FACTORS DETERMINING U.S. NATURAL PRICES POST 2008: A STRUCTURAL VAR ANALYSIS

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Section 1: Introduction

The exploration and production of natural gas in North America from shale formations in the past decade has attracted broad attention. A resource that at one time was considered scarce is now increasingly abundant. Natural gas plays a significant role in the United States in meeting the dual challenges of energy independence and reduced emissions of greenhouse gases and other pollutants. Nonetheless, natural gas pricing will continue to be a sensitive issue for consumers, policy-makers and the energy industry. While environmental advantages and fuel reliability are significant, pricing is the most important signal for investment and demand. Therefore, an understanding of price determinants under all market conditions is crucial for policy-makers who regulate and guide industry actions, and for investors seeking to maximize returns in the highly price-sensitive commodity sectors.

Notable new trends have arisen since 2008 that inform these drivers. One trend is a "decoupling of prices" as the co-movement between crude oil prices and natural gas prices weakened significantly. Another is the productivity boom the industry experienced due to the introduction of hydraulic fracturing and horizontal drilling that enable access to vast amounts of reserves located in shale formations. Between 2008 and 2016, proved U.S. reserves rose by 34% to 341.1 trillion cubic feet (Tcf). The relevance of these trends becomes more obvious when placed in the context of prior research on this issue. The research on the driving factors of natural gas prices lags far behind the research on the pricing mechanism of oil. Previous research has only focused on the integrated or decoupled relations between oil and natural gas prices. Subsequently, much research has focused on the debate over the relationship between crude oil and natural gas.

In this study, we will use a structural vector autoregression (VAR) model to examine the impact of various driving factors on gas prices. We use a structural vector autoregression model because a structural VAR model allows for endogeneity of fundamental gas variables such as storage. As documented by Nick, S. et al. (2014) in his paper, most approaches such as Brown & Yucel (2008), Mu (2007) and others treat gas inventories exogenous with respect to the natural gas prices. The flaw with the assumption of exogeneity of gas inventories is that it is inconsistent with a liberalized gas market. In an efficient and a liberalized gas market, it is unlikely that the storage operators will not be responsive to the market prices and adjust the flows accordingly.

The remainder of this study is structured as follows:

Section 2 reviews the other studies that have examined the drivers of natural gas prices in US and other countries.

Section 3 describes the data used for our analysis.

Section 4 explains the structural VAR framework and the identification of our model.

Section 5 discusses the results of the impulse response analysis and forecast error variance decomposition analysis.

Section 6 summarizes the results and suggests future trends in the data and opportunities for additional research.

Section 2: Review of Literature

For many decades, natural gas and refined petroleum products were seen as close substitutes as U.S. industry and in electric power generation. The substitutability between crude oil and natural gas was very high, and the choice between the two fuels often depended the least cost. It was widely accepted that the natural gas prices tracked those of crude oil. In an apparent confirmation of these observations, Bachmeir and Griffin (2006) found a weak relationship between oil and U.S. natural gas prices. These findings were contested by Villar and Joutz (2006), who found oil and natural gas prices to be cointegrated with a trend. In related work, Asche, Osmundsen and Sandsmark (2006) find cointegration between natural gas and crude oil prices, although their focus was on the U.K. market subsequent to natural gas deregulation.

In a slightly different vein, Hartley, Medlock and Rosthal (2007) found that substitution between residual fuel oil and natural gas is particularly strong in the U.S. North American Electric Reliability Council regions where there is sufficient fuel-switching capability. However, a study by Ramberg et al. (2012) have argued that relationship between crude oil and natural gas is not stable over time. They also argue that the price of oil has only weak explanatory power for short-term gas price fluctuations. Economic reasons for a decoupling of oil and gas prices could be the increasing production of shale gas in the United States or the rise of liquid spot markets in Europe fostering gas-to-gas competition, and therefore a slow but steady decline in oil-indexed contracts. Their arguments undermine the earlier work that has examined the tenuous link between natural gas and crude oil prices.

There is another body of work that has presented a structural model to examine the factors driving natural gas prices. The limitation of these studies such as Brown and Y¨ucel (2008), Mu (2007) or Ramberg and Parsons (2012) is that they treat gas inventories as exogenous with respect to gas prices and do not account for the role of liquefied natural gas (LNG). Maxwell, et al (2011) and Nick, S. et al (2014) addresses this limitation by proposing an approach that allows for endogeneity of fundamental gas market variables, such as storage and LNG supplies.

While our study does not consider LNG supplies, we add to the literature by reexamining the relationship in light of the new data since 2008 and include an important barometer of the impact of business cycles, namely industrial consumption of natural gas, ignored in many of the past analysis.

