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Are Oil Prices Important to U.S. Manufacturers?

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Abstract

Very little has been written about the effect that oil prices have on manufacturing output in the United States. This paper aims to shed light about the effect of oil prices, oil imports, and GDP on U.S. manufacturing output through a four-variable vector autoregression and explain the timing of these shocks through impulse response functions. Empirical results find that oil prices are significant in determining manufacturing output, but manufacturing output is also significant in determining oil prices.

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I - Introduction

Oil prices are one of the most controversial topics of debate among economists and politicians. Donald Trump said that oil was part of this country's blood, and that high oil prices would lead to loss of jobs.[1] While it is still up for debate whether oil prices have a statistically significant effect on GDP, this paper seeks to test the hypothesis that oil prices have a statistically significant effect on manufacturing output. Manufacturing output has been declining at a rapid rate in the U.S., and many politicians are quick to blame high oil prices. Do these politicians have a point? The results were inconclusive. Oil prices were statistically significant in projecting manufacturing output two periods later while manufacturing output was statistically significant in projecting oil prices in the next period. Furthermore, oil prices, GDP, and oil imports explain 75% of the variation in manufacturing output over time, which leaves 25% to other factors. Section II will cover some of the most influential literature on the subject of oil prices' effect on GDP and stock returns, section III will cover the data collected to run the model, section IV will go over the two vector autoregressions used to illustrate the impact that oil prices have on oil imports, GDP, and manufacturing output as well as the impulse response functions that better illustrate how a shock to oil prices affects manufacturing output as well as how a shock to manufacturing output affects oil prices, section V will go over the results of the two vector autoregressions, section VI will go over the results of the impulse response function, and section VII will conclude the paper with suggestions for further research.

[1]Donald Trump, *Time to Get Tough: Making America #1 Again* (Washington, D.C.: Regnery Pub., 2011) pg. 15-16.

II – Relevant Journals

In terms of relevant literature, most literature collected data either at the full macroeconomic level (quarterly GDP growth) or at the firm level with stock price returns. First, this paper will focus on the relationship between stock returns and oil price shocks. One of the most cited authors on oil prices and its effect on stock prices is Lutz Kilian. In his most recent study (2009), Cheolbeom Park and he attempt to measure this effect differently than Kilian had in the past. An interesting element of their study is that they don't treat oil as a purely exogenous commodity: "It has become widely accepted in recent years that the price of crude oil since the 1970s has responded to some of the same economic forces that drive stock prices, making it necessary to control for reverse causality."[2] This simply means that it is uncertain whether oil prices are driving returns or whether returns are driving oil prices. To test these constraints, they estimate a vector autoregression with variables including the percent change in crude oil production, real activity in global commodity markets, real price, and real stock returns[3]. They test out the response by the market to shocks in pricing. They find that a price shock that follows a positive demand shock for oil leads to sharp declines in stock market values for the most part.[4] Furthermore, not all the adjustment occurs on impact; there is some longer term smoothing out. In the case where there are precautionary shocks to demand, there is a negative and statistically significant market return that peaks about a month after the shock.[5] Kilian and Park also take a specific look at the automobile industry, where oil is a

[2]Lutz Kilian and Cheolbeom Park, "The Impact of Oil Price Shocks on the U.S. Stock Market," *International Economic Review* 50, no. 4 (2009):, doi:10.1111/j.1468-2354.2009.00568.x.
[3]Ibid.
[4]Ibid.
[5]Ibid.

significant input in both the operating and manufacturing aspects. Kilian and Park discover that there is a certain decrease in returns for automobile companies only during an oil specific demand shock. A general aggregate demand shock, by contrast, has an uncertain effect on returns.[6] Their overall finding is that in all areas, only an oil specific demand shock causes any sort of certain change to returns.[7]

Jungwook Park and Ronald A. Ratti also look at the effects of oil price shocks on the stock market; however, they look at European countries in addition to the U.S. This way, they can see if shocks have a country by country effect or a whole scale effect.[8] They use a VAR consisting of oil prices, real stock returns in the U.S. and 13 European countries, short-term interest rates, consumer prices, and industrial production. All variables are first-differenced in order to prevent serial correlation. An interesting caveat to their regression model is that they use world oil price instead of national price.[9]While there are not huge regional differences, not all countries have identical oil policies. Thus, this should increase the significance of oil price shocks to returns on the stock market, as all subsidies and other fiscal factors are removed from the equation. By using world prices, Park and Ratti also can illustrate that oil price shocks have the same statistical significance in the U.S. as they do across Europe. If they do, then the effect of an oil shock of any sort in the U.S. might also have some endogenous trade effect with Europe.

Nicholas Apergis and Stephen M. Miller took the research done by Kilian and Park and combined it with the research done by Park and Ratti to run their own study of

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[6]Ibid.

[7]Ibid.

[8]Jungwook Park and Ronald A. Ratti, “Oil Price Shocks and Stock Markets in the U.S. and 13 European Countries,” *Energy Economics* 30, no. 5 (2008): , doi:10.1016/j.eneco.2008.04.003.

