Energy Prices and Economic Growth

Granger Causality*

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*Dr. Ransom, thanks for being so consistently helpful, excited to teach, and well-prepared for class. It has been a pleasure

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1 Introduction

My interest in this subject came about from two events. The first was my capstone course where we read one academic paper on the effect that oil price changes have on employment. As an energy management dual major, the intersection of these topics was nearly too much to resist. The other event was simply my interest in the energy sector broadly. The U.S. became a net energy exporter in 2018 for the first time since the 1950s, which can have very real, and very beneficial effects on our economy. For example, in the 1970s, the United States economy was dramatically effected by the OPEC oil crises in 1973 and 1979. At that time we were to reliant on foreign energy sources that when OPEN severely cut production and simultaneously jacked up prices the price of WTI crude oil increased by over 100 percent overnight. With energy independence comes less volatility in these commodity prices, which could have positive effects on employment sectors across the economy.

My research topic for this paper has to do with analyzing the empirical relationship between energy commodity prices, both oil and natural gas, and economic growth in the form of real GDP. Phrased as a question, it would be: Does there exist a relationship between real gross domestic product, spot prices for WTI crude oil, and spot prices of HH natural gas? And, is this relationship causal. I have tested the relationships between all three variables on each other. Better understanding the relationship between them can allow for policy makers to be more informed when setting the agenda for energy policy for the future. One example would be granting the treasury or commerce department the ability to suspend futures trading during geopolitical turmoil, much like they are able to do with the stock market. The paper is standard in its formatting, which includes a literature review, data, empirical methods, research findings, and conclusion sections. It will all be followed by references, tables, and figures.

2 Literature Review

There exists many studies and papers on the topic of energy and economic growth. The literature on the junction of these topics is very extensive. A large portion of this literature is focused on either developing countries or countries that have been developed since data has been collected on these topics. In (Asafu-Adjaye, 2000) for example, estimates the causal relationship between energy consumption and income for India, Indonesia, the Philippines and Thailand using similar techniques to those used in this paper.

Here (Asafu-Adjaye, 2000) Here (Zhang and Cheng, 2009) Here (Paul and Bhattacharya, 2004) Here (Mehrara, 2007) Here (Ritchie, McDougall, and Claxton, 1981)

3 Data

The data used for this project comes from two main sources. The first data set comes from the Energy Information Association, which is an independent governmental agency that focuses on all statistics and analysis related to energy. In order to retrieve this data, I utilized the site API that will allow for specific time range of values to be pulled. This API function was included in the R package ”EIAdata”. It includes the spot prices for West Texas Intermediate (WTI) crude oil, which is set each day in Cushing, Oklahoma, where the largest intersection of pipes occur in the United States. These prices are for an entire barrel of crude oil, which is roughly 42 gallons worth. The date range for this data originally was from 1986-12-31 to 2018-12-31, and measured on an annual averaged basis, though I was forced to trim the years used in analysis to 1997-12-31 forward, as the specific code function I used for the Granger test required data columns of the same length. The second data set from this source included the spot price of Henry Hub (HH) Natural Gas, which is set daily in Erath, Louisiana. This price is measured as dollar per million British Thermal Units (BTU), which is the most common form of energy measure used in the US. Much like the WTI data, the HH spot prices are measured on an annual average frequency; this frequency was chosen only after attempting to utilize both weekly and monthly averaged data. In addition, the data were again trimmed to fit analysis length. I chose these variables because petroleum and natural gas represent the two highest percentage sources of energy in the United States at 36 percent and 28 percent respectively. The prices of these commodities are directly related to the demand and supply of energy (read production and consumption), and will allow us to get a broader image of the relationship.

The final data set comes from the final source from the St. Louis branch of the Federal Reserve. To retrieve this data, I again utilized a site API to pull data. This API function included in the R package ”fredr”. As for content, the data set was of real gross domestic product (rGDP throughout). It is measured in billions of chained 2012 Dollars that have been seasonally adjusted at an annual rate. The date ranges were again chosen to match the above range of 1997 to 2018 following many attempts at utilizing weekly, monthly, and quarterly data .I chose this variable to represent the Economic Growth portion of my analysis because adjusted GDP is the most basic measure of economic growth in the US Economy, just from a quantity measure that has been adjusted. To measure growth, it would be ideal to measure the log of rGDP or even the log of log(rGDP) as these measures would show a form of growth great or at least the percentage change; however, that is beyond what this paper examines as I was unable to get the said data measures to work with the lmtest granger operation. Figure one shows summary statistics for the three variables of measure.

4 Empirical Methods

My approach, as apparent by the title of the paper, relies on a Granger causal analysis, which is a statistical hypothesis testing method used for determining whether one a given time series is useful in forecasting another. In this case, we will be using spot price time series data for WTI crude oil and HH natural gas to determine if they are useful in forecasting real GDP, and vise versa.