Section 3: Data and Sources

Since the focus of the study is to look at the factors driving natural gas prices in the U.S. since 2008, the data collected is from January 1, 2008 until March 31, 2017. One of the questions we faced in this study is the choice over the frequency of the data. Weekly data is usually best suited to model natural gas prices. However, in our study, we have used monthly data because some variables were only available on a monthly basis. One of these variables is the industrial consumption of natural gas. Since the study period concurred with one of the worst depressions in U.S. history, it became important to model the impact of macroeconomic activity on the natural gas prices. This became one of the enhancements in analysis over the study by Nick, S. et al. (2014), which only partly models the macroeconomic environment. The data frequency limitation also applies to natural gas exports and imports. While we do not directly model the impact of LNG supplies, accounting for natural gas exports and imports will capture that impact partially.

Total rig count (both oil directed and gas directed) is another important variable in this analysis. There is an emerging viewpoint that the oil-directed rig-count is no longer relevant while discussing gas prices. But our hypothesis is that the impact of the total rig count on the natural gas price still needs to be examined. While there has been a decoupling of oil and gas prices, the relationship between the two cannot yet be discounted completely.

Although the U.S. has not been in a bullish gas market for many years, one factor will become a greater concern as we move toward the winter: storage. At levels almost 19 percent less than the five-year average, natural gas inventories are simply not where distributors and regulators want them to be, (at 2,567 Bcf as of August 31, 2018). Storage is crucial to meeting winter needs because the U.S. does not we produce enough contemporaneously to meet daily winter demand, as gas is utilized heavily in heating. And as the U.S. continue to export more gas, storage will become increasingly vital to help meet cold winter needs in China, Europe and elsewhere.

The natural gas futures market has had a history of wide price variances that continues to attract speculative activity. While non-commercial open interest in natural gas futures will wax and wane, the price variances during the early part of the study and their impact on speculative activities necessitated the inclusion of natural gas futures as one of the fundamental factors driving the natural gas price. The impact of seasonal characteristics are always important in the analysis of natural gas prices.

Section 4: Model

We employ a structural vector autoregression for modeling the interdependencies between the most significant market fundamentals that affect the natural gas price. The model in its reduced form can be written as:

$$Z_t = \alpha + \beta_1 Z_{t-1} + \ldots\ldots. + \xi_p Z_{t-p} + \mu_t \quad (1)$$

The dependent variable in eq (1) is a vector of *M* endogenous variables and ρ is the number of lags. μ_t is a K-dimensional vector of reduced-form errors with the properties E(ut) = 0, E(utu ′ s) = Σ_μ and E(utu ′ s) = 0 for s # t, where Σ_μ is an invertible K × K variance-covariance matrix.

However, as the reduced form equation (equation 1) does not account for the instantaneous causality between the variables, the structural model needs to be identified. This can be done by rewriting equation (1) as:

$$Z_t = \beta^*{}_1 Zt_{-1} + \ldots\ldots. + \xi^*{}_p Z_{t-p} + €_t \quad (2)$$

Z_t is an K×K matrix of instantaneous interaction among the variables and $\beta^*{}_1$ i is equal to $Z\beta_l$ for i = 0, . . . , p. $€_t$ is a row-vector of dimension K representing structural errors with variance covariance matrix $\Sigma_€$. As the instantaneous causality of the variables is captured by A, $\Sigma_€$ is diagonal. Therefore, the errors of the structural representation can be assigned to a single variable and therefore be interpreted in terms of economic theory, thus helping us deal with the limitations of the reduced form equation (1).

We adopt a customized identification structure for our model. In other words, we rely on the economic reasoning to impose restrictions on the model. These are summarized in Table 1.

Table 1: Identification of the Contemporaneous Matrix

	Crude Oil Price	Natural Gas Exports	Natural Gas Imports	Natural Gas Futures Price	Temperature	Natural Gas Industrial Consumption	Rig Count	Storage	BTU Price Spread	Natural Gas Price
Crude Oil Price	0	0	*	*	*	*	*	0	0	0
Natural Gas Exports	0	*	0	*	*	*	*	*	*	*
Natural Gas Imports	0	0	*	*	*	*	*	*	*	*
Natural Gas Futures Price	0	*	*	*	*	*	*	*	*	*
Temperature	0	0	0	0	0	0	0	0	0	0
Natural Gas Industrial Consumption	0	0	*	*	*	*	*	*	*	*
Rig Count	*	*	*	0	*	*	*	*	*	0
Storage	0	*	*	*	*	*	*	*	*	*
BTU Price Spread	*	*	*	*	*	*	*	*	0	*
Natural Gas Price	0	*	*	*	*	*	*	*	0	*

Each row of this table indicates an equation in the VAR model with the respective dependent variable. Each column indicates the instantaneous impact of a variable in each equation. The ⋆ denotes that a parameter is estimated from the data and that the model allows for an instantaneous relationship, whereas a 0 indicates that the according parameter is restricted to zero.