[9]Ibid.

the effect of structural oil-market shocks on stock market returns in the U.S. and seven other countries.[10] They take the VAR that Kilian used and modify it to only include three vector shocks: oil-supply shocks, global-oil demand shocks, and global-aggregate demand shocks[11]. The rationale for including only these three shocks is that they are completely exogenous of each other, which allows for much more significant results. For their data, they use monthly data from the CPI, an index of freight rates, oil prices per barrel in U.S. dollars, barrels pumped per day, and stock market price. They didn't include oil imports because imports might have an endogeneity issue with CPI and freight rates which are included already in the regression. The eight countries they choose are the U.S., UK, Japan, Germany, Italy, Australia, Canada, and France.[12] Of note is that from 1981-2007 (the time that the article covers), all the above-mentioned countries were net oil importers. Their findings were that the idiosyncratic demand shock, or global oil demand shock, was strongly statistically significant, the other two shocks were significant in some of the countries but not all, and, most importantly, the magnitude of the effect of all these shocks was very small.[13]

These findings lead to an interesting question: is oil output driving stock returns? Returns can come from a multitude of different policies, such as changes in the interest rate, changes in the consumer base, and changes in the political system to name a few. Especially within the automotive industry, oil price shocks could be offset by reducing costs of labor, rent, etc. Another question also arises from these papers: oil price shocks

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[10]Nicholas Apergis and Stephen M. Miller, "Do Structural Oil-market Shocks Affect Stock Prices?" *Energy Economics* 31, no. 4 (2009):, doi:10.1016/j.eneco.2009.03.001.
[11]Ibid.
[12]Ibid.
[13]Ibid.

clearly have a significant effect on market returns, but do oil price shocks actually affect GDP? Furthermore, is the short-term effect on the market based on actual data insights or on animal spirits caused by the shock? If the latter is true, then these papers are of no help in determining whether oil price shocks and volatility have any significance in the decline of manufacturing in the U.S.

Furthermore, when looking at the relationship between oil prices and stock returns, it appears that specific oil demand shocks are the most important and significant shocks. Is the same true when oil prices are compared to national GDP?

Mark Hooker focused on the relationship between oil prices and the U.S. macroeconomy. Specifically, he looked at supply side shocks caused by OPEC in 1973 and 1979 to see how much of an impact the shocks had on changes in GDP. Hooker chooses those points because from 1973-1979, the OPEC cartel had almost full power over the price of oil.[14] First, he examines the causal relationship of oil prices on GDP. In the most recent subsample of 1973-1994, oil price was not a statistically significant factor in determining GDP.[15] Furthermore, the coefficients in the 1973-1994 subsample were smaller than those in the 1948-1973 subsample. This is contrary to the theory that larger oil shocks should lead to a more drastic change in GDP. Secondly, Hooker then specifically attempts to measure two major oil shocks: OPEC I, which happened in 1973 after the Yom Kippur War, and OPEC II, which happened shortly after the fall of the Shah in Iran. Using a VAR, Hooker finds that the 1973 OPEC I shock was not significant

[14]Mark A. Hooker, "What Happened to the Oil Price-Macroeconomy Relationship?" *Journal of Monetary Economics* 38, no. 2 (1996):, doi:10,1016/s0304-3932(96)01281-0.

[15]Ibid.

in creating the recession that would later follow.[16] However, OPEC II had some significance in capturing the recession that followed, but it did not create a complete picture of the recession. Rather, other endogenous and domestic factors had much greater statistical significance.

One interesting factor of Hooker's paper is that it doesn't overtly consider the different political trends occurring in the United States starting in the 1970s. By 1973, the U.S. had fully escalated the Vietnam War into neighboring Cambodia. Large increases in government spending coupled with constant tax rates could have helped create the large inflationary period. In addition, the 1980s featured a decade-long war between Iraq and Iran. The war almost completely crippled the ability of either nation to produce oil, and thus forced the U.S. to look elsewhere for substitutes. Finally, this paper does not address the changes made in car manufacturing in the 1980s. Chevrolet and Ford specifically began to make much more fuel-efficient cars; thus, consumption of oil was much smaller during the period.

Evangelia Papapetrou looks at oil prices and their effect on employment in Greece. Papapetrou uses a multivariable VAR to analyze the effects in addition to an impulse response function featuring four different types of shocks: interest rate shocks, real oil prices shocks, industrial production shocks, and real stock returns shocks. For Greece, it appears that oil prices have a significant effect on employment, output growth, and industrial production and employment.[17] Furthermore, just like in the stock market returns example used by Park and Kilian, Papapetrou's results show increased amount of

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[16]Ibid.

[17]Evangelia Papapetrou, "Oil Price Shocks, Stock Market, Economic Activity and Employment in Greece," *Energy Economics* 23, no. 5 (2001): , doi:10.1016/s0140-9883(01)00078-0.

variance controlled for as the shock wears on. While oil prices are proven to have significant effects to stock market returns[18], it is uncertain how much of an impact these oil shocks have on pure manufacturing. Greece's GDP from construction and mining were near all-time lows in 2001, and thus this country might not be the best example of how an oil shock affects manufacturing of all sorts in the United States.

James D. Hamilton attempts to link oil prices to the U.S. macroeconomy through a different function. Instead of using a VAR, he uses one nonlinear time series to calculate the effect of oil prices on U.S. GDP.[19] By not running a VAR, Hamilton doesn't believe that there are any feedbacks, thus, GDP has no effect on oil prices in his model. This method is counter to what Park and Ratti (2008) did in their paper on oil prices and market shocks. This also suggests that stock markets could have a more linear relationship than GDP does with oil. Hamilton's first step is to reject the null hypothesis that the relationship between oil and GDP growth is linear. Using a Chi-squared test, he gets a value of 40.00, which overwhelmingly allows him to reject the null.[20] Furthermore, his nonlinear time series is very stable at all elements. One interesting note on this paper is that the five major oil price shocks post-World War II and pre-Iraqi Conflict were all in response to war in the Middle East. These shocks are all exogenous shocks, and because of that, these shocks were responsible for all of the price change.[21] Based on Hamilton's analysis, it can be argued that oil shocks have a strong indirect effect on GDP, and most of all, it appears that the oil price shocks are exogenously caused by Middle East conflict.

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[18]Ibid.

