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# Natural Gas and the US Economy: Some Preliminary Rules of Thumb[1]

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**Abstract**

I estimate the response of real US GDP to changes in the natural gas price. A 10% increase in the natural gas price due to an unexpected fall in supply leads to a 0.15% decrease in GDP when using data after 2005. I also find that price increases driven by export demand became a net positive for GDP between 2006 and 2017—an interesting result that requires further research. Finally, the response of GDP to an increase in natural gas production is small and positive since 2005.

Keywords: economic activity; natural gas; shale; rules of thumb
JEL Classifications: C11, C32, E37, Q43

[1] The analysis and conclusions expressed here are those of the author and not necessarily those of the U.S. Energy Information Administration.

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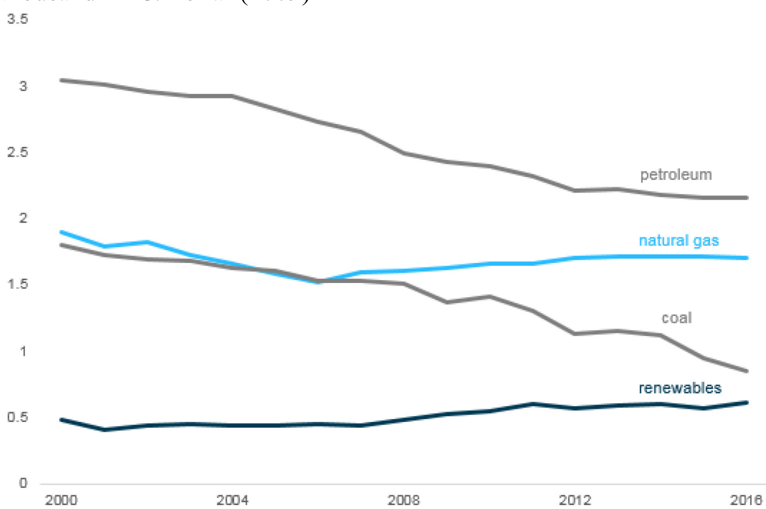
## Introduction

If natural gas had feelings, they would surely parallel those of Donald Duck. No matter what happens—low prices, increased production, greater use throughout the economy, burgeoning exports, growing geopolitical heft—oil, like Mickey Mouse, remains the star. But—in the United State at least—that may be changing for the first time since William Hart dug that initial Fredonia New York natural gas well in 1821.

The American shale boom has upended world energy markets and spread its tentacles throughout the U.S. energy sector and economy. Resulting changes in the last ten years have been profound. Unlike petroleum, natural gas consumption in the U.S. per unit of output—natural gas intensity—has remained flat since 2006, above both coal and renewables [Figure 1].[5]

Figure 1: US Energy Intensity of GDP

thousand BTU/Dollar (2009)



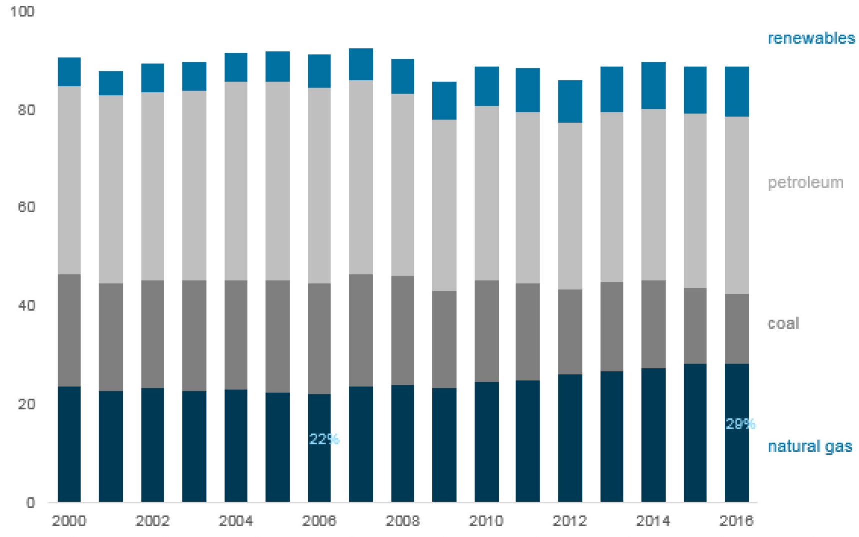

Source: BEA, EIA

While decreases in energy intensity can be desirable due to gains in efficiency, the trend in natural gas intensity is driven by greater use throughout the economy. This becomes apparent when looking at the use of natural gas relative to other fuels [Figure 2]. The relative share of American natural gas consumption across energy end-use sectors—transportation, residential, commercial, and industrial—has grown steadily since 2006. In fact, the interaction between natural gas and end-use sectors has fundamentally transformed between 2006 and 2017. The renewables share has also increased, while nuclear has remained flat, and both coal and petroleum have fallen.