The most meaningful restrictions are summarized as follows:

1. The crude oil price is assumed to have an instantaneous impact on the rig count and the BTU price spread. A low crude oil price is an indication of low demand and excess supply. This is likely to lead to a drop in the drilling activity.
2. The crude oil price has no instantaneous impact on the natural gas price.

3. Natural gas exports are assumed to have an impact on the domestic supply-demand balance, and there is likely to be an instantaneous reaction between the two.
4. There seems to be lack of a direct and instantaneous relationship between the prices for natural gas and crude oil and temperature, so we have set the restriction to zero. The logic is similar for natural gas imports and temperature.
5. The natural gas futures price is assumed to have an instantaneous impact on all of the variables barring the rig count.
6. The prompt month natural gas futures price is unlikely to have an instantaneous impact on the rig count, and the reverse is also expected to hold true.
7. Natural gas industrial consumption is assumed to have an instantaneous impact on all the variables. The impact of the rig count and storage on other variables follows a similar pattern to industrial end use and is instantaneous.
8. The level of natural gas storage has no impact on the crude oil price, so we have set the restriction to zero.
9. The BTU price spread is not going to impact the crude oil price or the natural gas price, and it is reasonable to impose restrictions on those two variables.
10. Since the impact of cooling degree days and heating degree days on the other variables is likely to face a similar pattern in terms of an instantaneous impact, they have been compiled together as the variable "Temperature" for the purposes of our analysis in the above table.
11. We also assume that some of the variables will have a lagged impact on others. For instance, we assume that temperature is likely to have a lagged impact on the rig count. However, exceedingly low temperatures coupled with high demand may make any lagged impact impractical.
12. Temperatures may have a lagged impact on industrial consumption, as many industries have part of their purchase portfolio in long-term transactions. Natural gas exports and the rig count also are likely to have a lagged impact on industrial consumption for natural gas.
13. The crude oil price spread is also likely to have a lagged impact. Petroleum prices, particularly during the study period, have not been a price competitive substitute for natural gas.

Section 5: Results

We conducted a lag criteria test to determine the number of lags to be used in the model (Table 2). The lag length which has a maximum negative value is chosen for our analysis. While there are a number of tests available to determine the lag length, as indicated in the table below, AIC and SC tests are considered are more reliable. Though the AIC test indicates that the lag length is 8, we use the SC criteria for determining the number of lags for our analysis. As a result, we chose the number of lags to be 1.

Table 2: Lag Criteria Test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	486.3	NA	4.2e-19	-8.2	-7.9	-8.1
1	1555.7	1896.8	4.4e-26	-24.3	-20.6*	-22.8
2	1776.4	345.4	1.25e-26	-25.6	18.5	-22.7
3	1922.1	197.6	1.48e-26	-25.7	-15.1	-21.4
4	2069.4	169.0	2.11e-26	-25.7	-11.7	-20.0
5	2262.16	180.9*	1.91e-26	-26.61	-9.13	-19.51
6	2494.2	169.5	1.5e-26	-28.1	-7.2	-19.6
7	2815.9	167.8	6.7e-27	-31.2	-6.88	-21.3
8	3336.0	162.9	7.2e-28*	-37.7*	-10.0	-26.5*

Table 3 tells us that since chi-sq is greater than the critical value (the P-value is smaller than significance level), then the null hypothesis is rejected. This means that taking all lags together, independent variable dependent variables can affect the dependent variable in the future or can predict future values.

Table 3: VAR Granger Causality/ Block Exogeneity Wald Tests

Dependent Variable: Log of Natural Gas Price

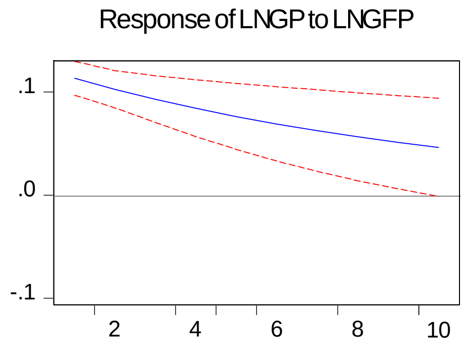
Excluded	Chi-sq	Df	Prob
LCDD	4.5	1	0.03
LHDD	2.3	1	0.12
LNGE	0.0	1	0.97
LNGFP	29.2	1	0.00
LNGI	1.34	1	0.24
LNGIC	4.7	1	0.02
LBTU PRICE SPREAD	0.0	1	0.93
LRC	0.22	1	0.63
LWTICO	0.01	1	0.90
LNGS	4.8	1	0.02
All	50.03	11	0.00

The structural moving average (MA) representation of our model can be used to infer impulse response functions. Dropping the intercept term, as it is of no interest for the analysis, allows the structural MA-form to interpret the impulse response functions.