[19]James D. Hamilton, "What Is an Oil Shock?," *Journal of Econometrics* 113, no. 2 (2003):, doi: 10.1016/s0304-4076(02)00207-5.

[20]Ibid.

[21]Ibid.

This conflict has historically led the U.S. into recession. Hamilton does not segment GDP by sector or industry either, which leaves room for the question of how do oil prices affect the manufacturing sector? Furthermore, are oil intensive industries truly hit harder by positive oil price shocks?

One of the few articles to use industry level data is one written by Kiseok Lee and Shawn Ni. They use input/output (hereon to be referred to as I/O) tables first to show in which industries petroleum is most used. They discover that the transportation industry is the largest user of petroleum, but they also find that transportation, industrial manufacturing, and residential/commercial manufacturing make up only one-third of the total consumption of petroleum.[22] To calculate the impact of oil on both oil intensive and oil lacking industries, they first use a VAR with both aggregate data and industry-level data.[23] The idea behind this is that once the causal effects of the variables are estimated, Lee and Ni can then run individual regressions on the separate industries. This should lead to more exogenous results and statistically significant variables. Looking at the impulse response functions, oil-intensive industries respond to oil price shocks with industry supply shocks. However, price is affected much more than quantity produced[24], which means that the supply curve must be relatively inelastic. For non-intensive oil industries, an oil price shock leads to a shift in both the quantity supplied and the price. The shock therefore has an increased effect on the demand curve[25], and due to the

[22]Kiseok Lee and Shawn Ni, "On the Dynamic Effects of Oil Price Shocks: A Study Using Industry Level Data," *Journal of Monetary Economics* 49, no. 4 (2002):, doi:10.1016/s0304-3932(02)00114-9.
[23]Ibid.
[24]Ibid.
[25]Ibid.

elasticity of this curve the peak response to the shock is very large. This makes sense that the shock would be on the demand curve because even though oil is not a significant input in the manufacturing of the car, it is a highly important input in operation of the car.

One thing that Lee and Ni did not cover was the effect of oil price shocks on pure manufacturing. In the following section, the link between oil price shocks and the manufacturing sector will be clarified as well as the link between oil price shocks and industry output using thirteen extra years of data.

III – Data Review

The data that we are using are wide and varied. The first data set has quarterly manufacturing output index data at the sector level from FRED, [26]and a weighted average quarterly oil price from the Energy Information Administration (EIA).[27]Because the raw data is in the form of monthly prices, the prices were converted into quarterly averages. Most of the cited studies used quarterly data in creating their models. The Energy Information Administration (EIA) provided monthly data on U.S. oil imports[28] and were converted to quarterly imports through aggregation of total imports of each month in the quarter. Finally, the U.S. quarterly GDP also comes from FRED.[29]

The data covers 115 quarterly periods from 3rd quarter of 1987 up to the 2nd quarter of 2016. This includes the 1990 Persian Gulf War, the attacks of September 11, 2001, the invasion of Iraq and the five-year Iraqi conflict, and the beginning of the U.S.'

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[26]"Manufacturing Sector: Real Output," *FRED*, accessed October 21, 2016, https://fred.stlouisfed.org/series/OUTMS.

[27]"U.S. Crude Oil First Purchase Price," *U.S. Energy Information Administration*, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=f000000_3&f=m.

[28]"Data 1: U.S. Imports of Crude Oil (Thousand Barrels),"*U.S. Energy Information Administration,* http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRIMU.S.1&f=M.

[29]"Gross Domestic Product", *FRED*, https://fred.stlouisfed.org/series/GDP

return to oil exporter. Of important note is that the manufacturing output data at the sector level does not exist in the form of gross output. Therefore, the raw data is both at an index and as a percent change.

Industry data is provided by FRED only at the yearly level. Due to the yearly nature of the data and the fact that a yearly weighted average oil price is not a fair representation of a price shock, this data will not be used in the VAR regression.

IV-Explanation of Models

We estimate the effect of oil prices on manufacturing output using two different VARs: a 3-variable VAR consisting of GDP, oil imports, and oil prices with a lag length of five quarters and a 4-variable VAR consisting of GDP, oil imports, oil prices, and manufacturing output with a lag length of four quarters. The reason for using different lag lengths is that the Akaike information criterion, or AIC, was minimized with different length lags in the 3-variable and 4-variable VARs. A VAR can best be described as time series for multiple different variables. This first model does not include manufacturing data because it is important to determine first how oil prices affect the largest scale parts of the economy. If oil prices are found to have no statistically significant effect on GDP but are found to have a significant effect on manufacturing output, then it can be said that manufacturing does not have a statistically significant effect on GDP. There are two possible interpretations to this data. One is that oil prices can be ignored when evaluating a country's health. While this seems to be a reasonable conclusion, it is far too simplistic. The more likely scenario is that oil impacts other parts of the economy such as the drilling, extraction, and refining segments in a way that offsets the effect that prices have on manufacturing. The second VAR will include manufacturing output as an index. This makes it a log variable, as it is measured in percent changes.

The standard one variable VAR model with n-lags can be written the following way:

$$y_t = \alpha + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \ldots + \beta_n y_{t-n} + e_t$$

For the first model, there are three variables so Y_t will be a three-variable vector. Something very important to consider is the ordering of integration of the variables, as inconsistency could lead to issues with the model as time lags and as the variables are differentiated. For the first VAR, y will contain oil imports, U.S. GDP, and oil prices. Of note is that each variable has been stationarized by taking the first difference, which can be written as y_t-y_{t-1}. As mentioned before, stationarizing variables is essential to avoiding serial correlation. This makes the R^2 much more accurate in determining how much of the variance has actually been accounted for. Each variable has its own equation; to make the full VAR, each of the one to one models are added together to form a matrix. Before the VAR is to be run, the variables will be Cholesky ordered by the speed of change. This guarantees more stable coefficients as well as more statistically significant coefficients. The second model is very similar to the first but manufacturing output is included as y_4 to each of the three equations. Manufacturing output also gets its own equation.