[5] Here, I use petroleum interchangeably with oil, as is commonly done: https://www.eia.gov/tools/faqs/faq.php?id=40&t=6

Figure 2: US primary fuel consumption (excluding nuclear)

quadrillion Btu




Source: EIA

Effects of these changes go far beyond the energy sector—particularly in terms of economic impacts. Greater production has led to lower natural gas prices—reducing both heating and electricity costs—and potentially freeing up money to spend on other goods. There has also been the need to invest in new pipelines, facilities, roads, power plants—and exports have risen as imports have fallen.[6]

To get at the implications of these changes, I estimate rules of thumb for the impact of natural gas prices and production on American economic activity over different time periods. I find that the response of US GDP to price increases driven by supply has become more negative since 2005. I also find that price changes driven by export demand became a net positive for GDP between 2006 and 2017. Finally, the response of US GDP to a change in natural gas production is small and positive since shale production began to increase.

**Background**

Natural gas impacts US Gross Domestic Product (GDP) primarily through consumer spending, firm investment, and the value of trade (Arora, 2014a).[7] Consumer spending is arguably the most directly linked to households, as natural gas affects both electricity and heating bills.

Lower heating and electricity costs may increase consumer disposable income and lead to greater spending on other goods and services, or might allow people to pay down credit cards and other types of debt. Higher heating and electricity costs work in the opposite direction. It appears that

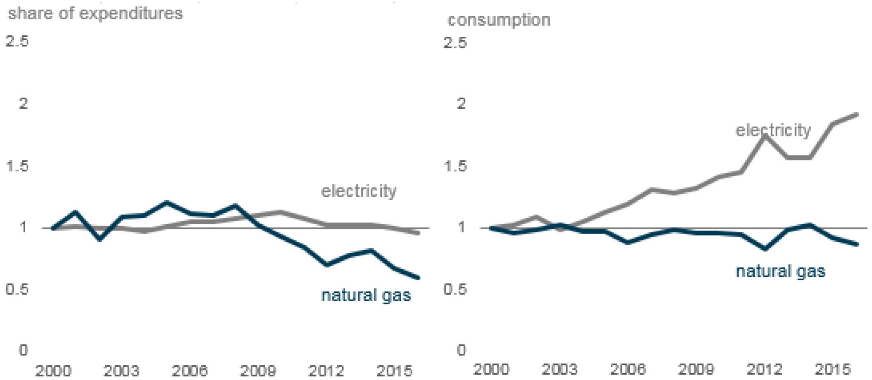
[6] Many papers have tried to quantify the importance of the shale boom for the US economy, but most have focused on oil or specific regions (see the references in Arora (2014)). Only a few have narrowed in on natural gas, and recent examples include Arora (2014a), Arora and Lieskovsky (2014), Hausman and Kellogg (2015), Kirat (2016), and Weber (2014).

[7] I focus here on the expenditure side of the national accounts because it makes the discussion clearer. The production and income sides of the national accounts will also reflect corresponding changes.

natural gas prices have led to lower heating and electricity spending nationally since 2000, as compared with consumption [Figure 3].