The impulse response functions of the response of natural gas prices to various variables are shown below. The Y axis shows the impulse response by percent upon natural gas (priced in U.S. dollars per mmBtu) and the X axis shows the time in months in the impulse response. A key is provided in the appendix to help interpret the acronyms used. Representing our model in a structural moving average allows us to interpret those impulse response functions. We observe that the impulse response functions are consistent with the economic reasoning.

Response of natural gas prices to natural gas futures prices

Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.

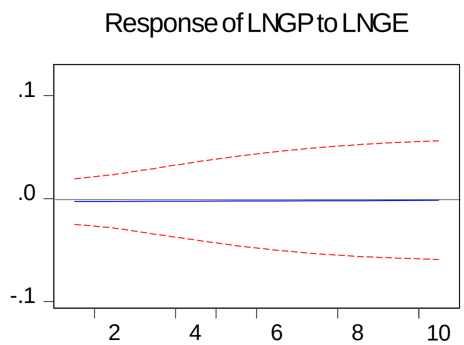


A futures market by design intends to be a leading indicator of spot market prices. But the period of time from current cash market activity and the start of a delivery month of the prompt futures contract is brief. There are only about 21 trading days in the period. The futures and cash markets can serve as a proxy for each other. A futures market is meant to serve as a hedge for upcoming activity. But market participants and speculators will take advantage of any anomalous prices through arbitrage. The two types of trading -- physical and financial -- serve as a check on each other.

The convergence of natural gas spot prices to futures has continued to improve over several decades. The cash market became liberalized in the United States in the late-1980s, and futures trading at the Henry Hub in Louisiana began in 1990 on the New York Mercantile Exchange (now CME). A Henry Hub look-alike futures contract trades on the Intercontinental Exchange. Advantages enjoyed by a participant in any of these markets because of superior execution or better information tend to be short-lived.

Response of natural gas prices to natural gas exports

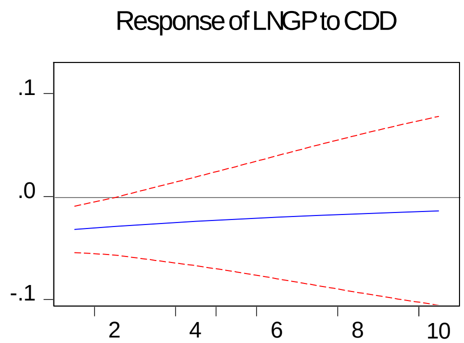
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.



Natural gas exports generally are approved by permit issued by the U.S. Department of Energy. Access to foreign markets were fairly static during the study period. Canada, like the United States, is a gas-producing nation. Opportunities for U.S. supply to reach Canadian markets have been limited to brief periods during high prices where transportation to export points and through Canadian pipelines was available at the same time. Mexico increased U.S. imports late in the study period as environmental goals called for the displacement of fuel oil for power generation. But U.S. gas production was growing faster than the demand from either of these faster markets, so the response of gas prices to exports is negligible to slightly negative. Whenever there was a change in the level of exports, gas supply could more than accommodate it. In fact, it is likely that exports were able to increase because of high supply and low prices as gas producers and sellers sought more markets.

Response of natural gas prices to cooling degree days

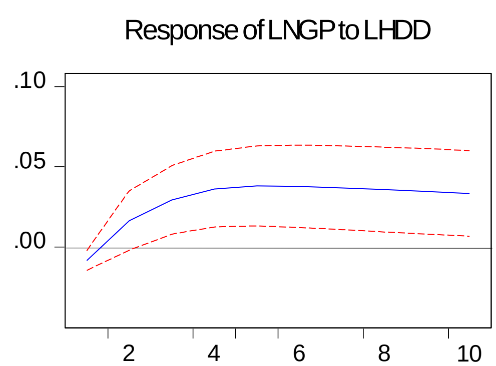
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.



The lower 48 states have a variety of climactic norms, and demand patterns for natural gas are far from uniform across the country. A cooling degree day (CDD) is accumulated at a monitoring station for each degree above an average daily temperature of 65° Fahrenheit. Cooling degree days generally signify less demand for natural gas for space heating because of moderate to high temperatures. As a result, the immediate response of prices to more CDDs than normal is negative. However, the prevalence of air conditioning in almost all areas of the country gives consumers the option to cool structures at will. The high level of integration of the national pipeline and power grids allows for efficient wheeling of resources. A lengthy period of extensive heat in several regions requires power generation for cooling load, so as CDDs continue to mount in the summer, gas prices will rise. It should be noted that three of the most populous states in the U.S. have climates least like the others: California, Texas and Florida. Long-lasting or simultaneous CDD accumulation above the norm in those states will support natural gas prices on a national basis.