The next part of the model involves impulse response functions. I have calculated six orthogonalized impulse response functions; the first three measure the effect of independent and isolated shocks to GDP, oil prices, and oil imports on manufacturing output, and the second three measure the effect of a manufacturing output shock on GDP, oil prices, and oil imports. The reason for measuring the shocks both ways is that all four of the variables are endogenous variables. Endogeneity simply means that two variables have impact on each other. For instance, if the equation for variable y is $y_i = x_i + z_i$ while the equation for variable z is $z_i = x_i + y_i$. Because y is needed to calculate z and z is needed to calculate y, there is endogeneity. A VAR allows for easier understanding of if there is a feedback loop between two variables, which is important if only one of the equations is important. If all we care about is projecting oil prices, and GDP is statistically significant in determining oil prices but oil prices are also statistically significant in determining GDP, then there is uncertainty about the validity of oil prices as a metric. This creates a nuisance in the calculation of future oil prices. The standard formula for an impulse response is the following where y is a state vector and e is a vector of shocks for n periods:

$$y_t = A^n y_{t-n} + A^{n-1} e_{t-(n-1)} + \ldots + e_t$$

For the impulse response functions, I have calculated a horizon of 40 periods into the future. This means that I will be able to show the effect of a singular shock over 10 years of time. This should leave enough time for the shock to wear off and for y_t to return to zero.

V – Results of VAR

The results of the first VAR are listed below.

Vector autoregression

Sample: 7 - 116		Number of obs =	110
Log likelihood =	-2263.825	AIC =	42.03318
FPE =	3.63e+14	HQIC =	42.51114
Det(Sigma_ml) =	1.51e+14	SBIC =	43.21157

Equation	Parms	RMSE	R-sq	chi2	P>chi2
fdimports	16	29983.1	0.5924	159.8561	0.0000
fdprice	16	8.37333	0.2467	36.01737	0.0018
fdgdp	16	70.4182	0.3410	56.92082	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
fdimports						
fdimports						
L1.	-.2015352	.0923873	-2.18	0.029	-.382611	-.0204594
L2.	-.3035912	.0816236	-3.72	0.000	-.4635705	-.1436118
L3.	-.1301488	.0862257	-1.51	0.131	-.2991481	.0388504
L4.	.5438654	.0835662	6.51	0.000	.3800786	.7076522
L5.	.0310736	.0945325	0.33	0.742	-.1542067	.2163539
fdprice						
L1.	-499.3942	383.1546	-1.30	0.192	-1250.363	251.575
L2.	279.5446	414.4405	0.67	0.500	-532.7439	1091.833
L3.	-322.2486	425.0826	-0.76	0.448	-1155.395	510.8981
L4.	926.0721	407.4487	2.27	0.023	127.4873	1724.657
L5.	-605.9954	384.1506	-1.58	0.115	-1358.917	146.926
fdgdp						
L1.	80.79789	44.53288	1.81	0.070	-6.484947	168.0807
L2.	79.93139	47.76468	1.67	0.094	-13.68566	173.5484
L3.	-79.41801	49.28856	-1.61	0.107	-176.0218	17.18578
L4.	-16.53177	48.9915	-0.34	0.736	-112.5534	79.4898
L5.	-55.89161	44.88331	-1.25	0.213	-143.8613	32.07806
_cons	1091.574	6550.993	0.17	0.868	-11748.14	13931.28

fdprice						
fdimports						
L1.	.0000311	.0000258	1.21	0.227	-.0000194	.0000817
L2.	-9.35e-06	.0000228	-0.41	0.682	-.000054	.0000353
L3.	.0000448	.0000241	1.86	0.063	-2.43e-06	.000092
L4.	.0000131	.0000233	0.56	0.574	-.0000326	.0000589
L5.	.0000101	.0000264	0.38	0.701	-.0000416	.0000619
fdprice						
L1.	.4341737	.107003	4.06	0.000	.2244517	.6438957
L2.	-.3218196	.1157402	-2.78	0.005	-.5486661	-.094973
L3.	-.0537379	.1187122	-0.45	0.651	-.2864095	.1789337
L4.	.0076063	.1137876	0.07	0.947	-.2154132	.2306259
L5.	-.1357856	.1072812	-1.27	0.206	-.3460528	.0744816
fdgdp						
L1.	-.0208082	.0124366	-1.67	0.094	-.0451835	.0035672
L2.	.0096191	.0133392	0.72	0.471	-.0165252	.0357634
L3.	.0210907	.0137647	1.53	0.125	-.0058877	.0480691
L4.	-.0098911	.0136818	-0.72	0.470	-.0367069	.0169247
L5.	-.0070123	.0125345	-0.56	0.576	-.0315794	.0175549
_cons	.9607155	1.829486	0.53	0.599	-2.625011	4.546442

fdgdp						
fdimports						
L1.	.0002923	.000217	1.35	0.178	-.0001329	.0007176
L2.	-.0003809	.0001917	-1.99	0.047	-.0007566	-5.14e-06
L3.	-.0001079	.0002025	-0.53	0.594	-.0005048	.000289
L4.	-.0000616	.0001963	-0.31	0.754	-.0004463	.0003231
L5.	-.0002908	.000222	-1.31	0.190	-.0007259	.0001444
fdprice						
L1.	1.444667	.8998755	1.61	0.108	-.3190566	3.20839
L2.	-1.242117	.9733536	-1.28	0.202	-3.149855	.6656209
L3.	-.9215847	.9983476	-0.92	0.356	-2.87831	1.035141
L4.	-.9140139	.9569326	-0.96	0.340	-2.789567	.9615395
L5.	-.8435159	.9022148	-0.93	0.350	-2.611825	.9247927
fdgdp						
L1.	.2627191	.1045898	2.51	0.012	.0577269	.4677113
L2.	.2407553	.11218	2.15	0.032	.0208866	.460624
L3.	.1577734	.1157589	1.36	0.173	-.06911	.3846567
L4.	.0935031	.1150613	0.81	0.416	-.1320128	.3190191
L5.	-.131127	.1054128	-1.24	0.214	-.3377322	.0754783
_cons	46.48308	15.38564	3.02	0.003	16.32778	76.63838

