock variable. Also in this model the lagged value of *DOProd* just as it was in Models 2 and 2.1. Based on Model 4's VIF table, there is a high degree of multicollinearity between the variables *lagDOProd* and *lagIOQ*.[30] Due to this, *lagIOQ* was then dropped from the equation (Model 4.1) and all

[29] The OLS results for Model 4 are on Table 12.
[30] The correlation and VIF tables for Model 4 are found on Table 12.

independent variables were found significant at the 5% level. A new VIF table was then run and there were no signs of multicollinearity.[31]

[31] The OLS results and VIF table for Model 4.1 are found on Table 13.

Section 7

CONCLUSIONS AND POLICY RECOMMENDATIONS

Based off the results from the OLS estimations, I conclude that crude oil prices are endogenous of GDP. Contrary to what was hypothesized, in every model, the price of domestic crude oil was highly significant and positive. This means that as the price of domestic crude oil increases, so does GDP. Model 2.2 supports Killian's view that there could possibly be reverse causality and that as GDP increases the domestic price of domestic crude oil increases as well. However, when it comes to contractionary effects of crude oil price shocks, only the imported crude oil price supported this. Not only are firms paying abroad for these imports, but at least some of the money spent by consumers on energy products will not be recycled back into the domestic economy, resulting in a decline in GDP. Nordhaus (2009) also says that macro externalities would arise due to the total domestic expenditure. This may help explain why *DOProd* had a negative coefficient

Looking at the results from Model 3, personal consumption less food and energy decreases when the price of imported crude oil increases and/or there is a crude oil price shock. This is interesting because this suggests that people actually do change the way they consume based off of crude oil energy prices and price shocks in an attempt to smooth their consumption. This could in turn effect GDP if consumption declines enough or for long enough. Once the price of crude oil changes how we consume, which then effects GDP, this becomes a demand side problem. Although the recent spike in oil prices in the early 2000's could have effected consumption, it may have not effected consumption enough to see economic downturns as bad as in the 1970's and 1980's.

Results from Model 4 show that the quantity of imported crude oil is insignificant and that the sign on the coefficient for domestic oil production is negative. This again agrees with Nordhaus' (2009) point about macro externalities being caused by domestic expenditure.

So why did the most recent energy price shock not hurt the economy as much as shocks in the past? It could be that the oil price shocks of 1973 had a lot to do with exogenous political events, such as bad policy that enhanced the contractionary effects on the macroeconomy. Oil price controls were implemented during a time of oil price shocks. Another reason may be simply that the magnitude of the oil price shock in the early 2000's was smaller now than they were before. It could also be due to the fact that producers and consumers view and therefore react differently to changes in the price of oil. Nordhaus (2007) says that people are starting to view energy increases as a permanent tax and instead of altering their consumption of energy, they smooth consumption elsewhere which would explain why Model 3 shows the import price of crude oil and the oil shock variable with negative signs.

In the case that the bad policies of the 1970's were coupled with a severe oil price shock, it would be in policy makers' best interest to try and lessen the impact that oil prices have on GDP in the future. A start would be to reconfigure tax incentives towards domestic oil producers so that it can help to balance out the high cost of labor and capital which seems to be the reason for OLS results displaying a negative coefficient for domestic oil production. Along with domestic production, foreign policies need to be implemented with other oil producing countries in an attempt to reduce the world oil price. These foreign policies would have to be coupled with environmental regulations

on things such as carbon emissions. This is because if prices get too low and consumption of oil increases with every dollar that oil decreases, the environment will take a tremendous hit. Along with issues on the environment and thinking more long-run, the amount of government funded research for technological innovation for renewable and non-renewable energies should be increased to the capacity that the country is financially able to support. More tax incentives should be offered to not only producers of renewable energy but also to firms and households that consume it. These tax breaks could be increased by not only the dollar amount but by the range of possible ways to qualify for them.