Figure 3: Index of US consumer expenditures and energy consumption

index, 2000 = 1



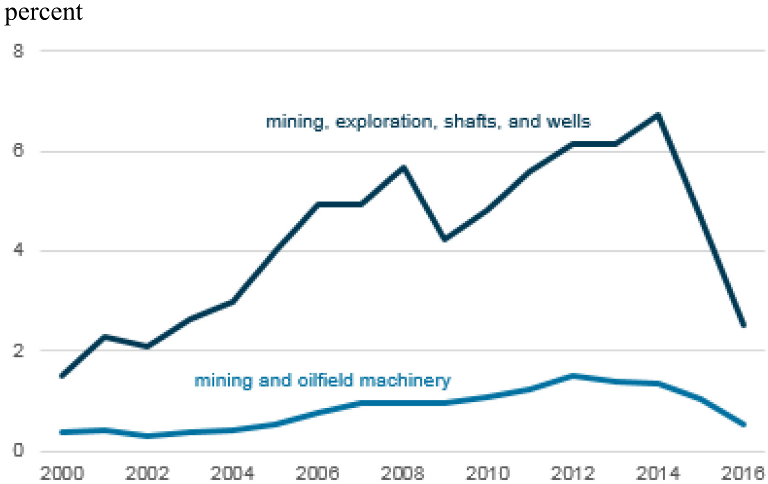

Source: BEA, EIA

Consumer spending on electricity and residential natural gas have grown slower than corresponding measures of energy consumption—indicating lower prices. Because of taxes, fees, and other costs these lower prices may not be responsible for the entire difference between the series, but are an important factor.

Natural gas—and oil—production have also had an impact on US investment in fixed assets, particularly non-residential investment [Figure 4]. A rough estimate is that about 25-30% of the investment shown was related to natural gas.[8] The share of non-residential investment due to mining and exploration as well as mining machinery grew steadily from 2000 until 2014.

Figure 4: Share of US non-residential investment

percent




Source: BEA, EIA

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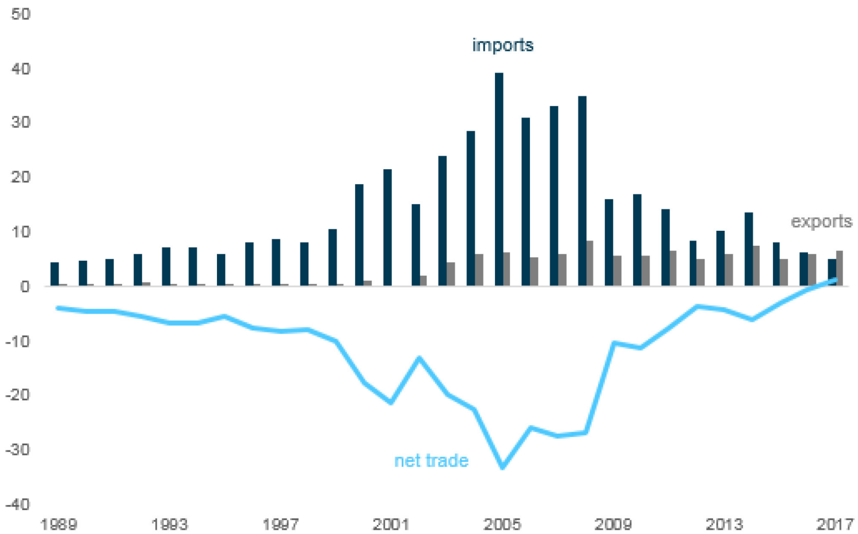
[8] This estimate is based on US expenditures on natural gas versus expenditures on oil.

While much of this had to do with oil, the share of non-residential investment in mining and exploration grew by nearly six times between 2000 and 2014. And although that share fell substantially in 2014, it is likely to recover somewhat with oil prices.

The most surprising effect of recent changes in US natural gas markets has been on trade—natural gas imports have traditionally been greater than exports in value terms [Figure 5].

Figure 5: Value of US natural gas trade

billions of dollars (2009)




Source: BEA, EIA

That changed in 2016 due to a reduction in the value of imports and greater exports. Net exports of natural gas are now a slight addition to US GDP.

Given these changes in consumption, investment, and trade expenditures related to natural gas, it is likely that the relationships between natural gas prices and production and the US economy have also undergone a shift. Figure 6 brings this together by showing the approximate expenditures on natural gas relative to US GDP.[9]

[9] Approximate because I use the Henry Hub spot price as a proxy for the natural gas price. A more detailed calculation would include regional and end-use variation in natural gas pricing.

Figure 6: Natural gas expenditures relative to US GDP

Source: BEA, EIA, FRED

I turn next to quantifying these relationships and then show how they have changed since 2006.

**Models and Data**

I am interested in two different rules of thumb—the natural gas price elasticity of US GDP and the natural gas production elasticity of US GDP. These quantify the average percent response of real US GDP to a percent change in the natural gas price or production. To my knowledge both are inherent in various macroeconomic models, but have not been explicitly discussed elsewhere. And most model responses that I am aware of have not been updated to reflect recent changes in US energy markets.