Oil imports had the largest R^2 of the three equations in the vector at 60%, meaning that oil prices are better explained by this 3 variable VAR than the other endogenous variables in the model. Oil price did not have a statistically significant effect on the quantity of barrels imported while GDP of the previous two quarters had a significant effect on the quantity of barrels imported. The coefficients for the two significant GDP period lags were both 80. Thus, if quarterly GDP increased by $100B, 80,000 more barrels would be imported in each of the next two periods.

For price per barrel, only 25% of the variance was explained by previous price, imports, and GDP. The fact that price per barrel explains imports more than imports explain price makes sense, as the U.S. is not the only nation to import oil. The fact that

U.SS. imports have any effect on oil pricing shows that the U.S. is a relatively large part (but not 100%) of global demand. Oil imports from a lag of three quarters had a significant effect on price; however, the coefficient was almost zero. Price also had some autocorrelation with a one period lag; thus, in this model, the best predictor of oil price change was the previous quarter's price change.

For GDP, only 34% of the variance was explained by previous GDP, price, and imports. This makes intuitive sense, as oil price and oil imports make up a very small part of the expenditures model of GDP. Furthermore, neither oil imports nor price are statistically significant in determining changes in GDP. GDP has autocorrelation, which means that the change in GDP will be positive if the previous period's change in GDP is positive.

For the most part, the 3-variable VAR shows that the first difference in GDP from the previous period has statistical significance when projecting oil price, the first difference from the previous two periods is significant in projecting imports, and that all the variables have some sort of autocorrelation with the previous period.

When manufacturing is added to the VAR, the R^2 for price and GDP jumps by almost 20%. In addition, the R^2 for the index change in manufacturing output is almost 75%, which implies that its VAR explains more of oil prices than any of the other endogenous variables. The AIC increases, but the overall significance of the model increases due to the addition of the manufacturing output.

Vector autoregression

Sample:	6 - 116		Number of obs	=	111
Log likelihood	= -2393.581		AIC	=	44.35282
FPE	= 2.17e+14		HQIC	=	45.02619
Det(Sigma_ml)	= 6.31e+13		SBIC	=	46.01271

Equation	Parms	RMSE	R-sq	chi2	P>chi2
fdimports	17	29785.6	0.5980	165.1249	0.0000
fdprice	17	7.24517	0.4361	85.82822	0.0000
fdgdp	17	59.6402	0.5273	123.8281	0.0000
fdoutput	17	1.10713	0.7464	326.6797	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
fdimports						
fdimports						
L1.	-.2399595	.0821605	-2.92	0.003	-.4009912	-.0789278
L2.	-.3093942	.0835363	-3.70	0.000	-.4731223	-.145666
L3.	-.1774042	.0836557	-2.12	0.034	-.3413663	-.0134421
L4.	.5157648	.0832081	6.20	0.000	.35268	.6788497
fdprice						
L1.	-784.0355	410.6209	-1.91	0.056	-1588.838	20.76661
L2.	-9.90284	425.4167	-0.02	0.981	-843.7042	823.8985
L3.	-430.9687	426.7876	-1.01	0.313	-1267.457	405.5196
L4.	582.9211	402.7555	1.45	0.148	-206.4651	1372.307
fdgdp						
L1.	60.81067	52.15276	1.17	0.244	-41.40686	163.0282
L2.	24.78824	54.21328	0.46	0.648	-81.46784	131.0443
L3.	-155.9324	53.31251	-2.92	0.003	-260.423	-51.44177
L4.	-6.393093	56.35148	-0.11	0.910	-116.84	104.0538
fdoutput						
L1.	-748.0485	3007.528	-0.25	0.804	-6642.695	5146.598
L2.	3149.923	3934.419	0.80	0.423	-4561.396	10861.24
L3.	7388.459	3867.832	1.91	0.056	-192.3531	14969.27
L4.	-5666.21	2674.895	-2.12	0.034	-10908.91	-423.5128
_cons	9991.756	8303.432	1.20	0.229	-6282.671	26266.18

