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THE SHALE BOOM AND THE EFFECTS ON ENERGY MARKETS:
A Look Into Natural Gas and Crude Oil Futures and Spot Prices and their Relation to Economic Growth

by

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of

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in

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Introduction

A key political concern for the United States (US) since World War II has been its dependence on foreign energy. These concerns have arisen from a volatile nature of crude oil prices and the country's preexisting beliefs of peak oil in the early 1970s, resulting in unpredictable energy markets. Highlighted have been episodes of rising oil prices leading to recessions, higher inflation rates, and economic stagnation (Brown and Yucel, 2013). Changing this story are recent gains in both crude oil and natural gas production, helping to vault the country to at least temporary energy stardom. In fact, 2014 statistics from the US Energy Information Administration (EIA) showed that domestic total technically recoverable *shale gas* resources are at 665 trillion cubic feet. The EIA also showed that in the year 2000 natural gas from shale formations provided only 1% of US natural gas production; by 2010 it was over 20% and the EIA predicts that by 2035, 46% of the natural gas supply will come from shale gas.

Regarding oil, domestic reserves of total technically recoverable *shale oil* are estimated at 58 billion barrels (US EIA, 2014). In addition to shale oil, an updated announcement in 2009 from the US Geological Survey showed more reserves in an existing formation, resulting in an even larger amount of total technically recoverable *oil shale* reserves at 2.6 trillion barrels, according to the Institute for Energy Research. This revolution has helped to turn the vulnerabilities related to energy into strengths by potentially supporting the country's energy needs for the next several hundred years at current consumption rates.

The news also brings critical energy policy implications, as the reserves have the potential to significantly lower domestic energy prices and bring energy independence to the US. The findings in this paper provide insight on the pricing in natural gas and crude oil commodities markets seen after the shale boom, which are then related to economic performance in the US. I begin with a review of carbon-based energy markets, the history of hydraulic fracturing, a literature review, and then continue with the theoretical model and methodology.

By kinked times series regression I simultaneously attempt to determine and estimate any changes seen in 10 different US spot and futures prices of crude oil and natural gas before and after the shale boom. This information is important as these prices sequentially affect the prices seen in broader energy markets, such as those of electricity and transportation, while also impacting policy-making as the country continues to seek cleaner energy. In the event of a decline in energy prices, not only does it provide an avenue for economic growth but also the potential to reshape the future of energy markets and further stimulate research and development.

For the analysis I follow microeconomic theory such that an increase in supply of a good will result in lower prices for that good. Because of the shale boom, the domestic supply and estimated available reserves of both crude oil and natural gas became increasingly large and I hypothesize a decline in the prices of both commodities. Additionally, there has never been a general agreed upon consensus on the causality issue of whether economic growth leads to declining energy prices, or if cheaper energy is causal to more rapid economic development. Thus, the last component I investigate is a question similar to this, where I test the effect of energy prices on US gross domestic product (GDP). My hypothesis here is that if there is a decline in energy prices, there will be an associated rise in US GDP.

Carbon-Based Energy Markets

US energy market volatility dates back many years to the 1860s and up through World War II. Some worldwide stability finally came throughout parts of the 1950s-60s, as there was more than one power in the world oil market. The volatility notably returned in the 1970s after the Yom Kippur War, where in December 1973 oil prices spiked 130% over and above the earlier 70% spike in October of that same year after the Organization of Petroleum Exporting Countries (OPEC) oil embargo (Ross, 2013). When the embargo was lifted, oil prices were $12 per barrel, roughly four times the pre-crisis price. This shock resulted in years of inflation and stagnation for many oil-importing countries and further instability in oil prices with the newly gained market power of OPEC.

Faced with more expensive oil, oil-importing countries were left with the decision to pay the higher prices, cut back on oil consumption, or seek new and alternative energy sources. Choosing the latter, the US made large investments in alternative energy and energy efficiency. The results were further developing technologies in energy sources such as coal, natural gas, and nuclear power, helping to revolutionize the energy industry and the outlook on its future. Additionally, the US was given a head start on the idea of energy conservation, given the perception of an imminent depletion of global oil and gas reserves after the addresses of President Jimmy Carter on the energy crisis, where he warned that oil wells "were drying up all over the world" (Ross, 2013). Carter also urged for price deregulation and fuel switching to solar energy and other renewable sources, while further developing the energy potential from fossil fuels in shale formations.

In attempt to alleviate fuel shortages and find stability in energy pricing, the United States government began further spending on energy innovation within the country. Federal energy investment rose sevenfold from 1973-1979 (Ross, 2013), where the largest gains were seen in fossil fuel energy research and development programs, which grew from $143 million in 1974 to $1.41 billion in 1979 (Dooley, 2008). Another longer period estimate from Shellenberger and Nordhaus (2011) states that federal Energy Department investment expenditures approached $24 billion for fossil fuel research from 1978-2007, where billions more were also spent through the Gas Research Institute and on unconventional gas credits.

However, in 1979 after the Iranian revolution and the fall of the Shah another oil shock was seen. This shock was a decline in worldwide crude oil production of roughly 10%, causing widespread panic and driving the price of crude oil from just under $16 per barrel to nearly $40 per barrel between 1980-81 (Kubarych, 2005). In the following 25 years three more large oil shocks occur, but collectively the realization of the country's oil dependence and vulnerability to imported energy to go along with the fear of running out of oil spurned large investments in energy research and development. Following the need to exploit other existing energy sources, government investment, private entrepreneurship, technology innovations, private land and mineral rights ownership, high natural gas prices in the 2000s, and a number of other factors all made important contributions to an energy revolution and what is now known as the shale boom (Wang & Krupnick, 2013).

The Difference Between Shale Gas, Shale Oil and Oil Shale

For the purposes of this paper I only concern the energy production from shale formations, but for clarification, shale gas, shale oil, and oil shale are vastly different energy resources with different scales of proven reserves despite their similar names.

Within shale rock formations both natural gas and crude oil can be found. Shale gas is simply natural gas trapped in a shale formation, and shale oil is a high quality crude oil trapped in shale rock that does not require special processing. Oil shale on the other hand is not oil nor is it necessarily found in shale rock. It is instead a precursor to oil as it is a sedimentary rock containing kerogen and is rich in organic material. To actually be of use the oil shale must be heated to 600-750 degrees Fahrenheit to separate the kerogen from the rock, which can then be extracted from a well using the traditional method. The resultant petroleum-like liquid can then be processed into superior quality and high value liquid fuels, however the technologies for developing oil shale are still underdeveloped and unrelated to my paper.

Hydraulic Fracturing (Fracking) and Its History

Hydraulic fracturing is a simple process. It frees trapped high quality crude oil or natural gas by creating fractures in the surrounding rock formation by injecting the rock with high pressure bursts of a mixture of water, proppant (frac sand) and industry-specific chemicals after drilling. The proppant is left behind in the newly created cracks, thus holding open or “propping open” the cracks and allowing the oil and gas resources to seep or flow more freely into well for extraction through the well bore.

The origins of fracking however, date back to around the Civil War period, when in 1866 Edward A.L. Roberts was granted US patent no. 59,936 (US Patents Office, 1875). His invention was known as the “Exploding Torpedo,” which aided in the process for recovering petroleum by use of an underground nuclear explosion. The invention resulted in conventional oil production increases of 1,200% within the first week after underground explosion, helping his company to flourish while also helping other companies do the same to their wells. This invention gave birth to the modern day fracking industry, where Roberts' patent is said to have been responsible for more civil litigation in defense of a patent than any one in US history (Wells, 2014).