Table 1 - Model 1 OLS Estimation Results

GDP	Coef.	Robust Std. Err.	t	P>t
DOP	64.57688	9.982637	6.47	0.000
DOProd	-.0021587	.0007687	-2.81	0.008
IOP	-28.01221	6.309187	-4.44	0.000
IOQ	.0009576	.0003553	2.70	0.010
LnOilShock	-4902.175	2738.662	-1.79	0.081
Constant	11726.7	2820.098	4.16	0.000

Number of Observations = 44

R-Squared = 0.9771

Table 2 - Plotted Residuals for Model 1

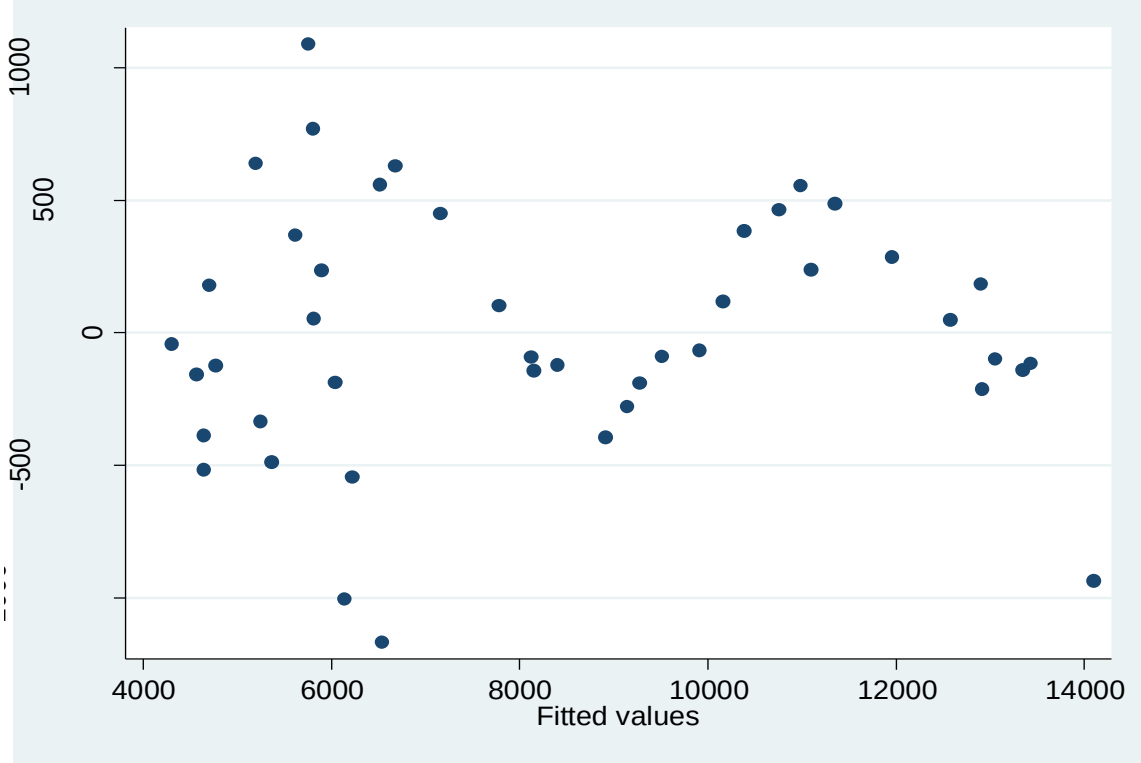


Table 3 - Model 1 Correlation and VIF Tables

	GDP	DOP	DOProd	IOP	IOQ	LnOilShock
GDP	1.0000					
DOP	0.7647	1.0000				
DOProd	-0.9716	-0.6858	1.0000			
IOP	0.2384	0.7102	-0.1863	1.0000		
IOQ	0.9231	0.6184	-0.9546	0.2345	1.0000	
LnOilShock	0.2639	0.4885	-0.2661	0.5342	0.2927	1.0000

Variable	VIF	1/VIF
DOProd	26.74	0.037392
IOQ	17.49	0.057181
DOP	8.38	0.119354
IOP	4.82	0.207413
LnOilShock	1.47	0.680629
Mean VIF	11.78	