fdprice						
fdimports						
L1.	.000035	.00002	1.75	0.080	-4.18e-06	.0000742
L2.	-5.81e-06	.0000203	-0.29	0.775	-.0000456	.000034
L3.	.0000344	.0000203	1.69	0.091	-5.45e-06	.0000743
L4.	2.77e-06	.0000202	0.14	0.891	-.0000369	.0000424
fdprice						
L1.	.2806587	.0998809	2.81	0.005	.0848956	.4764218
L2.	-.3134502	.1034799	-3.03	0.002	-.5162671	-.1106332
L3.	.083022	.1038134	0.80	0.424	-.1204486	.2864925
L4.	.1382055	.0979677	1.41	0.158	-.0538077	.3302188
fdgdp						
L1.	-.0577553	.0126858	-4.55	0.000	-.0826191	-.0328916
L2.	-.0158371	.013187	-1.20	0.230	-.0416832	.0100091
L3.	.0346723	.0129679	2.67	0.008	.0092556	.060089
L4.	.0220894	.0137071	1.61	0.107	-.0047761	.0489549
fdoutput						
L1.	3.356346	.7315623	4.59	0.000	1.92251	4.790182
L2.	.5330999	.9570227	0.56	0.578	-1.34263	2.40883
L3.	-3.164233	.940826	-3.36	0.001	-5.008218	-1.320248
L4.	.5287372	.6506514	0.81	0.416	-.746516	1.803991
_cons	1.462101	2.019758	0.72	0.469	-2.496551	5.420754
fdgdp						
fdimports						
L1.	.0002096	.0001645	1.27	0.203	-.0001128	.0005321
L2.	-.0002128	.0001673	-1.27	0.203	-.0005406	.0001151
L3.	-.0000251	.0001675	-0.15	0.881	-.0003534	.0003032
L4.	-8.75e-07	.0001666	-0.01	0.996	-.0003274	.0003257
fdprice						
L1.	.1953288	.8221912	0.24	0.812	-1.416136	1.806794
L2.	-1.035766	.851817	-1.22	0.224	-2.705297	.6337642
L3.	.734033	.854562	0.86	0.390	-.9408778	2.408944
L4.	.7712346	.8064422	0.96	0.339	-.8093631	2.351832
fdgdp						
L1.	-.0671891	.1044261	-0.64	0.520	-.2718606	.1374823
L2.	.0868723	.1085519	0.80	0.424	-.1258856	.2996301
L3.	.3426717	.1067483	3.21	0.001	.1334489	.5518946
L4.	.3442677	.1128333	3.05	0.002	.1231186	.5654168
fdoutput						
L1.	30.93377	6.02201	5.14	0.000	19.13085	42.73669
L2.	-1.2542	7.877935	-0.16	0.874	-16.69467	14.18627
L3.	-28.69949	7.744608	-3.71	0.000	-43.87865	-13.52034
L4.	1.531077	5.355975	0.29	0.775	-8.966441	12.02859
_cons	33.70925	16.62606	2.03	0.043	1.122766	66.29574

fdoutput						
fdimports						
L1.	-5.01e-07	3.05e-06	-0.16	0.870	-6.49e-06	5.48e-06
L2.	-4.14e-07	3.11e-06	-0.13	0.894	-6.50e-06	5.67e-06
L3.	-2.23e-07	3.11e-06	-0.07	0.943	-6.32e-06	5.87e-06
L4.	-1.25e-06	3.09e-06	-0.40	0.687	-7.31e-06	4.81e-06
fdprice						
L1.	.0133381	.0152628	0.87	0.382	-.0165763	.0432526
L2.	-.0539901	.0158127	-3.41	0.001	-.0849824	-.0229977
L3.	-.0005694	.0158637	-0.04	0.971	-.0316616	.0305229
L4.	-.0122235	.0149704	-0.82	0.414	-.0415649	.017118
fdgdp						
L1.	.0008085	.0019385	0.42	0.677	-.0029909	.004608
L2.	-.0008433	.0020151	-0.42	0.676	-.0047928	.0031062
L3.	-.0007853	.0019816	-0.40	0.692	-.0046692	.0030986
L4.	.001968	.0020946	0.94	0.347	-.0021373	.0060733
fdoutput						
L1.	1.040649	.1117897	9.31	0.000	.821545	1.259752
L2.	-.236689	.1462422	-1.62	0.106	-.5233184	.0499403
L3.	-.0182104	.1437671	-0.13	0.899	-.2999889	.263568
L4.	-.1312037	.0994257	-1.32	0.187	-.3260745	.0636671
_cons	.0567809	.3086382	0.18	0.854	-.5481388	.6617005

For imports, the price of a barrel of oil is statistically significant at the 90% confidence level and negative. If the price of a barrel of oil goes up by $10.00 in the current quarter, oil imports will decrease by 7.85 million barrels in the next quarter. This is a huge change at almost double the median change in imports. Fortunately, the median change in price was $0.66/barrel, thus the large change in imports would almost certainly be reversed in the following quarters. Changes in GDP lagged three periods have a significant effect on the quantity of barrels imported; however, the coefficient is negative. An increase in GDP will cause a decrease in oil imports three quarters later. This does not make intuitive sense, as one would expect oil imports to increase as income increased. But this rise in GDP could also be independent of manufacturing; a rise in oil production or a rise in oil-lacking services could easily cause national income to increase without having any effect on oil imports. This effect could be due to possible increased purchase of American oil with increased budgets or an increased purchase in cheaper, foreign oil if national income decreases. Imports are also negatively autocorrelated from the previous period. There could be some federal policy behind this, but if the number of barrels imported in the period is greater than the number of barrels imported in the previous period, it can be expected that the number of barrels imported next period will be smaller than the number of barrels imported in the current period.