The next evolution of the Exploding Torpedo came in 1947, in Grant County, Kansas, where the very first experimental hydraulic fracturing treatment took place in a natural gas play (Suchy and Newell, 2012). Similarly to what fueled Roberts' invention, the treatment was performed to bypass a clogging in the oil-bearing rock formation, though this treatment had no connection to shale formations. Two years later on March 17, 1949, the first two commercial hydraulic fracturing operations were successfully completed. The Halliburton and Stanolid Co. performed one on an oil well near Duncan, Oklahoma and another on an oil well near Holliday, Texas (Suchy and Newell, 2012). These initial treatments were unsophisticated, but the production trials provided enhancement to existing methods and the potential for advancement in the techniques, fluids, modeling and types of hydrocarbon extraction was made further known.

In the mid-1970s when energy spending began to increase, a partnership of private oil and natural gas operators, the US Department of Energy (DOE) and predecessor agencies, and the Gas Research Institute combined to develop the technologies for the commercial production of natural gas from the Devonian shale play in the eastern US (US EIA, 2011). The collaboration helped to foster the technologies of 3D imaging and mapping, horizontal drilling, slick-water fracturing, and multi-stage fracturing, that later became crucial to the economical production of crude oil and natural gas from shale formations. Due to the capital-intensive nature of the industry however, minimal incentives resulted in risky investments needed for development and such investments were rare for smaller oil and gas firms in the beginning, as innovations in technologies within the oil and gas industry are difficult to maintain as proprietary. Instead, the larger and more independent firms made these expenditures with the aid of government spending in the 1970s, 1980s, and 1990s. Most notable was Mitchell Energy, a large private company headed by George Mitchell, for its work in developing shale.

Mitchell Energy was the first company to correctly combine the practices after trial and error and $250 million of internal investment (Steward, 2007) in research and development from 1981-1997. Although faced with much doubt and opposition they were wasting time and money, Mitchell Energy was incrementally able to create the improvements needed to perfect the practices, thus lowering costs of extraction and enabling profitable shale gas production (US EIA, 2011). Further evidence that technology has improved within the industry can be seen in the time it has taken to drill a well. Halliburton began an ambitious program in 2009 to improve its drilling practices. The results reduced average drilling days per well from 18-20 to less than 9, and provided company savings of $75,000 per drilling day saved (Halliburton, 2011).

Literature Review

To put the volatility of US energy markets into perspective, a study by Regnier (2007) found that crude oil, refined petroleum, and natural gas prices are more volatile than prices for about 95% of products sold by domestic producers. She also found that relative to crude commodities, crude oil prices are currently more volatile than about 65% of other products. Generally speaking however, studies on oil markets are widely available, such as the one by Yang, Hwang and Huang (2002) that researched the factors affecting price volatility of the US oil market. Their model attempted to forecast this volatility and predicted an increase in oil prices following a 4% cut in OPEC production. Another study by Ghalayini (2012) studied oil price volatility and the factors that affect oil spot price. The results found that together, five variables of oil price, oil demand and supply, the dollar-exchange rate value and activity in futures markets validate a long-run relationship. Further, the estimates of the Vector Error Correction Model showed that supply negatively influences oil spot price in the long run, but demand is a significant explanatory power in the short run only.

Chin, Le Blanc and Coition (2005) took an approach from another school of thought to the determination of crude oil prices, which is that commodity markets are generally efficient and futures prices have the power to forecast realized spot prices. Not too surprisingly their widely supported approach showed futures prices to be unbiased predictors of future spot prices, although the prediction error was large. Other hypotheses for the fractions of oil price variations not explained by oil inventories include: the difference between spot and futures prices, speculation defined as the long-run positions held by non commercials of oil, gasoline and heating oil in the New York Mercantile Exchange (NYMEX) futures market, OPEC's spare capacity along with the relative level of US commercial stocks, and finally, different long-run and short-run interest rates (Ghalayini, 2012).

Less pronounced, unfortunately, are studies for natural gas markets. One study by Acaravci, Ozturk, and Kandir (2012) showed a unique long-term equilibrium relationship between natural gas prices, industrial production and stock prices in five European Union countries. Kinnaman (2011) estimated a 1% increase in the price of natural gas would increase the number of new wells drilled by 2.70%. Other existing studies primarily integrate natural gas markets with oil markets, which I believe buries the effects that natural gas is having on the current US energy outlook. However, given the impeding greenhouse gas goals and regulations, new natural gas studies are beginning to relate to changes in the electric power sector, of which has undergone a transformation due to the rise in the availability and use of shale gas. Already seen have been some of the most significant changes in the operation of the electricity generation portfolio since World War II, due to the use of natural gas in its production.

Simulating the impacts of forthcoming EPA rules on power plants, decarbonization options, and other environmental regulatory options such as the expansion of natural gas use outside of the power sector, the models of Logan et al (2013) showed a strong growth in natural gas generation and a 2.5-fold increase in natural gas demand by 2050. Further regarding environmental stewardship, Jacoby, O'Sullivan and Paltsev (2012) reviewed the policy impact of shale gas by analyzing two scenarios of greenhouse gas control—one mandating renewable generation and coal retirement, the other using price to achieve a 50% emissions reduction. The results showed shale gas benefitting the national economy and easing the task of emissions control, likely providing support for the continued fuel switching of power plants to natural gas in order to meet renewable portfolio standards.

In terms of shale energy production, Rystad Energy (2012) stated that shale oil resources in the US became economically exploitable at oil prices between $45 and $70 per barrel, with higher quality shales such as the Bakken and Eagleford plays closer to the lower bound. The production of shale oil also has lagged that of shale gas by several years according to Aguilera and Radetzki (2014), because of the forces on prices seen in the industry resulting in the exploitation of alternative fuel sources. Brigida (2014) investigated the switching relationship between natural gas and crude oil futures prices and found that natural gas and crude oil prices are cointegrated. His analysis showed that the two prices did not permanently decouple in the early 2000s, but rather experienced a temporary shift in regimes, which I believe to be a credit to the advances in production of shale gas years earlier than shale oil.

Regardless, shale extraction is still at a relatively young stage and whatever one thinks about shale gas today, with many holding concerns about its environmental consequences, there is no denying the economic return on taxpayer investments. Shale is largely influencing structural changes in US energy markets, helping to bring more domestic energy independence and likely allowing the United States to go from net gas importer to a net gas exporter over the next decade. Concentrating studies to those related to the prices of crude oil and natural gas, there have been no existing estimates to quantify any changes in energy prices seen post shale boom. Considering the demand and supply side, my analysis in this paper will provide insight on the pricing in both natural gas and crude oil commodities markets, estimating domestic US spot prices and four futures contracts for each resource. I believe the estimates provided in this paper have great potential to spawn into further research once more fracking-related data comes available.