Response of natural gas prices to heating degree days

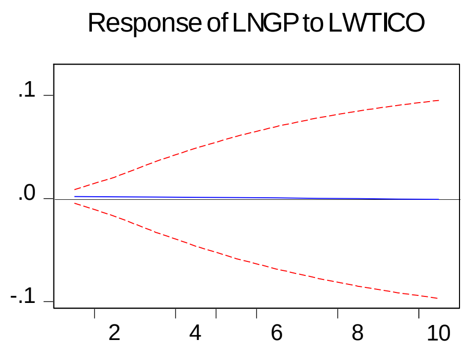
Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.



Natural gas is traditionally but not exclusively a space heating fuel in the U.S. A heating degree day (HDD) is accumulated at a monitoring station for each degree below an average daily temperature of 65° Fahrenheit. Natural gas use is highly sensitive to temperature, so much so that local distribution companies are prepared for multiple spikes in usage during a single day based on weather forecasts. The wholesale gas market can respond to these needs in a brief period of time. Generally, all that is required is to ensure that a connecting pipeline has adequate transportation capacity in an upcoming delivery cycle. As a result, the immediate response of prices to more HDDs than normal is positive. The U.S. and Canada also have many gas storage facilities in geological formations and in pipeline systems. Without storage, the response of prices to HDDs would be even more pronounced.

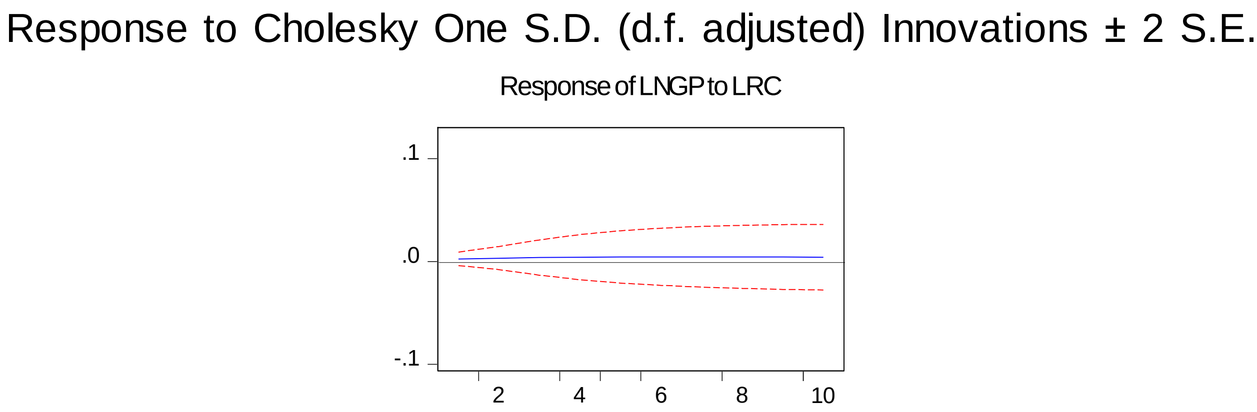
<u>Response of natural gas prices to crude oil prices</u>

Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.



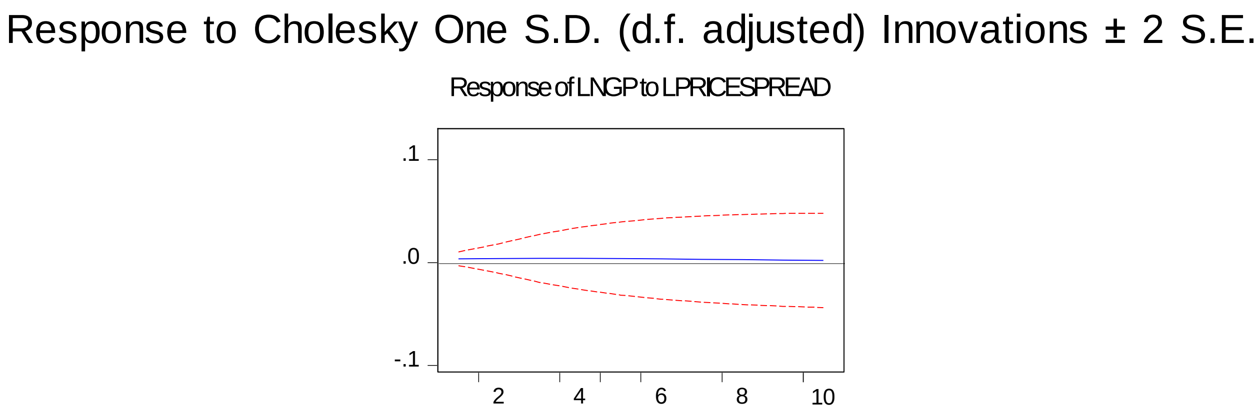
The ability to substitute refined petroleum products for natural gas on a price per Btu basis is a well-established. A barrel of oil is expected to contain 6 million Btu. Oil products can be substituted for gas both for space heating and electricity production. Oil products have largely fallen out of favor for both of those purposes based on price and for environmental considerations. But significant dual-fuel capability does exist and price volatility encourages a reassessment of fuel choices from time to time. Every commercial interest, from utilities to generators to distributors, is highly aware of arbitrage opportunities. Highly liquid markets for natural gas, crude and refined products make it nearly impossible to obtain an advantage in information. The impact of crude oil prices on natural gas prices is negligible.