The tests run in this paper can best be depicted as a variation of the following equations (which are one Granger causality test):

$$x(t) = \sum_{j=1}^{k} + \alpha_i x(t-1) + \sum_{j=1}^{k} \beta_j z(t-j) + c_2 + u_2(t) \tag{1}$$

$$z(t) = \sum_{j=1}^{k} + \alpha_i z(t-1) + \sum_{j=1}^{k} \beta_j x(t-j) + c_2 + u_2(t) \tag{2}$$

where x_t represents the a continuous variable of WTI Petroleum price data and z_t represents a continuous variables for real GDP data in year t. These equations represent a Grangner causality test on both variables x and z. The first equation tests whether past values of z are useful in predicting values of x. The second portion of equation one represents the lagged inputs of z to be tested on x. The second equation is functionally the same test in equation one, but it switches variables x and z to test if past values of x are useful in predicting z.

The next two equations represent the second Granger causality test:

$$y(t) = \sum_{j=1}^{k} + \alpha_i y(t-1) + \sum_{j=1}^{k} \beta_j z(t-j) + c_2 + u_2(t) \tag{3}$$

$$z(t) = \sum_{j=1}^{k} + \alpha_i z(t-1) + \sum_{j=1}^{k} \beta_j y(t-j) + c_2 + u_2(t) \tag{4}$$

These equations are the same methods presented in the previous two, though the variables tested have changed. In this case, y_t represents a continuous variable for Henry Hub natural gas spot prices from the data described above. Additionally, z_t still represents the real GDP data in this test. As mentioned, the third equation is testing whether lagged, or previous, values of z are useful in predicting values of y. The fourth equation is testing whether lagged values of y are useful in predicting values of z.

The following equations represent the final Granger causality test performed in this paper:

$$x(t) = \sum_{j=1}^{k} + \alpha_i x(t-1) + \sum_{j=1}^{k} \beta_j y(t-j) + c_2 + u_2(t) \tag{5}$$

$$y(t) = \sum_{j=1}^{k} + \alpha_i y(t-1) + \sum_{j=1}^{k} \beta_j x(t-j) + c_2 + u_2(t) \tag{6}$$

These equations are the same methods presented in the previous four, though the variables tested have changed. In this case, x_t represents a continuous variable for WTI crude oil spot prices from the data described above. Additionally, y_t still represents the Henry Hub natural gas spot prices in this test. As mentioned, the fifth equation is testing whether lagged, or previous, values of y are useful in predicting values of x. The sixth equation is testing whether lagged values of x are useful in predicting values of y.

It is worth noting that the form in which I performed these three Granger tests above was not in VAR format exactly as shown above. The equations represent the theory and application of the tests, though I used a handy R function from the *lmtest* package called *grangertest*. This function allows you to test perform the tests in a very simple manner. For example, to perform the first Granger test (equations one and two), you simply have to type $grangertest(x, z, order = 2)$, which performs the test with lag order of two.

5 Research Findings

The main results are reported in Tables one through three. The way to carry out a Granger causality test is the same process as a regular OLS regression. We set up both a null hypothesis and test whether that hypothesis holds up given the statistical outputs from the $grangertest()$ function that we used in R.

As such, the hypothesis for the first Granger causality test is as follows:

H_0 = values of z (Real GDP values) do not cause the values of x to change.

H_1 = values of z (Real GDP values) do in fact cause the values of x to change.

The $grangertest()$ function also provides statistics that allows us to interpret our output with an F test. For the given output of this test, we are given an F stat of 2.1786 and a P-stat of 0.1477, which is 14.77 percent. To determine whether to accept or reject the H_0 hypothesis, we look at the given value of the P-stat. The general rule of thumb is if the P-stat ¡ the level of significance at 0.05 or 5 percent, then you can reject the null hypothesis and say that your variable effects the outcome of the other, or put another way, it is causal. In this instance, the p-stat is not below the 5 percent level of significance, so we accept the H_0 value and say that past values of z (rGDP) do not change values of x (WTI).This also holds true for the testing of past values of x on z as well.

For the second test, the hypothesis for the Granger causality test is as follows:

H_0 = values of z (Real GDP values) do not cause the values of y to change.

H_1 = values of z (Real GDP values) do in fact cause the values of y to change.

For the test results we are given an F-stat of 3.3178 and a P-stat of 0.06411 or 6.41 percent. In this instance, the p-stat is not below the 5 percent level of significance, so we accept the H_0 value and say that past values of z (rGDP) do not change values of y (WTI). This also holds true for the testing of past values of y on z as well.

For the third test, the hypothesis for the Granger causality test is as follows:

H_0 = values of y (Real GDP values) do not cause the values of x to change.