I use a standard econometric model to calculate the rules of thumb. In terms of the price elasticity, the model differentiates between reasons for the price change, and I am able to separate out demand due to heating/weather and demand due to natural gas exports. It is based upon Arora and Lieskovsky (2014), and I use this to back out the price elasticity of US GDP due to supply changes, the price elasticity due to heating/weather demand changes, the price elasticity due to export demand changes, and the production elasticity of US GDP.

The five variables in the model (in order) are natural gas production, natural gas exports, real GDP, residential natural gas consumption, and the natural gas price. The ordering of these variables matters for my results because I identify the model using exclusion restrictions. Changing the order will give different results.

I show results over two different sample periods: 1973 through 2005, and also from 2006 through 2017Q3. By breaking the sample up this way I am able to see how much of a difference recent changes make in the estimates. And, as shown above, 2006 is about the time that drilling from shale plays started to affect natural gas use. Because I want rules of thumb for real US

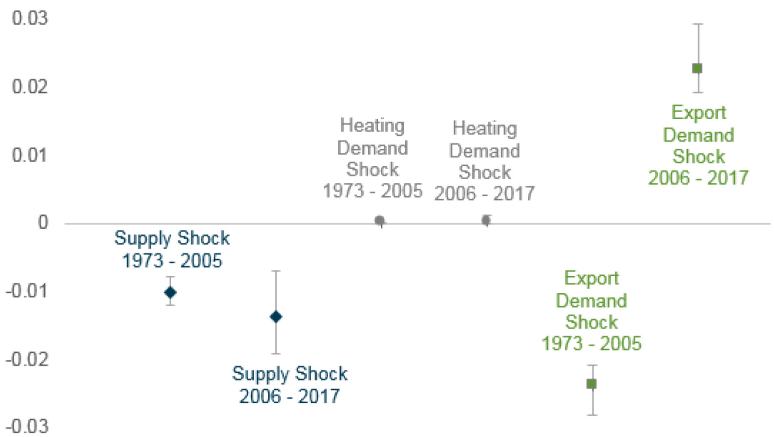
GDP, the data are at a quarterly frequency. See Appendix 1 for full details on data, estimation, and identification.

**Results**

Natural gas price elasticities are summarized in Figure 7. Two features stand out. The first is that median values for supply-driven elasticities are negative for both samples, but become more negative in the later sample period. There is, however, some variation in the supply-driven elasticity for the 2006 to 2017 period in terms of the 10$^{th}$ and 90$^{th}$ percentiles.

Figure 7: Natural gas price elasticities of GDP

median estimates and 10th/90th percentiles




Source: EIA, BEA, BLS

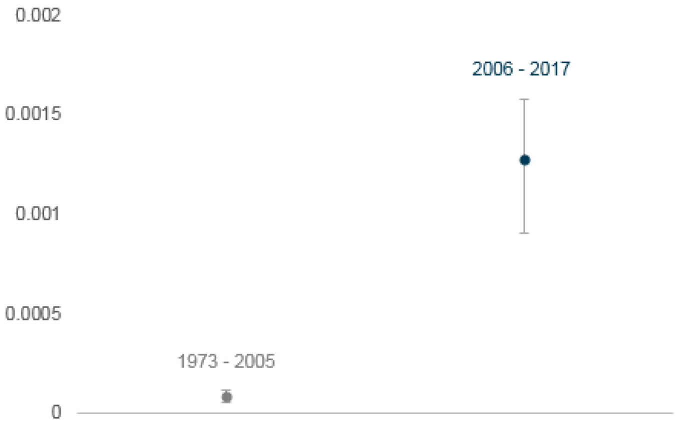
The second feature is that attempting to isolate the effect of shale in the sample (2006-2017) completely flips the export-driven elasticity. The median export-driven natural gas price elasticity rises from below -0.02 to above 0.02. The median heating demand driven elasticities do not change much with the sample, staying close to zero in either case.

What are the implications? For one thing, the use and availability of shale has changed the relationship between natural gas and the US economy. This is particularly true when unexpected foreign demand for US natural gas exports raises the price. After 2005 the resulting production increases far outweigh the negative effects of higher natural gas prices. This is a unique result that requires further research.

This is also the reason that the median supply-driven price elasticity is more negative in the later sample—unexpected falls in supply have a bigger economic impact with shale. The direct influence of supply has changed as well, and this can also be seen in the elasticity of US GDP to natural gas production [Figure 8].