Response of natural gas prices to the rig count



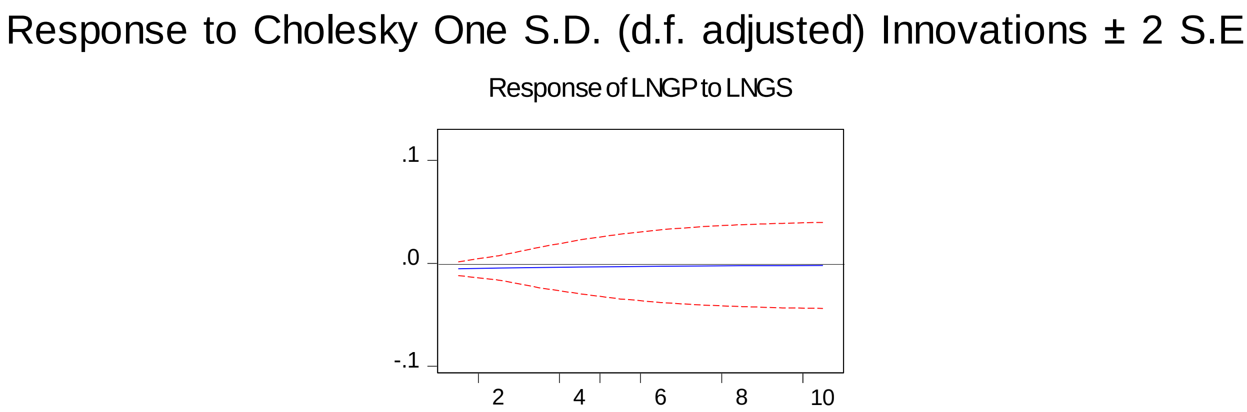
Traditional economic models suggest that the rig count would respond immediately and consistently to the direction of natural gas prices. The inverse relationship is equally important. Buyers and sellers are acutely aware of supply not just in the short term but over the many months or years between the time a well is spudded and when hydrocarbons reach the market. In the study period, gains in the rig count raised prices slightly. On top of that, the most significant development of the study period is the increased production per well because of improvements in horizontal drilling and hydraulic fracturing. This is a seemingly contrary result that only can be explained by factors outside of the MVAR analysis.

Response of natural gas prices to the Btu spread of crude oil



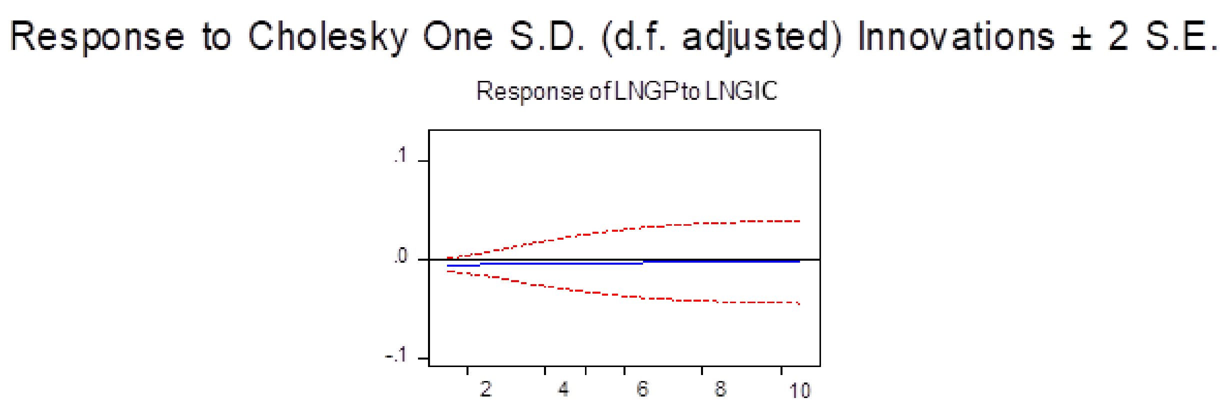
The relative heating values of natural gas and diesel fuel are well understood, as is the hypothetical value of a barrel of crude oil. Natural gas prices will move independently of each of these fuels throughout market cycles. But our study found that as one of those fuels ceases to move in concert with the other, it suggests a lack of availability. This can occur because of crude oil supply, end-use demand, inventory, and logistics factors – all affected in turn by economic activity, government regulation, and geopolitics. Natural gas prices have a slight tendency to compensate with a wider spread and to rise in the near term. The result is somewhat similar to the crack spread, which expresses the value at which petroleum products can be sold relative to crude oil. The MVAR analysis shows that the variance falls to near zero within 10 weeks, however.