Table 4 - Model 2 OLS Estimation Results

GDP	Coef.	Robust Std. Err.	t	P>t
lagDOP	59.77284	13.96751	4.28	0.000
lagDOProd	-.0023341	.0008454	-2.76	0.009
lagIOP	-26.92279	7.416392	-3.63	0.001
lagIOQ	.0009756	.0003815	2.56	0.015
lagLnOilShock	-7778.552	3422.893	-2.27	0.029
Constant	12467.5	3082.113	4.05	0.000

Number of Observations = 43

R-Squared = 0.9691

Table 5 – Plotted Residuals for Model 2

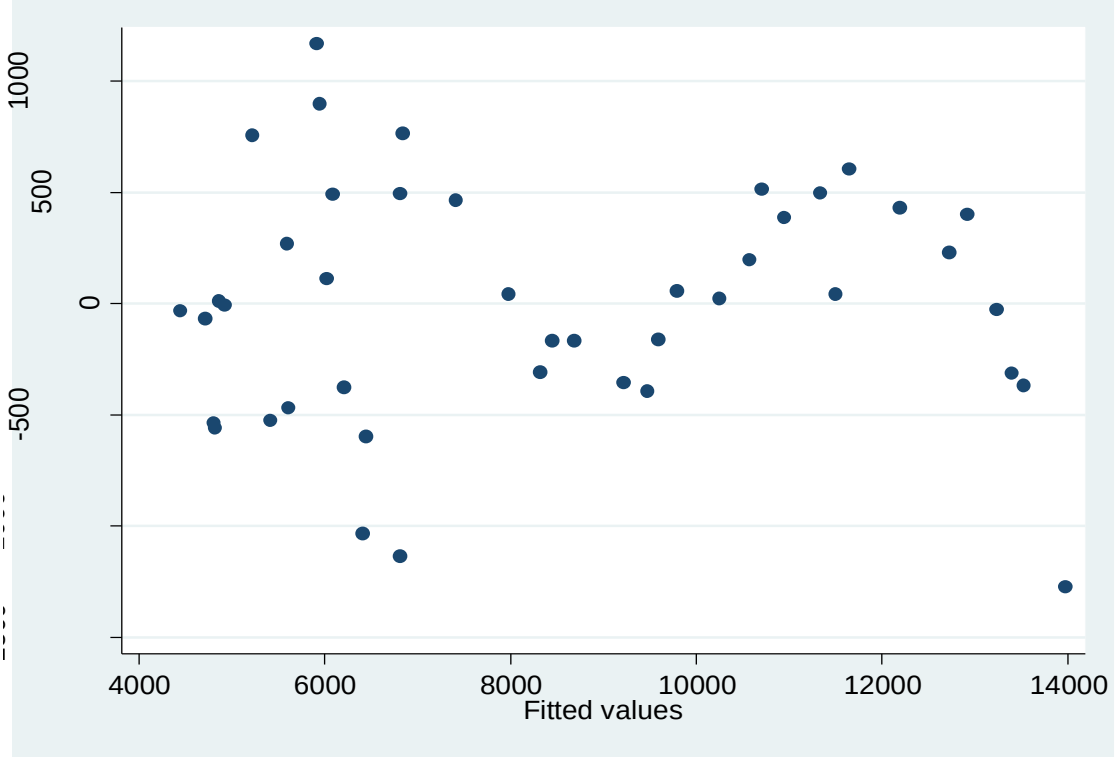


Table 6 - Model 2 Correlation and VIF Tables

	GDP	lagDOP	lagDOProd	lagIOP	lagIOQ	lagLnOilShock
GDP	1.0000					
lagDOP	0.7336	1.0000				
lagDOProd	0.9712	-0.6899	1.0000			
lagIOP	0.1376	0.6559	-0.1284	1.0000		
lagIOQ	0.9252	0.6289	-0.9540	0.1951	1.0000	
lagLnOilShock	0.1777	0.4256	-0.2275	0.4865	0.2647	1.0000

Variable	VIF	1/VIF
lagDOProd	26.18	0.038199
lagIOQ	17.12	0.058402
lagDOP	7.33	0.136418
lagIOP	4.26	0.234883
lagLnOilShock	1.37	0.731262
Mean VIF	11.25	