Theoretical Model and Data

It is simple microeconomic theory to expect that an increase in the supply of a good will lead to a reduction in the price of that good. In addition, theory follows that a decline in price of a good should lead to a decrease in demand for substitute goods, and thus a decrease in prices of substitute goods. In the case of energy markets, it can also be theorized that prices of energy are explained well by the available supply of the resource. To explain the prices of crude oil I follow the model of Yang, Hwang and Huang (2002), which is actually an inverse oil demand function, seen in equation (1):

(1) $$\mathit{Oil\ Price} = \beta_0 + \beta_1\,\mathit{Natural\ Gas\ Price} + \beta_2\,\mathit{Coal\ Price} + \beta_3\,\mathit{Real\ GDP} + \beta_4\,\mathit{Oil\ Consumption}$$

Altering this model to account for a supply shock, I follow with a theoretical model to explain natural gas prices with variables for oil price, coal price, real GDP and natural reserves. My initial model is as follows in equation (2):

(2) $$\mathit{Natural\ Gas\ Price} = \beta_0 + \beta_1\,\mathit{Oil\ Price} + \beta_2\,\mathit{Coal\ Price} + \beta_3\,\mathit{Real\ GDP} + \beta_4\,\mathit{Natural\ Gas\ Reserves} + \beta_5\,\mathit{Other\ Variables}$$

The theoretical model I use for oil is similar, as a variety of factors go into explaining crude oil prices. These factors can include production quotas set by OPEC and oil reserves in addition to those variables in the initial model. Also important I theorize is the number of oil and gas rigs in operation, which provides a variable related to exploration efforts, potentially portraying a positive signal to investors. The crude oil model is shown in equation (3):

(3) $$\mathit{Oil\ Price} = \beta_0 + \beta_1\,\mathit{Natural\ Gas\ Price} + \beta_2\,\mathit{Coal\ Price} + \beta_3\,\mathit{Real\ GDP} + \beta_4\,\mathit{Oil\ Reserves} + \beta_5\,\mathit{Active\ Rigs} + \beta_6\,\mathit{Other\ Variables}$$

For the analysis of energy prices affecting GDP I use an even more basic model than exists in the literature, with GDP as the dependent variable and the associated energy prices as the independent variables of concern, to go along with several other independent variables. The initial model to test this relation between energy is as seen in equation (4):

(4) $US\ Real\ GDP = \beta_0 + \beta_1\ Energy\ Price + \beta_2\ Population + \beta_3\ Energy\ Consumption/Supply + \beta_4\ Other\ Variables$

The time series monthly data used in the analysis cover a maximum range of January 1973 to April 2014 (not all variables cover this complete range), and come from several sources, primarily the EIA. For definitional purposes, a spot price is the price for a one-time open market transaction for immediate delivery of a specific quantity of product at a specific location where the commodity is purchased "on the spot" at current market rates (US EIA). A futures price is the price quoted for delivering a specified quantity of a commodity at a specified time and place in the future (US EIA).

The Henry Hub natural gas spot price (NG Spot) and the West Texas Intermediate crude oil spot price (Crude Spot) are the two spot prices used for analysis in this paper. Both the NYMEX crude oil and NYMEX natural gas futures data came in four contracts, with the first contract specifying the earliest delivery date and expiring on the third business day of the month preceding the delivery month. The second through fourth contracts represent the successive delivery months following the first contract. Each of these data sets came from the EIA, and are a monthly average of the respective daily prices. The units for the natural gas are dollars per British thermal unit, and for crude oil are dollars per barrel.

I also found data for NYMEX Central Appalachian coal futures prices from the EIA. These data only had a range covering 2006-12, or 98 observations with only 36 after the shale boom, so I opted to proxy for coal price with average retail electricity prices (Electricity). These data also come from the EIA and are an average of the retail electricity prices seen by residential, commercial, industrial, and the electric power sector, and are represented as cents per kilowatt hour, including taxes.

The Real GDP data, in billions of dollars, I obtained from an online source, Macro Advisers. This data could be a potential criticism, but it was one of the few sources I could find with monthly GDP data and I opted to use this GDP data as opposed to expanding the quarterly GDP from the St. Louis FRED. For natural gas reserves I used data for total natural gas in underground storage (NG Storage) from the EIA, which is a composite of the inventory of natural gas stored underground in several sources, including: depleted reservoirs in oil and/or gas fields, aquifers, and salt cavern formations. The data are represented in billion cubic feet and included because I believe the total inventory of natural gas should be a direct effect of the increases in natural gas supply after the shale boom. The natural gas consumption data (NG Cons) come from the EIA and have the same units, representing total monthly US consumption of natural gas.

For crude oil reserves I opted to try several different production variables throughout the analysis. The variables include crude oil stocks (CO Stocks), crude oil production (CO Prod), and active rigs (Rigs). Crude oil stocks represent the inventories of crude oil stored for future use, reported at the last day of the month in thousand barrels. Crude oil production is the volume of crude oil produced from US oil reservoirs, reported as a monthly average in thousand barrels per day. The active rig data are the total number of rigs (both crude oil and natural gas) that are, on average, crewed and working every day of the month.

Lastly, two other variables were used to further control for seasonal demand of natural gas. The variables are: heating degree days (HDD) and cooling degree days

(CDD), and are taken from the National Oceanic Atmospheric Administration's (NOAA) Climate Prediction Center. The data represent the average number of days per month, and capture the seasonal demand for energy needed to heat or cool houses and business. The data are calculated on a grid system by the NOAA and are constructed as a composite for the entire US. Summary statistics for each variable can found below in Table 1.

Table 1. Summary Statistics

Variable	Observations	Mean	Std Dev	Min	Max
Coal Fut.	96	60.6265	16.929	39.61	119.7
NG Spot	206	4.717	2.33	1.72	13.42
NG Fut. 1	242	4.3848	2.4025	1.426	13.454
NG Fut. 2	242	4.4811	2.4579	1.448	13.827
NG Fut. 3	242	4.5526	2.5057	1.49	14.178
NG Fut. 4	243	4.5829	2.5178	1.519	14.01
Crude Spot	338	41.1998	30.2245	11.35	133.88
CO Fut. 1	371	40.1455	29.0987	11.31	134.02
CO Fut. 2	350	40.811	30.0877	11.3	134.52
CO Fut. 3	372	40.1673	29.4771	11.35	134.78
CO Fut. 4	350	40.7931	30.4086	11.49	134.89
Electricity	318	7.182	2.0269	3	10.7
Real GDP	262	12,928.71	2,025	9,153.57	15,993.09
CDD	493	104.4909	116.0212	1	405
HDD	493	373.4199	322.7423	3	1,184
NG Cons	492	1,751.398	406.956	939.93	2,911.58
NG Storage	460	6,389.855	784.7395	4,446	8,294.3
CO Stocks	494	793,050.5	255,713.6	233,035	1,094,891
CO Produced	494	7,111.995	1,368.396	3,979.811	9,395.214
Energy Cons.	492	7,294.755	944.8498	5,439.4	9,456.532
Rigs	496	2,900.24	850.04	1,549	5,367

Methodology – Natural Gas

Altering the generic model of Yang, Hwang and Huang (2002) to create a supply-side model, I ran ordinary least squares (OLS) regressions to explain natural gas spot prices with the independent variables of crude oil spot price, electricity retail price, real

GDP, and natural gas consumption simply to view some preliminary results. This initial regression did not provide an answer to my research question, so to help provide an answer and an estimate I created a dummy variable (Shale Boom) to put into the model, which took the value of zero for each month before January 2010 and one thereafter. I was unable to find literature specifying an exact month and year associated with the shale boom, so I tested the dummy variable by backdating, where I found the time period around the beginning of 2010 to fit the model appropriately.