H_1 = values of y (Real GDP values) do in fact cause the values of x to change.

For the test results we are given an F-stat of 1.7642 and a P-stat of 0.2051 or 20.51 percent. In this instance, the p-stat is not below the 5 percent level of significance, so we accept the H_0 value and say that past values of y (rGDP) do not change values of x (WTI). This also holds true for the testing of past values of x on y as well. It is also worth mentioning that changing the lag order selection did not lead to results that were significant for all three of the tests in this paper, from the measure of p-stat in the F-test.

6 Conclusion

The findings of this research have not been consistent with predicted results. The literature (even beyond what is presented in this paper) on the topic of economic growth and energy are pretty consistent in stating that there is at least a partial causal relationship between them, though this paper was not able to prove that. This failure is likely due to the data and approach of the analysis in the models used in this paper. In considering the data used, there are a few assumptions and practices used that were likely the cause of the failed results. Firstly, only annual data was used due to the author's inability to get the *grangertest* function to accept the daily, weekly, monthly, and quarterly data from the HH and WTI spot prices. Additionally, upon looking back it makes more sense to take the log of the rGDP data to get the percent change in economic output (i.e. growth) rather than the raw output. Or, even better, to take the log of the log of rGDP to get a form of growth rate during the timeline. If the issues mentioned above were accounted for in further analysis, then the results produced would likely be consistent with the literature on the intersection of these topics.

This focus of research is still important, however, even given the results of this paper. Energy is perhaps the most significant factor contributing to the success of the human race, very broadly. Efficiently harnessing it allowed for the industrial revolution that saw the greatest percent change in economic growth ever over the time period. Given that the US has recently become a net exporter of energy in the last year, the understanding of the relationship between economic growth and energy consumption is vital. Greater energy dependence will likely lead to more price stability, which in-turn effects many other sectors of the economy. Further analysis should focus on the causation between energy sources and economic growth, as the energy consumption and production portfolio is ever changing towards a more renewable focused industry.

References

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Figures and Tables

Table 1: Granger test 1

Model 1:	z ~Lags(z, 1:2) + Lags(x, 1:2)		
Model 2:	z ~Lags(z, 1:2)		
Res.Df	Df	F	Pr(>F)
15			
17	-2	2.1786	0.1477

Signif. codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 1

Table 2: Granger test 2

Model 1:	z ~Lags(z, 1:2) + Lags(y, 1:2)		
Model 2:	z ~Lags(z, 1:2)		
Res.Df	Df	F	Pr(>F)
15			
17	-2	3.3178	0.06411

Signif. codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 1

Table 3: Granger test 3

Model 1:	y ~Lags(y, 1:2) + Lags(x, 1:2)		
Model 2:	y ~Lags(y, 1:2)		
Res.Df	Df	F	Pr(>F)
15			
17	-2	1.7642	0.2051