Table 7 – Model 2.1 OLS Estimation Results (excluding *lagIOQ*)

GDP	Coef.	Robust Std. Err.	t	P>t
lagDOP	42.31266	13.71227	3.09	0.004
lagDOProd	-.0044278	.0003254	-13.61	0.000
lagIOP	-15.46715	7.610236	-2.03	0.049
lagLnOilShock	-7060.375	3671.197	-1.92	0.062
Constant	20199.8	909.3521	22.21	0.000

Number of Observations = 43

R-Squared = 0.9629

Table 8 – Model 2.2 OLS Estimation Results (excluding *lagDOProd*)

GDP	Coef.	Robust Std. Err.	t	P>t
lagDOP	84.4905	13.09975	6.45	0.000
lagIOP	-41.92337	7.747758	-5.41	0.000
lagIOQ	.0019397	.0001504	12.90	0.000
lagLnOilShock	-8144.207	3436.284	-2.37	0.023
Constant	4100.145	317.9764	12.89	0.000

Number of Observations = 43

R-Squared = 0.9623

Table 9 – Model 2.2 Correlation and VIF Tables (excluding *lagDOProd*)

	GDP	lagDOP	lagIOP	lagIOQ	lagLnOilShock
GDP	1.0000				
lagDOP	0.7336	1.0000			
lagIOP	0.1376	0.6559	1.0000		
lagIOQ	0.9252	0.6289	0.1951	1.0000	
lagLnOilShock	0.1777	0.4256	0.4865	0.2647	1.0000

Variable	VIF	1/VIF
lagDOP	3.24	0.308509
lagIOP	2.27	0.439648
lagIOQ	1.95	0.513776
lagLnOilShock	1.37	0.732253
Mean VIF	2.21	

Table 10 – Model 3 (excluding *DOProd*) Results

PCLFE	Coef.	Robust Std. Err.	t	P>t
DOP	.7529926	.1344693	5.60	0.000
IOP	-.3429712	.1100335	-3.12	0.003
IOQ	.0000177	1.98e-06	8.93	0.000
LnOilShock	-120.1361	47.87533	-2.51	0.016
Constant	26.59896	5.791468	4.59	0.000

Number of Observations = 44

R-Squared = 0.9047

Table 11 – Model 3 (excluding DOProd) Correlation and VIF Tables

	PCLFE	DOP	IOP	IOQ	LnOilShock
PCLFE	1.0000				
DOP	0.7179	1.0000			
IOP	0.2102	0.7102	1.0000		
IOQ	0.8920	0.6184	0.2345	1.0000	
LnOilShock	0.1923	0.4885	0.5342	0.2927	1.0000

Variable	VIF	1/VIF
DOP	3.59	0.278338
IOP	2.61	0.383293
IOQ	1.90	0.526352
LnOilShock	1.47	0.681961
Mean VIF	2.39	

Table 12 – Model 4 OLS and VIF Table Results

GDP	Coef.	Robust Std. Err.	t	P>t
lagDOProd	-.0051416	.0006328	-8.13	0.000
lagIOQ	-.0000188	.0003426	-0.05	0.957
lagWAPC	16.20432	6.202885	2.61	0.013
lagLnOilShock	-8993.396	3536.228	-2.54	0.015
Constant	21960.51	2437.303	9.01	0.000

Variable	VIF	1/VIF
lagIOQ	11.48	0.087144
lagDOProd	11.45	0.087315
lagWAPC	1.91	0.523433
lagLnOilShock	1.36	0.735325
Mean VIF	6.55	

Table 13 – Model 4.1 OLS and VIF Table Results

GDP	Coef.	Robust Std. Err.	t	P>t
lagDOProd	-.0051093	.000204	-25.05	0.000
lagWAPC	16.18202	6.098373	2.65	0.011
lagLnOilShock	-9019.917	3364.454	-2.68	0.011
Constant	21831.88	620.3945	35.19	0.000

Variable	VIF	1/VIF
lagWAPC	1.90	0.525235
lagDOProd	1.51	0.662904
lagLnOilShock	1.34	0.745936
Mean VIF	1.58	

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