Adding this dummy variable to the model, the output for this regression can be seen as regression 2 in Table 2 below. The output showed significance at the 99% level for each of the explanatory variables except the consumption variable. The negative coefficient on the dummy variable was also significant at the 99% level. Being that I also wanted to control for demand and potentially seasonality for energy consumption, I then added variables for CDD and HDD. This regression can be seen as regression 3 in Table 2. The results of this model stayed consistent for each variable, significant at the 99% level with the exception of HDD, which was only significant at the 95% level. This model also showed improvement on its coefficients, as I was able to obtain the desired significances and provided a univariate interpretation that the slope of the average price for the time period before 2010 and the period after were in fact statistically different, but it still did not provide an answer to my research question or an estimate for a price change.

Looking to control for a time trend and further control for seasonality, I added year and month variables to control for each of these trends to finally create a time series regression. Adding time variables to the model with this dummy variable created what is known as a kinked regression, estimating a disconnect, which can be a jump or fall, in the fitted regression line of a *time series* model for price at a point in time. If significant, the dummy variable indicates that there has been a statistically significant change in price after the shale boom, where its coefficient provides an estimate for the price change. The output for this model is shown as regression 4 in Table 2 (the month variables are omitted from each table for the purposes of a neater paper).

Table 2. Initial Results 1-6 and Initial Times Series Results 5 & 6 (Level-Level)
Dependent Variable: *Natural Gas Spot Price (in $/million Btu)*

Variable	Initial	2	3	4	5
Shale Boom		-.4.35***	-4.3396***	-1.7284***	-.7698*
		(.3145)	(.3136)	(.4143176)	(.4597147)
Crude Spot	0.02466**	.0533***	.0565***	.03106***	.03987***
	(.0118623)	(.0087)	(.0087)	(.0071989)	(.007222)
Electricity	-.99943***	-.7454***	-.9347***	.64022**	.73204***
	(.2821926)	(.2025)	(.22515)	(.2864903)	(.275572)
Real GDP	0.0012017***	.00115***	0012***	.002735***	.00211***
	(.0002555)	(.00018)	(.00019)	(.0003425)	(.0003618)
NG Storage	-.0007259***	-.0005***	-.00047***	-.0038***	-.0034***
	(.0002062)	(.00015)	(.00015)	(.0003623)	(.0003576)
CDD			.004***	.0107**	.0089**
			(.0015)	(.0041731)	(.0040249)
HDD			.0012**	.00195	.0023153
			(.00057)	(.0018047)	(.0017326)
Year				-.64592***	104.05***
				(.1494741)	(25.27113)
Year^2					.0261***
					(.006301)
Intercept	-0.0052674	-3.6*	-4.3532***	1,278.91***	-103,690***
	(2.754248)	(1.9859)	(1.9925)	(293.2331)	(25,338.48)
Adjusted R^2	. 2805	.6324	.6416	.8059	.8216
F-Stat P-Val	0.0000	0.0000	0.0000	0.0000	0.0000
N	204	204	204	204	204

Note: Standard Errors are in parentheses.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level.

The coefficient estimates from regression 4 came with some lowered significances, but importantly the dummy variable remained significant at the 99% level, meaning there is potentially a difference in the price of natural gas before and after the shale boom. Taking a further look into transforming several of the variables, I looked at the scatterplots of the dependent variable and each independent variable and found there to be a nonlinear trend in the plot of NG Spot and Year. I then added a Year^2 term to the model to help remedy this nonlinearity, where the results of this regression are shown in regression 5 above. Several of other the variables also seemed to have nonlinear trends, particular in the plots of the other prices and GDP. I did not worry about these trends as much as the next step I used was to natural log-transform each variable, which is a technique to remedy the nonlinearities. The estimates of the newly transformed variables and level CDD and HDD variables are seen in regression 6 in Table 3 below.

Table 3. Time Series Transformed and Robust Regressions (Ln-Ln)
Dependent Variable: *Natural Gas Spot Price*

Variable	**6** **(Level CDD, HDD, Time)**	**7** **(Level Time)**	**Robust** **(Level CDD, HDD, Time)**
Shale Boom	-.0692945 (.069799)	-.0806934 (.0720494)	**-.210772***** **(.0647463)**
Crude Spot	0.3402*** (.0641845)	.334458*** (.0649638)	**.284006***** **(.0735377)**
Electricity	1.43466*** (.3536158)	1.40495*** (.3607344)	**1.41479***** **(.4269131)**
Real GDP	5.357*** (.7715423)	5.35915*** (.7921986)	**7.20031***** **(.7569968)**
NG Storage	-4.62353*** (.3596769)	-4.8025*** (.3340012)	**-4.95654***** **(.3619154)**
CDD	.0012795** (.0006225)	-.08364** (.0406382)	**.0015118*** **(.0007777)**
HDD	.0006429** (.000265)	-.048797 (.0589034)	**.0006368**** **(.0002652)**
Year	18.28996*** (4.029654)	17.28*** (4.126268)	**-.136586***** **(.023635)**
Year^2	-.0045906*** (.0010039)	-.00434*** (.001028)	**Omitted** **(Collinearity)**
Intercept	-18,230.63*** (4,040.665)	-17,220*** (4,137.359)	**245.7498***** **(41.14185)**
Adjusted R^2	. 8960	.8937	**Not Provided**
F-Stat P-Val	0.0000	0.0000	**0.0000**
N	204	204	**204**

Note: Standard Errors are in parentheses. Time indicates the month and year variables, robust regression omits Year^2 due to collinearity present with this method.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level.

Regression 6 relatively had the same statistical significances, however the dummy variable had no statistical significance. I then tried the model with natural log-transformed CDD and HDD variables, but the output resulted in the same insignificance for the dummy variable. Looking further into this issue I checked for heteroskedasticity and serial correlation to see if either of these issues could be affecting the standard errors and consequentially resulting in incorrect significance tests. To test for heteroskedasticity I used two tests in Stata: the Cameron and Trivedi's test for heteroskedasticity, and also the Breusch-Pagan/Cook-Weisberg (BP/CW) test. Not too surprisingly with a time series model each of the tests failed to reject the null hypothesis of a constant error term variance, meaning that heteroskedasticity was not likely affecting the model.

I then tested the model for serial correlation by computing the Durbin-Watson (DW) statistic for each regression. The DW statistic for regression 7 was roughly .58, and that for regression 8 was .56. As the DW statistic is constrained to $\in [0,4]$, the statistic for each regression showed there to be a presence of positive serial correlation. This meant the coefficients were unbiased, but the standard errors in each regression were not efficient. With a serial correlation problem likely affecting the significances of each variable I decided to use Newey-West standard errors to estimate the model robustly, which remedied the issue by providing more efficient standard errors.

The results of these turned out to be as predicted, largely improving the standard errors for each variable and most resulting importantly again in a significant dummy variable. However, important to take note of was a collinearity issue with the robust outputs, resulting in the $Year^2$ term being dropped, and thus changing the coefficient estimates. The outputs for this robust regression can be seen above in Table 3, which is the chosen model for natural gas spot prices with level CDD and HDD variables for interpretation purposes.

The next set of regressions run were those for the natural gas futures contracts. Table 4 includes the regressions for contract 1, which were run in a similar fashion to the spot prices. This time each estimate was run as a time series regression, but again starting with level-level regressions and then transforming variables to find the model of best fit to provide the most accurate estimate for the Shale Boom dummy variable. The only new additions to the model are the spot prices for crude oil and natural gas, as the literature suggests futures contract prices trend towards spot prices in the long run, explained by arbitrage and the results of supply and demand.