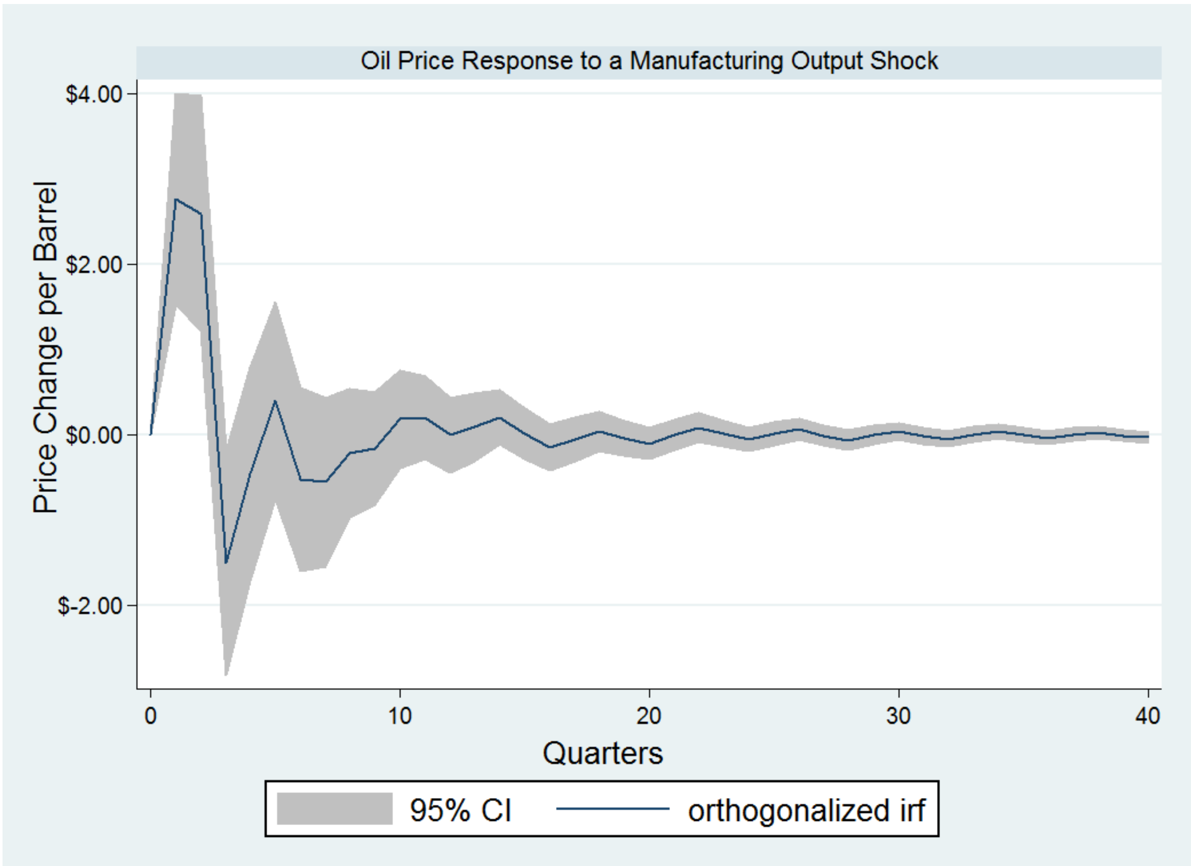
For price, imports lagged by one period are also statistically significant at the 90% confidence level. Thus, there is endogeneity between barrels imported and oil prices, as both variables are significant in calculating the future price of the other. However, the coefficient for the oil imports lagged by one period is almost zero. An increase of 10,000 imported barrels of oil would increase the price per barrel by less than one cent. Price is also positively autocorrelated with its previous period price. Thus, past price change is a good predictor of present price change. Of most interesting note is that now a one period lag of GDP and manufacturing output is significant at the 99.9% confidence level while a three-period lag for both GDP and manufacturing is significant at the 99% level. The coefficient for GDP lagged one period is both negative and large. A $100B increase in GDP will lower the price of oil by almost $6 a barrel next quarter. However, the coefficient for GDP lagged three periods has a slightly lower value, but with a flipped sign. The reason that three period lagged GDP and current period oil prices have matching signs could be due to other economic changes. Three periods could be enough for suppliers to increase their price for the wealthier client. For manufacturing output, the same can be said, except that a one period lag has a positive sign whereas a three-period lag has a negative sign. If manufacturing output increases by 1%, the price of oil the next quarter increases by $3.36. This might not be enough time to truly view what happens with output, however, as if manufacturing output increases by 1%, the price of oil three quarters later will have fallen by $3.16. This is a marginal change, and after three quarters, the effect of an output shock will have been reversed. The impulse response function showing the change in price per barrel following an oil shock graphically shows this change. The reason for this change could be that if manufacturing output increases, immediately oil supplying nations will charge a higher price, as their customers might be more willing to pay, but as time increases, manufacturing output could begin to slow from the higher oil prices, and thus suppliers will lower their prices to the now poorer customer.

GDP has a much interesting outcome from this model. Oil price does not have a statistically significant relationship with GDP. Thus, it is safe to reject the argument that oil prices affect GDP. GDP also is not autocorrelated with lags of one quarter and two quarters, but has a statistically significant relationship with manufacturing output lagged one period and three periods. The signs on the correlation coefficients here also flip between the 3 period lag and the one period lag. If manufacturing output increases by 1%, GDP first increases by $31B, adjusts, and then, assuming no changes to output, decreases by $28.7B. The reason for this is simple: if firms immediately increase output, investment increases and GDP increases. However, a purchase of a manufactured good is not a regular purchase, thus less is purchased and GDP falls back closer to its original level.