Figure 8: Elasticity of US GDP to a natural gas production change

median estimates and 10th/90th percentiles




Source: EIA, BEA, BLS

Although the movement is small, modifying the sample period results in a larger response of GDP to an increase in natural gas production—from just above 0 to over 0.001. So a 10% year-over-year increase in natural gas production for a particular quarter will raise US GDP by slightly more than 0.01%. The $10^{th}$ and $90^{th}$ percentiles are also relatively tight around the estimate over this time period as well.

There are, however, some caveats about interpreting these estimates that should be mentioned. First, because of the way in which electricity pricing is structured across states, there is great variation in what residential, commercial, and industrial customers are actually paying—and how often that changes. Additionally, these estimates are picking up many things that happened in the US economy over the respective sample periods, including with oil. And because natural gas production is tied up with oil production, this could have an influence on the results.[10]

I also identify the model in a particular way—summarized in Appendix 1—and changing the identifying assumptions will alter these results. The model results are only as good as those identifying assumptions. Finally, the shale-based sample has only 11 years of data, and this limits the accuracy of the estimates.

## Conclusion

To put these results into perspective, I calculate some back-of-the-envelope estimates for the impact of natural gas price and production changes on real US GDP. Natural gas prices fell an average of 3% each quarter between 2006 and 2017; natural gas production rose about 5% each quarter over that period (year-on-year); natural gas exports increased by nearly 15% each quarter (year-on-year); and real GDP grew nearly 0.4% quarter-on-quarter.

Assuming all of the price fall was due to supply, the model estimates the effect was to raise GDP an average of 0.05% each quarter. The effect of production was to raise real GDP 0.005% each quarter. Taken together—and caveating with the fact that all of the price changes were not just

[10] Although adding the oil price as a regressor does not substantively change the results.

supply-driven—the model estimates that on average natural gas prices and production contributed about a tenth of US GDP growth over the 2006 to 2017 period.

For now at least, the American shale revolution has put natural gas front and center—letting it have a moment in the sun. Donald Duck would be jealous.

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**Appendix 1: Data**

The marketed natural gas production, residential consumption and export numbers are from EIA's monthly energy review; natural gas price is the BLS's producer price index for natural gas; and economic activity is real GDP from the BEA. Production, consumption, and exports are summed over the three months in a quarter, while the price is averaged. The sample begins in 1973 (when EIA energy data becomes available) and runs through the third quarter of 2017. Each model uses the annual log difference in each variable, except for real GDP and the natural gas price, where I use the quarterly log difference. The quarterly differences are used for GDP because it is reported that way by the BEA; the price series uses a quarterly difference because it is seasonally adjusted by the BLS.

I apply a novel method to back out the main results of the paper. The model is a Bayesian Vector Autoregression (BVAR) that I identify using a modification of the traditional sign-restriction based approach (for more on the traditional approach see Arora (2014b)). All specifications use 4 lags, and those that run through 2017 include a dummy variable for the 2008/2009 US recession.

In each case I start by using standard Minnesota priors and identification via exclusion restrictions. The ordering of variables is (see Arora and Lieskovsky (2014) for more information): marketed US natural gas production, US natural gas exports, real US GDP, residential US natural gas consumption, and the natural gas price. As emphasized in the main text, changing this order will change the results.

I repeat these estimates two millions times while varying hyper-parameters of the Minnesota prior over a grid. I then keep only responses from the model that meet pre-specified criteria. These criteria eliminate counter-intuitive results such as price elasticities of demand that are positive, or price elasticities of supply that are negative (see Kilian and Lee (2014) for more on such criteria when using sign restrictions).[11] For the final estimates I back out the median and $10^{th}$ and $90^{th}$ percentiles of the model runs that meet all of the criteria.

I calculate the price elasticities by taking the values of the respective impulse responses at two quarters. For example, the price elasticity of GDP due to export demand is the response of GDP due to export demand at two quarters divided by the response of price due to export demand at two quarters. The production elasticities of GDP do not need to be calculated, as they are the response of GDP to supply shocks at two quarters.

[11] The criteria:

- Response of consumption to price is negative up to two quarters.
- Response of production to price is positive up to two quarters.
- Responses of price to consumption, GDP to production, and price and production to GDP are positive up to two quarters.
- Response of price to production is negative up to 2 quarters.
- Response of GDP due to price from supply is negative and greater than -0.03.
- Response of GDP due to exports is positive and less than 0.03.