Table 4. Time Series Transformed and Robust Regressions
Dependent Variable: *Natural Gas Futures Price - Contract 1*

Variable	**9** (Level-Level)	**10** (Ln-Ln except Time)	**11** (Ln-Ln except Time)	**Robust Fut. C1** (Ln-Ln except Time)
Shale Boom	-.2003545** (.0857381)	-.0433596*** (.0145709)	-.0445082*** (.0140114)	**-.0608375*** (.0176356)**
NG Spot	1.002411*** (.0138006)	.956557*** (.0153693)	.9586072*** (.0136907)	**.9751786*** (.0144357)**
Crude Spot	0.0025814* (.0014603)	.030131** (.0144466)	.0314991** (.0136556)	**.0252648* (.0150882)**
Electricity	-.0830055 (.0531331)	-.0667634 (.0784999)	-.0799503** (.0645131)	**-.1312401* (.0771285)**
Real GDP	-.0000745 (.0000742)	.0540586 (.1823982)		
NG Storage	.0002672*** (.000076)	.175987* (.1011635)	.1892864** (.0904429)	**-.2470635** (.0977686)**
Year	6.199195 (4.980772)	1.823322** (.9014736)	1.906988** (.8540191)	**.0037559 (.0029856)**
Year^2	-.0015441 (.0012424)	-.0004546** (.0002247)	-.0004752** (.0002132)	**Omitted (Collinearity)**
Intercept	-6,223.225 (4,991.844)	-1,830.02** (903.4211)	-1,914.709** (854.9244)	**-9.478348* (5.564213)**
Adjusted R^2	.9938	.9953	.9953	**Not Provided**
F-Stat P-Val	0.0000	0.0000	0.0000	**0.0000**
N	204	204	204	**204**

Note: Standard Errors are in parentheses. Time indicates the month and year variables, robust regression omits Year^2 due to collinearity present with this method.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level

Before the robust estimation, the model for natural gas futures contract 1 also had issues with heteroskedasticity and positive serial correlation. Again to remedy this issue the model was estimated with Newey-West standard errors, where the estimates are seen in bold above in Table 4. This estimate also dropped the coefficient for Year^2 due to collinearity and consequentially changing the estimates, but the estimate for a change in price was statistically significant at the 99% level, indicating a decline in price after the shale boom for the first futures contract.

The outputs for natural gas futures contracts 2-4 are next in Table 5, which only includes the robust final chosen models for each contract. Each final model differs slightly from the next as the successive contracts were explained better by the previously issued contracts and less explained by the original variables in my model.

Table 5. Time Series Transformed and Robust Regressions (Ln-Ln)
Dependent Variable: *Natural Gas Futures Price - Contracts 2, 3, 4*

Variable	Fut. C2 Robust (Level: Time)	Fut. C3 Robust (Level: Time)	Fut. C4 Robust (Level: Time)
Shale Boom	**-.0387236***** **(.0096893)**	**-.0224894***** **(1.793277)**	**-.031463***** **(.0091433)**
NG Fut. 1	**1.445059***** **(.0869077)**	**-1.038668***** **(.1078576)**	**.1671288**** **(.071518)**
NG Fut. 2		**1.793277***** **(.077212)**	**-.908356***** **(.1746851)**
NG Fut. 3			**1.715067***** **(.110912)**
NG Spot	**-.4733885***** **(.0862718)**	**.2226782***** **(.0537025)**	
Crude Spot	**.0048558** **(.0076242)**		
Electricity	**.0581794** **(.0447162)**		
NG Cons.	**-.0124238** **(.0314863)**	**-.1069789***** **(.0383427)**	
Year	**.0029109** **(.0018148)**	**.0040634** **(.0009438)**	**.0037074***** **(.0009212)**
Year^2	**Omitted** **(Collinearity)**	**Omitted** **(Collinearity)**	**Omitted** **(Collinearity)**
Intercept	**-3.824072** **(1.701719)**	**-7.28846** **(1.701719)**	**-7.37569***** **(1.833306)**
Adjusted R^2	**Not Provided**	**Not Provided**	**Not Provided**
F-Stat P-Val	**0.0000**	**0.0000**	**0.0000**
N	**204**	**204**	**204**

Note: Standard Errors are in parentheses. Time indicates the month and year variables, robust regression omits Year^2 due to collinearity present with this method.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level

The same transformation techniques were applied to the early regressions for each natural gas futures contract before choosing the final estimates in Table 5, except natural gas consumption showed to be more powerful when explaining contracts 2-4 instead of the supply variable. Each model exhibited the same problems with heteroskedasticity and serial correlation, which led to each model being robustly run with Newey-West standards errors to remedy, and again the Year^2 term was omitted due to collinearity. The robust regressions resulted in a significant shale boom dummy variable with 99% confidence for each of the contracts, indicating the shale boom has had a downward effect on natural gas futures prices as well. Although not provided in the regression outputs, each of the non-robust outputs had very high adjusted-R^2 estimates similar to the early outputs seen in Table 4 for contract 1, potentially indicating a problem with the model.

Results and Interpretations – Natural Gas Prices

The regressions for both natural gas spot and futures prices included only 204 observations, limited by the variation of dates available for each variable. The fit of the models improved with each new regression run after incorporating the chosen explanatory variables and corresponding transformations, and interestingly enough each of the final models was explained by a different combination of variables. The final model for natural gas spot price concluded with the robust regression in Table 3 with the level CDD and HDD variables. This model was chosen as the representative model as it included the variables that follow theory most appropriately to go along with its significant coefficient estimates. The interpretations of this model are straight forward and are as follows: the dummy variable reads (by kinked regression) that for the years following the shale boom, starting in January 2010, there has been an associated 21.08% decline in the spot price of natural gas, clearly following the hypothesis and economic theory that an increase in the supply of a good leads to a decline in its price.

The rest of the variables are not as important but they are still important in the regression as they help to provide a more accurate estimate for the price decline, but they are as follows: the coefficient on crude oil spot price reads that a 1% increase in the price of crude oil associates with a .28% increase in the spot price of natural gas; a 1% increase in the average retail price of electricity associates with a 1.41% increase in the price; a 1% increase in real GDP associates with a 7.2% increase in the price; a 1% increase in the underground storage of natural gas associates with a 4.96% decline in the price; a one-day increase in the average monthly number of cooling degree days associates with a .15% increase in the price of natural gas, and a one-day increase for that of heating degree days associates with a .063% increase in the price of natural gas.

The year variable reads that as each year passes there is an associated 13.66% decline in the price of natural gas. The Year^2 variable was omitted from the robust regressions due to collinearity with the year variable. I attempted to change the lag term in the Stata command, but still could not come up with an explanation; I assume it may be a problem embedded within the data. The intercept term in the regression was significant, but in a natural log-transformed model this estimate does not provide a meaningful interpretation.

Similarly, the first contract for natural gas futures prices showed a statistically significant decline after the shale boom, though it is smaller than the decline in spot price at 6.08%. The smaller decline in price is due to what I presume to be the idea that futures contracts contain more information based on their historical tendencies and trends towards spot prices. If futures prices trend toward spot prices it means they already contain most of the information that spot prices hold. The final models did vary from the model for spot price; I noticed the futures prices for contracts 2-4 seemed to be better explained by the demand side of natural gas.

The effects of the shale boom however, became smaller for each successive contract with the exception of contract 4, which saw almost 1% larger of a price decline than that of contract 3. Formally, contract 2 saw a 3.87% decline, contract 3 a 2.25% decline, and contract 4 a 3.15% decline. Interesting also were the explanatory variables of contract 4, which only included the previous three contracts in addition to the time series year and month variables. The futures contract outputs also lost explanatory variables from the initial model with each successive contract, while adding previous futures contracts as explanatory variables to each successor contract.