Signif. codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 1

Table 4: Summary of x

Min.	1st Qu.	Median	Mean	3rd Qu.	Max
14.42	30.55	53.72	56.08	77.69	99.67

Table 4: Summary of y

Min.	1st Qu.	Median	Mean	3rd Qu.	Max
2.090	2.810	3.950	4.343	5.195	8.860

Table 4: Summary of z

Min.	1st Qu.	Median	Mean	3rd Qu.	Max
11522	13590	15469	15169	16421	18566

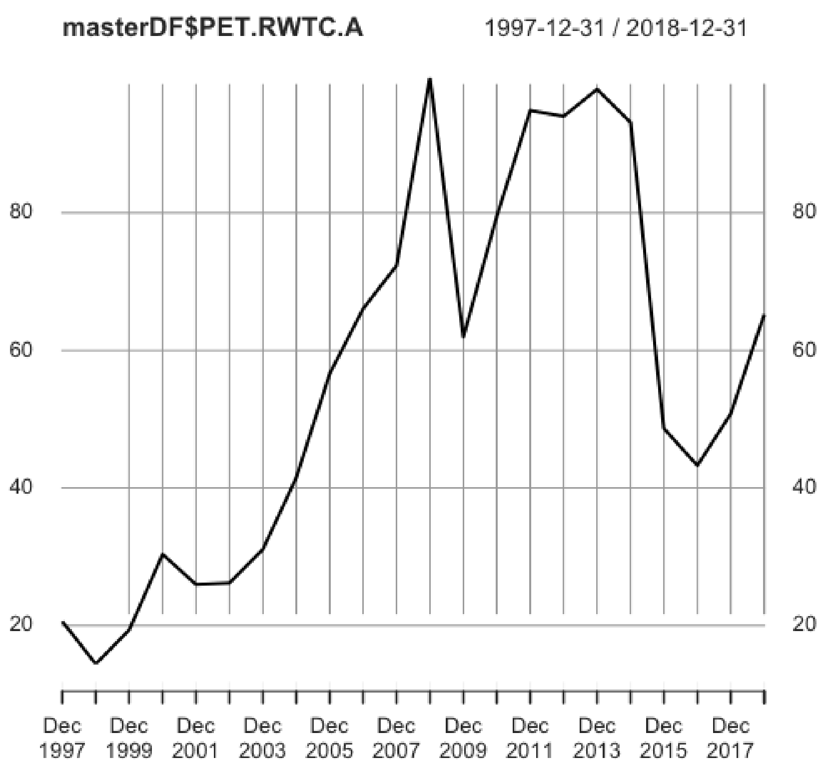

Figure 1: WTI Crude Plotted

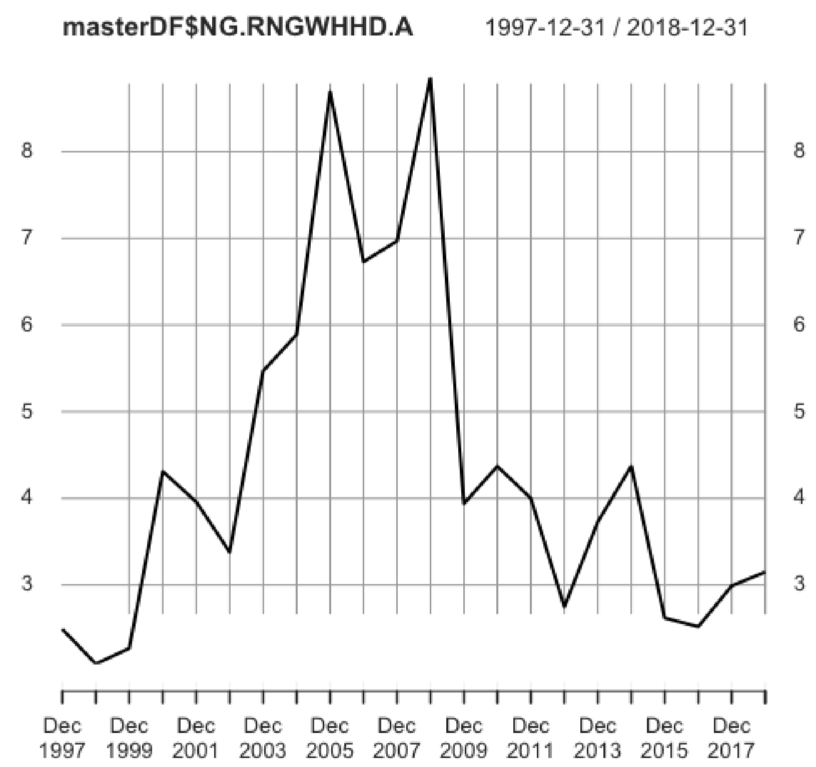

Figure 2: HH Natural Gas Plotted

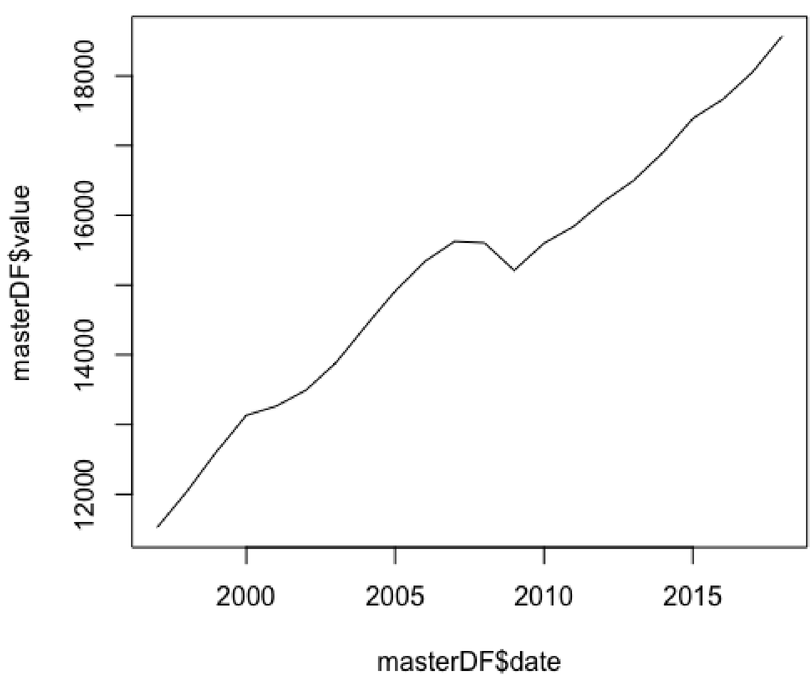

Figure 3: rGDP Plotted