<u>Response of natural gas prices to storage</u>



Storage of natural gas in salt caverns, depleted reservoirs or on the pipeline network comprises one of the most important fundamental drivers for the unregulated wholesale market system. The quantity of natural gas in storage is reported by operators on a weekly basis to the U.S. Energy Information Administration. After vetting (a statistical process examines all submissions), an estimate is produced of the amount of storage that exists in each region of the country, and nationwide. The results are disseminated in a way that approaches near-perfect information. Attempts are made by the private sector to mirror or model the number ahead of its release. While it is possible to make accurate predictions about the amounts withdrawn or injected into storage, there is little advantage over other market participants that accrues. No storage operator can trade upon a better number.

Examination of data during the study period found that when quantities of gas in storage rose, prices declined. The seasonality of injection and withdrawal cycles is so predictable that over time, the response is minimal.

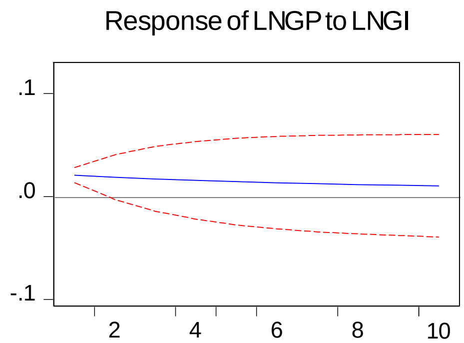


The U.S. is home to many energy-intensive industries that have chosen to locate their facilities straddling the natural gas transportation network. Many of these businesses are in commodity industries themselves, and so are keenly aware of the competitive and comparative advantages of foreign firms. In the study period, the growing abundance of gas from shale fields encouraged the expansion and new construction of manufacturing plants for industries like fertilizers and petrochemicals. The glass, steel and refining industries also benefit markedly from low natural gas prices.

As gas is only one significant input for these firms, they are encouraged to lock in an acceptable price for the feedstock well ahead of or very early in their sales cycle. Industries want a gas price that will clear the market for their end product, but not always the lowest gas price. Because their gas is purchased long in advance, their gas prices are nearly indifferent to industrial usage in the study period, a time of relative abundance. The MVAR model showed how they responded negatively. Because gas prices are low, industrial consumption of gas has been able to increase.

<u>Response of natural gas prices to natural gas imports</u>

Response to Cholesky One S.D. (d.f. adjusted) Innovations ± 2 S.E.



Canada has been a willing supplier of gas to U.S. for many decades. Because of Canada's sparse population, the country has much more gas than it needs. Because of many interconnections and different producing basins in the two countries, their transmission systems increasingly supply each other and act as one, fulfilling market needs and displacing expensive gas. Imports of more U.S. supply by Canada are increasingly likely.

During the study period, consistent but weather-dependent flows could reliably be assumed from British Columbia and Alberta to U.S. markets in the West and Upper Midwest. High demand from these regions generally coincides with very cold weather in much of North America. Increased imports immediately correspond with higher prices. Weather trends are generally viewed as short-term events, and the response reverts toward the mean in later weeks.

<u>Forecast Error Variance Decomposition Analysis</u>

In order to understand the relative contribution of the variables considered in the model, we performed a forecast error variance decomposition analysis. The variance decomposition indicates the amount of information each variable contributes to the other variables in the regression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. Table 5 shows the estimated shares of the variance of the natural gas price accounted for by the structural innovations of each variable. The period in the left hand column is expressed in months. The variance is the percentage impact on the natural gas for week for each variable.