Methodology – Crude Oil

The next set of regressions run attempt apply the same sets of prices, however the prices are instead for those of crude oil. Beginning with the spot price, in Table 6 below, similar transformations to the initial model used were used to create the new outputs. Only included this time are the outputs with the shale boom dummy variable, along with the new variables applied to the initial model for crude oil. The initial level-level model in regression 16 was run with a bit of uncertainty for what it would show; but it provided an output to work with and gave me an idea of where the model may be in need of improvement. Checking the model for heteroskedasticity and serial correlation, both issues were present according to the BP/CW test and DW statistic. The next step was a natural-log transformation to each of the variables, with the exception of CDD and HDD. This model showed some improvement in terms of significances for each variable, however, the sign on the shale boom dummy variable was the opposite of expected.

Table 6. Time Series Transformed and Robust Regressions (Ln-Ln)
Dependent Variable: *Crude Oil Spot Price ($/Barrel)*

Variable	**16** (All Lev-Lev)	**17** (Level CDD, HDD, Time)	**18** (Level HDD, Time)	**Robust** (Level HDD, Time)
Shale Boom	15.68721*** (4.149342)	.1941648*** (.0719757)	.1789945** (.0709088)	**.1976814*** **(.1154688)**
NG Spot	3.3239*** (.5362503)	.3017801*** (.0560205)	.2996438*** (.0560537)	**.2357341***** **(.0526917)**
Electricity	18.87333*** (2.85837)	1.56762*** (.4365683)	1.590658*** (.4366204)	**1.566828***** **(.4313556)**
Real GDP	0.016795*** (.0036055)	2.552066*** (.8886913)	2.54632*** (.8896651)	**2.926714**** **(1.203324)**
CO Stocks	-0.0000768*** (.0000221)	-.6199078* (.3697242)	-.662246* (.3684056)	**-.6160952** **(.4145303)**
CDD	-.0224472 (.037277)	-.0007732 (.0006519)		
HDD	-.0398695*** (.0147791)	-.0005314* (.0002727)	-.000456* (.0002655)	**.0568471** **(.0490203)**
Rigs	.0008522 (.0029364)	.3897712*** (.133699)	.3843382*** (.1337689)	**.4588361***** **(.0935809)**
Year	-1,220.075*** (298.1201)	-3.647247 (6.427659)	-4.188701 (6.418548)	**.0138128** **(.0341169)**
Year^2	.3033335*** (.0742279)	.0009141 (.0015991)	.0010493 (.0015969)	**Omitted** **(Collinearity)**
Intercept	1,226,594 (299,323.2)	3,619.565 (6,455.26)	4,162.404 (6,446.166)	**-50.85197** **(58.80458)**
Adjusted R^2	. 9155	.9389	.9388	**Not Provided**
F-Stat P-Val	0.0000	0.0000	0.0000	**0.0000**
N	204	204	204	**204**

Note: Standard Errors are in parentheses. Time indicates the month and year variables, robust regression omits Year^2 due to collinearity present with this method.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level

The tests for heteroskedasticity on this model were uncertain, as the BP/CW test failed to reject the null of a constant error term variance, but yet the Cameron & Trivedi test rejected the null. The DW statistic was very low at .276, indicating positive serial correlation. Further looking into the model, joint significance testing of the CDD and HDD variables failed to reject the null hypothesis that the two variables are jointly insignificant in regression 17 above, which meant the insignificant CDD variable could be dropped. Rerunning the model without CDD provided the results seen in regression 18. This estimate also had the same issues with heteroskedasticity uncertainty and serial correlation, so I ran the same regression robustly with Newey-West standard errors to estimate the bolded regression in Table 6 above, although the Year^2 term was dropped due to collinearity. This final chosen model for crude oil spot price showed a price increase statistically significant at the 90% level.

Table 7. Time Series Transformed and Robust Regressions
Dependent Variable: *Crude Oil Futures Price (Contract 1)*

Variable	**20** **(Level-Level)**	**21** **(Ln-Ln except Time)**	**22** **(Ln-Ln except Time)**	**Robust** **(Ln-Ln except Time)**
Shale Boom	.1339553* (.0683502)	.0009704 (.001441)	.0011326 (.0014232)	**-.0022479**** **(.0010067)**
CO Spot	.997445*** (.0011777)	.9961501*** (.001465)	.9953113*** (.0011715)	**.9961282***** **(.0017216)**
NG Spot	-.0003721 (.0087973)	.0006119 (.0010629)		
Electricity	.0953435* (.0515065)	.0144536 (.0090306)	.0130862* (.0073904)	**.003952** **(.0078943)**
Real GDP	-.000013 (.00006067)	-.0108531 (.0178068)		
CO Stocks	.00000144*** (.000000366)	.0279118*** (.0074033)	.0269406*** (.0075072)	**.0239197***** **(.0084248)**
Rigs	.0000375 (.0000476)	.0037221 (.0027108)	.0047556** (.0019094)	**.0030001** **(.0022608)**
Year	6.717884 (5.021401)	.1541496 (.1268037)	.208923*** (.0698648)	**.0004741*** **(.0002735)**
Year^2	-.0016807 (.00125)	-.0000384 (.0000315)	-.0000521*** (.0000175)	**Omitted** **(Collinearity)**
Intercept	-6,714.827 (5,042.722)	-154.8999 (127.3559)	-209.8987 (69.91694)	**-1.2977**** **(.5824447)**
Adjusted R^2	1.0000	1.0000	1.0000	**Not Provided**
F-Stat P-Val	0.0000	0.0000	0.0000	**0.0000**
N	204	204	228	**228**

Note: Standard Errors are in parentheses. Time indicates the month and year variables, robust regression omits Year^2 due to collinearity present with this method.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level

Moving to the futures contracts for crude oil, the outputs for contract 1 are shown above in Table 7. The same methodology from the natural gas futures contracts applied here, except the variable for active rigs was added to the model. Again left out of the table were CDD and HDD variables, as they had no significance when testing the initial model. Problems with the model were evident from the initial output. Many of the variables were insignificant and a very high adjusted R^2 value blatantly stuck out. Natural log-transformation was done to each of the variables and I reran the regression only to find similar results. Continuing with the model transformation the variables of natural gas spot price and real GDP were dropped, as they were the most insignificant variables and also not jointly significant. This estimate is shown in Table 7 as regression 22. The significances for each variable in the regression improved, but the adjusted R^2 value was still perfectly high (1.000) and indicating a potential problem. I then tested the next two most insignificant variables for joint significance, electricity price and active rigs, to see if either could be dropped. These to variables showed to be jointly significant however, which I believe could be due to a relation between electricity prices and the number of natural gas rigs included in the active count. Next I tested the model for heteroskedasticity to find it present, and also for serial correlation where the DW statistic of 1.85 indicated the model was likely free of serial correlation. Due to the high adjusted R^2 value and presence of heteroskedasticity, I still decided to run the model robustly with Newey-West standard errors to obtain the final chosen model, bolded in Table 7 above.

Continuing with crude oil contracts 2-4, the same analysis and intuition were used but each prior contract was added to the model for its successor(s) similarly to the models for the natural gas futures contracts. The final robust chosen models for each contract are shown below in Table 8. These contracts had very similar final models, where I ran each final model robustly due to the presence of heteroskedasticity and serial correlation. Although the robust regressions provided more efficient standard errors there still seemed to be a problem with the models somewhere as the adjusted R^2 value was extremely high for each before running with robustness. I chose each model by transforming the independent variables to remedy any premeditated problems, and then systematically eliminating the variables that did not have significance in the successive contracts.