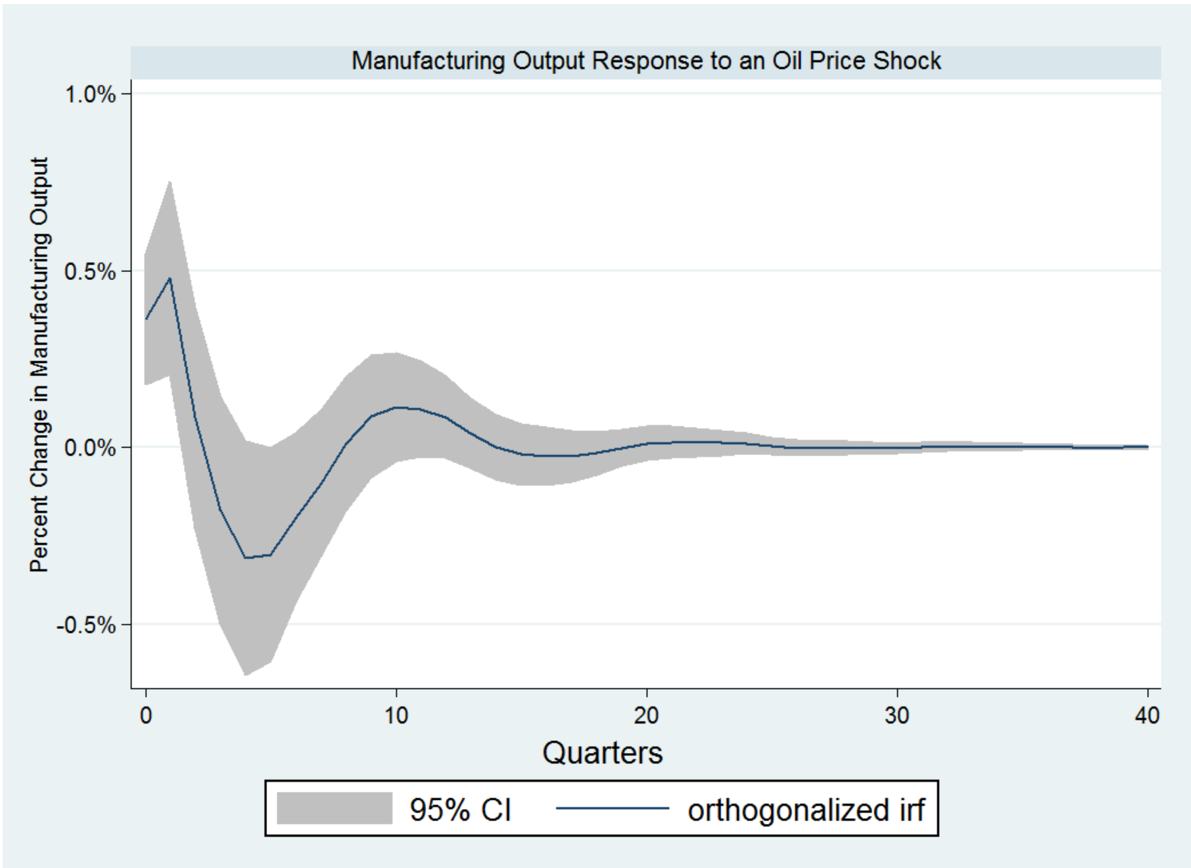
Finally, there are significant results for the most interesting equation in the vector: manufacturing output. Manufacturing output is highly autocorrelated with the output from the previous period and changes at almost a 1 to 1 ratio. Oil imports have no significant effect on manufacturing output. This makes complete sense as a country that wants to build infrastructure or goods will import oil, but a positive shock to oil imports might not necessarily change manufacturing output. GDP also has no statistically significant effect on manufacturing output, which means that there is also no endogeneity between GDP and manufacturing output. This is odd, in that these results show an elasticity of demand for domestic manufacturing goods to be approximately zero. But most interestingly, oil prices lagged two quarters are statistically significant at the 99.9% confidence level. If the price of oil goes up by $10 a barrel, manufacturing output two quarters later will fall by 0.5%. 0.5% is not a significant decrease for national income, as a 0.5% decrease in output leads to a $15B decrease in GDP the quarter after (by contrast, quarterly GDP changed usually by an absolute value close to $100B each quarter). But a 0.5% decrease does lead to a loss of jobs in the sector itself, so while the whole country might be unaffected, the manufacturers are not. Especially in manufacturing industries that are more oil intensive, the effect on job loss could be much heavier. Based on this, it is safe to say that oil prices significantly affect manufacturing output, just not immediately. Because manufacturing output is also statistically significant when calculating oil prices, there is a feedback loop between the two variables. This means the two variables are endogenous, and thus it is almost impossible to figure out which variable has a stronger impact on the other.

VI – Results of IRF

The impulse response functions can best show the effect of how a shock on one variable impacts a different variable over time. First, we will look at the effects that a shock to manufacturing output had on oil prices.



A manufacturing shock has an almost immediate positive effect on the price per barrel of oil; however, there is a negative shock of almost the exact same size as the original shock shortly after. The small decrease after the first quarter shock is caused by the endogeneity of the two variables. An increased price has a negative effect on manufacturing output in the second quarter, and that outweighs the insignificant positive effect that increased output has on oil prices for the quarter. By 10 quarters (2.5 years) the effect of the shock has completely worn off and output holds constant until the next shock.



An oil price shock has a strong and immediate influence on manufacturing output. The graph for the oil price shock is much smoother than that of the manufacturing output shock. Even so, the magnitude of the price shock is almost identical to the magnitude of the manufacturing output shock. Therefore, due to the endogeneity issue mentioned above, it is very difficult to tell which effect is stronger: manufacturing output on oil price or oil price on manufacturing output.

VII - Conclusion

In conclusion, we find that manufacturing output has a statistically significant effect on oil prices; however, we also find that oil prices have a statistically significant effect on manufacturing output. This feedback loop creates problems, as it is harder to isolate what sectors oil prices are truly important and exogenous in. Possible future studies include finding quarterly industry data to calculate the effect oil prices have on certain industries, or possibly breaking apart the manufacturing sector into oil intensive industries and oil lacking industries to see if oil prices and the two separate sectors still have a feedback loop. To figure out what variables are exogenous with manufacturing output, certain state policies could be examined along with the political parties in control of state legislatures. Other commodity prices such as steel could also be included to see if they have any exogenous effect on manufacturing prices. Still the point remains: it is known that oil prices are significant in determining future manufacturing output, and it is known that manufacturing output is significant in determining future oil output.

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