Table 4: Forecast Error Variance Decomposition for Natural Gas Price

Period	LCDD	LHDD	LNGE	LNGI	LNGIC	LNGS	LBTU PRICE SPREAD	LRC	LWTICO	LNGFP	LNGP
1	0.43	0.04	0.17	1.73	4.48	0.02	0.13	9.91	1.1	71.8	10.04
2	0.40	2.56	0.61	1.84	7.7	0.35	0.08	8.93	2.5	68.09	6.88
3	0.36	6.90	0.84	1.34	7.6	0.57	0.18	7.82	4.8	62.08	7.4
4	0.35	10.90	0.90	1.05	6.7	0.71	0.41	6.9	7.4	56.6	7.89
5	0.39	13.77	0.91	0.89	5.9	0.80	0.70	6.2	10.0	52.14	8.11
6	0.50	15.68	0.92	0.81	5.2	0.81	1.03	5.7	12.4	48.4	8.24
7	0.68	16.96	0.93	0.79	4.6	0.77	1.34	5.4	14.6	45.3	8.37
8	0.88	17.86	0.95	0.80	4.2	0.70	1.63	5.1	16.5	42.7	8.48
9	1.06	18.54	0.97	0.81	3.9	0.66	1.88	4.8	18.1	40.5	8.57
10	1.16	19.07	0.97	0.83	3.8	0.69	2.09	4.6	19.2	38.6	8.60
11	1.20	19.49	0.96	0.86	3.8	0.77	2.26	4.4	20.4	37.1	8.60
12	0.04	19.79	0.94	0.88	3.9	0.88	2.42	4.3	21.1	35.4	8.55

The variance decomposition of forecast errors among the variables differs widely from the impulse response the same variables. That is to say, they have more impact on the other variables in the group than on natural gas prices alone.

For instance, the effect of cooling degree days is minimal, but that of heating degree days reach their maximum explanatory power over a long time horizon, or nine to twelve months. While our study and the SVAR approach does not allow for a direct link to be drawn, heating degree day accumulation is essentially dictating the natural gas storage levels that will be available at the start of the next season.

It is interesting to note that several of the variables such as natural gas exports, imports, industrial consumption of natural gas, the BTU price spread to oil and natural gas storage barely explain two percent to four percent of the fluctuations in natural gas prices. The explanatory power of the rig count is greater in the near term at roughly 10 percent, but then declines to 4 percent over the long term.

The crude oil price, similar to heating degree days, explains more of the fluctuations in natural gas prices as the study period extends to 12 months. It is interesting to note that much of the fluctuation in natural gas price is explained by the futures price of natural gas. Even though the explanatory power of natural gas futures declines from 71 percent in month 1 to 35 percent in month 12, it nevertheless accounts for sizable variations or fluctuations in the natural gas price. The SVAR model does not directly explain the correlation, but it is one that many traders have long understood. In liberalized physical and financial energy markets, the pricing of several commodities can have a high correlation when the price trend of the most actively commodity is extended. This was seen in the 2008 price spikes in crude oil and natural gas.

Section 6: Conclusion and topics for further study

Our paper presents a structural market to examine the dynamics of natural gas markets in the U.S. since 2008. While some research has been done in the recent years examining the fundamental drivers of natural gas markets in the U.S., most of them have not focused on the dynamics of the natural gas markets during the recession and its aftermath. Our research confirms some of the earlier analysis, namely that abnormal temperatures during the winter, or high heating degree day accumulation, have a significant impact on natural gas prices.

One of the most significant findings is that natural gas futures are nearly a proxy in determining natural gas spot market prices. This was not unexpected. While some degree of speculative activity is always present in gas futures, hedging by various sectors in the value chain (producer, marketer, distributor, industrial) remains larger.

The diverse results of the impulse response and the forecast error variance decomposition analysis give pause where the price of crude oil is concerned. The SVAR impact of crude oil on natural gas prices is negligible while the impact on the other variables is rises over time. Crude oil and natural gas are the most traded individual energy commodities in the U.S. Many companies are active traders and transporters of all energy commodities and participate in the related financial markets for both hedging and speculative purposes. They are obligated by company policy to balance trading strategies with risk management limitations and margining rules. An examination of crude oil physical and futures prices, combined with data from the Commitment of Traders report of the Commodity Futures Trading Commission, could shed more light on how crude oil affects natural gas in both an SVAR and multivariate analysis.

One of the major limitations of our study is that our analysis is based on monthly data. There is little doubt that analysis based on weekly data may prove more useful. However, weekly data on indicators of the impact of business cycles or economic activity instead industrial consumption of natural gas would need to be available.

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Appendix

Key for log of variables

Variable	Definition
LCDD	Cooling degree days
LHDD	Heating degree days
LNGE	Natural gas exports
LNGFP	CME Henry Hub natural gas prompt month futures price
LNGI	Natural gas imports
LNGIC	Industrial consumption of natural gas
LBTU PRICE SPREAD	BTU price spread between natural gas and crude oil
LRC	Rig Count
LWTICO	CME WTI light, sweet crude oil prompt month futures price
LNGS	Natural gas storage
LNGP	Henry Hub spot natural gas price