Table 8. Time Series Transformed and Robust Regressions
Dependent Variable: *Crude Oil Futures Price (Contracts 2, 3, 4)*

Variable	**Fut. C2 Robust** (Level Time)	**Fut. C3 Robust** (Level Time)	**Fut. C4 Robust** (Level Time)
Shale Boom	**-.0237876*** (.0043197)**	**-.0008403 (.0012098)**	**-.007693 (.000543)**
CO Fut. 1	**2.745591*** (.4811833)**	**-.8708932*** (.1261447)**	**.3142907*** (.0264982)**
CO Fut. 2		**1.634044*** (.0313757)**	**-1.467314*** (.0654214)**
CO Fut. 3			**2.149384*** (.0405229)**
CO Spot	**-1.797509*** (.4795225)**	**.228106** (.1067163)**	
NG Spot			
Electricity	**.0436529 (.0402508)**	**.0350562*** (.0117494)**	**.0094472** (.0043815)**
Real GDP			
CO Stocks	**.1517786*** (.0368621)**	**.0341495*** (.0122818)**	**.0173995*** (.0065181)**
Rigs	**.028559*** (.0097808)**	**.0037478 (.003135)**	**.0031838** (.001325)**
Year	**.0053616*** (.0012226)**	**-.0000151 (.0003873)**	**.0000983 (.0001422)**
Year^2	**Omitted (Collinearity)**	**Omitted (Collinearity)**	**Omitted (Collinearity)**
Intercept	**-12.94515 (2.586986)**	**-.5102409 (.844701)**	**-40.85521 (40.94632)**
Adjusted R^2	**Not Provided**	**Not Provided**	**Not Provided**
F-Stat P-Val	**0.0000**	**0.0000**	**0.0000**
N	**228**	**228**	**228**

Note: Standard Errors are in parentheses. Time indicates the month and year variables, robust regression omits Year^2 due to collinearity present with this method.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level

The first and second crude oil futures contract were the only contracts to show a decline in price after the shale boom, which I have no explanation for other than a potentially incorrect model resulting in incorrect estimates for one or a combination of the model estimates, or contracts three and four simply were not effected. Several of the independent variables did change across the models, but the varying significances were interesting, given the shale boom dummy variable became statistically insignificant after the second contract. Unlike the last natural gas futures contract, the last crude oil futures contract had two of the initial explanatory variables included and statistically significant.

Results and Interpretations – Crude Oil Prices

The final model for crude oil spot price included a total of 204 observations; the final models for the futures prices each included 228. The chosen model for spot prices was selected as it best represented the problem given the variables. Apparent in the spot price model though are several problems that were unable to be remedied. The problems began with extremely high adjusted R^2 values and when completing the transformations for each of the variables in the model, bringing with some uncertainty. Most concerning however, was the significant and opposite expected sign on the shale boom dummy variable. The final model indicates an increase in the price has instead occurred, and estimates it at 19.77%. It is difficult to say if or how accurate the signs and estimate are, but if the pattern of following world oil price exists then this could very well be a reasonable estimate. These results go against my hypothesis but they could agree with that of Aguilera and Radetzki (2014), who state there is only one world oil market and the only likely effects of the shale boom seen in the US are those relating to its crude oil imports and exports.

The futures contracts showed some slightly better results, which might indicate an incorrectly specified spot price model. Strangely, other than the initial level-level model, none of the outputs for futures contract 1 showed a strong statistically significant shale boom effect until the model was run robustly. When robustly run, the shale boom variable was significant and in the predicted direction at the 95% confidence level. The decline in price was small though at only .225%, but it was significant nonetheless. The second contract had a little bit larger of a decline in its price at 2.38%, including significance at the 99% level. The estimates for contracts 3 and 4 were also in the predicted negative direction, however, neither had significance at any level and therefore could not provide a worthy estimate. This either indicates a problem with the model or simply that the later contracts have not seen an effect from the shale boom.

Collectively between the two models I find it difficult to say whether oil prices have truly seen changes because of the shale boom. It is known however, that the increases in shale oil production and supply occurred slightly later than those of shale gas, which could potentially be a reason for not seeing significant negative changes in oil prices as of yet. The benefits of the added domestic supply may not have taken full effect yet and as mentioned earlier the scale of shale oil is much smaller than that of shale gas and oil shale. Once oil shale can be exploited I am confident a decline in each of the domestic oil prices will be seen.

Methodology – US GDP and Energy Prices

The methodology I used for this analysis is similar to what was used previously, with OLS time series regressions. Knowing the potential of an endogeneity problem at hand, I regressed US real GDP on the energy price variables most importantly, among others, and assuming that lower energy prices would associate with higher levels of GDP. The initial regression with crude oil spot price as the important independent price variable of concern showed significant explanatory variables, indicating that energy markets largely affect GDP. The only insignificant variable in the initial regression showed to be population and the expected sign on crude oil spot price was opposite of expected. I then decided to drop the population variable and add an energy supply variable, crude oil stocks, where this output is seen in regression 27 in Table 9 below. The estimates for this model did not change, every variable was statistically significant but the estimate on crude oil price still had the opposite sign of what I was looking for.

Table 9. Time Series Regressions for Testing GDP and Energy Pricing Relationship (Ln-Ln)
Dependent Variable: US Real GDP

Variable	**27** **(Level Time)**	**28** **(Level Time)**	**29** **(Level Time)**	**30** **(Level Time)**	**31** **(Level Time)**	**32** **(Level Time)**
CO Spot	.0251238*** (.0041718)					
NG Spot		.0306419*** (.0049841)				
CO Fut. 1						-.0712581 (.051281)
CO Fut. 2						.0954714* (0520686)
NG Fut. 1					-.11841*** (.0317146)	
NG Fut. 2					.1321266*** (.0321803)	
Electricity			**-.09069***** **(.024339)**	**-.06286***** **(.0217065)**		
Energy Cons.	.2100361*** (.0430113)	.3241353*** (.050637)		**.3871732***** **(.0483232)**	.3116042*** (.0481293)	.2348751*** (.0433614)
CO Stocks	-.0624093** (.0276183)					
NG Storage		.2337709*** (.0382091)		**.0909774***** **(.0293607)**		
Year	3.420895*** (.1962483)	2.213121*** (.2992845)	**4.46999***** **(.1839696)**	**3.652245***** **(.1997607)**	2.962895*** (.2192394)	3.564939*** (.1855436)
Year^2	-.0008485 (.000049)	-.0005476 (.0000746)	**-.00111***** **(.000046)**	**-.000906***** **(.0000499)**	-.000734*** (.0000547)	-.000885*** (.0000463)
Intercept	-3,439.545*** (196.3153)	-2,231.3*** (300.1009)	**-4,494.644** **(184.1165)**	**-3,677.323** **(199.8719)**	-2,983.6*** (219.5621)	-3,584.1*** (185.5071)
Adjusted R^2	.9908	.9806	**.9825**	**.9865**	.9887	.9907
F-Stat P-Val	0.0000	0.0000	**0.0000**	**0.0000**	0.000	0.0000
N	261	204	**228**	**228**	**240**	261

Note: Standard Errors are in parentheses. Time indicates the month and year variables, robust regression omits Year^2 due to collinearity present with this method.
***Significant at the 1% level. **Significant at the 5% level. *Significant at the 10% level

I then ran a similar regression again, except using natural gas spot price instead of crude oil, along with a natural gas storage variable instead of population. The estimates, seen in regression 28, were almost identical to those for crude oil, with significant estimates and an incorrect expected sign on the natural gas price. The third type of price tested by regression was electricity prices, which finally showed a negative association with real GDP and is bolded and seen as regression 29 above. Building onto this model, I added the natural gas storage and energy consumption variables, which seemed to improve the model slightly in terms of the statistical significance along with the negative association between price and real GDP. This model is also bolded and seen as regression 30 in Table 9 above.

The last two prices investigated were the futures prices for both commodities. Each contract was used in a time series model individually, but none provided a significant negative association with price. The only time a significant and negative estimate was seen was when several futures contracts were used in the same regression to explain real GDP, as in regressions 31 and 32 above, yet each output generally showed one negative association, which was not always significant. I further ran several of the prices without the time series variables and without the other explanatory variables in the theoretical model. Each time, the regression of real GDP on the energy price resulted in an incorrect expected sign.

Results and Interpretations – US GDP and Energy Prices

This analysis seemed to be one that could be relatively simple, but that was not the case. Every model run with natural gas or crude oil as an explanatory variable resulted in a sign that was opposite of anticipated. As shown in Table 9, each of these two commodities prices shows a positive associated increase in real GDP with an increase in price, not negative as anticipated. The only exception to this was when multiple prices were included in a regression, such as those in regression 31 and 32, in which case one variable obtained the correct sign but the other still had the incorrect one. Further extending the model beyond just crude oil and natural gas prices, regressions were run with electricity price as the important explanatory variable. This resulted in some different results than what had been seen before.

Each regression run showed a decline in real GDP with an increase in the price of electricity. For example, in regression 30 a 1% increase in the price of electricity associates with a .063% decline in real GDP. Intuitively this makes sense as when businesses or households must pay more for the power they use it inhibits them from spending that money as disposable income elsewhere, constricting GDP growth. Also attempted in several models was the incorporation of the number of active rigs as an explanatory variable. None of these outputs were put into a table but including the variable did nothing to change the sign on the natural gas or crude oil price variables, though it did magnify the negative relation when included in the models with electricity prices.

Looking at the correlation tables, the correlations were high between prices and GDP and none were less than the .4048 between the natural gas spot price and real GDP, and all were positive as well. Collectively this analysis did little to answer the research question at hand; there is largely an endogeneity issue in the spurious regressions. The results made clear the need for a more sophisticated model, such as two-stage least squares utilizing an instrumental, however they also may be helpful in explaining how important energy is in macroeconomic modeling given the extremely high goodness of fit values.

Conclusion, Discussion and Further Extensions

Following economic intuition the answers this paper provides to the research questions are interesting and potentially valuable. Following the estimated robust regression for natural gas spot prices, the results reasonably show there has been a decline in natural gas spot prices seen in the US in the time period after the shale boom. Although the number of observations in the time period after 2010 is only 48 (2010 – 2013), I believe this model is the best of them all in this paper. The estimates have the correct expected signs and the model is just as it controls for both time and seasonality trends with the year and month variables included in the time series regressions. The accuracy of the estimate for the decline in price at 21.08% is somewhat uncertain, but the estimate was significant and in the predicted negative direction.

The results from the natural gas futures contracts also showed similar results. The final model for the first two contracts showing statistically significant price declines of 6.08% and 3.87%, and the final model for contracts 3 and 4 with statistically significant declines of 2.25% and 3.15%, respectively. The accuracy of these estimates is also uncertain and could be further examined, but the analysis still provides a good basis for natural gas prices.

Oil prices on the other hand showed some unexpected and very uncertain results, which I believe there might also be an explanation for. The reasoning is that there currently is only one true world oil market, meaning that what happens in the US (in this study is price), the market becomes highly diluted and less of an effect is seen. If that is the case then it can reasonably be assumed that US oil prices are not completely independent from world oil prices, and they do in fact follow the lone world market. The results in this research really seem to reflect the global market, and as Aguilera and Radetzki (2014) note, the main change related to the oil market in the US is the decline in US import needs. A further reason however, could be the scale factor of the shale oil reserves, which is much smaller than that of shale gas and oil shale. Once oil shale can be further exploited, I predict that a much more significant change in oil prices will occur.

Looking to extend this research further, the first way I see reattempting would be to find data on fracking costs and operating expenses. I am curious as to whether these costs get reflected in the commodities' pricing; I do not believe research has been done on this idea. Extending this same concept to another angle and depending on any environmental impacts found, a future explanatory variable that could factor into these price sets is environmental damage and or prevention. Although the typical well is drilled to over 7,500 feet below the surface, while the water table is generally at around 1,000 feet, an adverse event could hypothetically increase the price as a result of higher extraction costs related to ensuring environmental protection and the mass usage of existing resources such as water.

The environmental concern however, brings in an interesting benefit of fracking. It is genuinely known that the fracking process uses a liquid combination that is not necessarily environmentally friendly, but this actually creates an incentive structure. The issue provides companies and other entrepreneurs the opportunity to invent cleaner methodologies to incorporate into fracking. This also, is already being seen. A great example is GasFrac Energy Services (TSX: GFS), which offers a waterless fracking technology by using a process involving a gelled liquefied petroleum gas (LPG) instead of water. This process sidesteps the water issue as most of the LPG injected into the shale is also later extracted and then resold on the market. This is an improvement because in conventional fracking more than 80% of the water or frac fluid stays in the rock formation. Nuverra Environmental Solutions (NYSE: NES) offers a variety of services to shale drillers, including the hauling and treating of the water used in frac jobs. Two other similar companies, US Silica Holdings (NYSE: SLCA), which mines, process, and sells commercial silica; and CARBO Ceramics (NYSE: CRR), which manufactures ceramic proppant, are further examples of innovations to the materials used in fracking, as they offer products to replace the frac sand used in the process. The materials leave a wider and more consistent pore space in the shale cracks due to their uniformity, thus improving the extraction rates and also the quantity of oil and gas believed to be recoverable in the well. It is examples such as these that I believe are inspirational to the industry and remove another angle that environmentalists use to attack fracking. If the materials of or the disposal of frac fluid can be improved, there is a large profit to be made as well as cost savings for fracking companies.

Another interesting question would be to theorize what would have happened to US energy markets without shale innovation, specifically without shale gas production. Along the same lines as that question, a controversial topic would be a research attempt at whether or not the shale boom would have been possible without the government investment in energy research. There is no doubt that government energy innovation investments could be made more efficiently and effectively, but it would be a mistake to imagine that the US would be better off without them, according to Shellenberger and Nordhaus (2011). The US has been instrumental to the extension of shale research to other countries worldwide. Other countries have attempted to copycat the production and search processes for shale formations, which has been the recent trend to create a more diversified world energy market. Countries new to shale gas however, have an advantage over the US in that the current shale technologies are much more advanced than those that existed with the early developments in the US. Perhaps new innovations or adaptations will be needed to exploit the shale plays abroad, but the technologies and jobs that energy extraction from shale brings will provide a stimulatory benefit to any economy. The hope for each country with recoverable shale formations is that its reliance on imports such as natural gas or crude oil will be derailed, and eventually it can obtain a more diversified and stable energy future through lower energy prices, just as the shale boom is helping the US to accomplish.

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