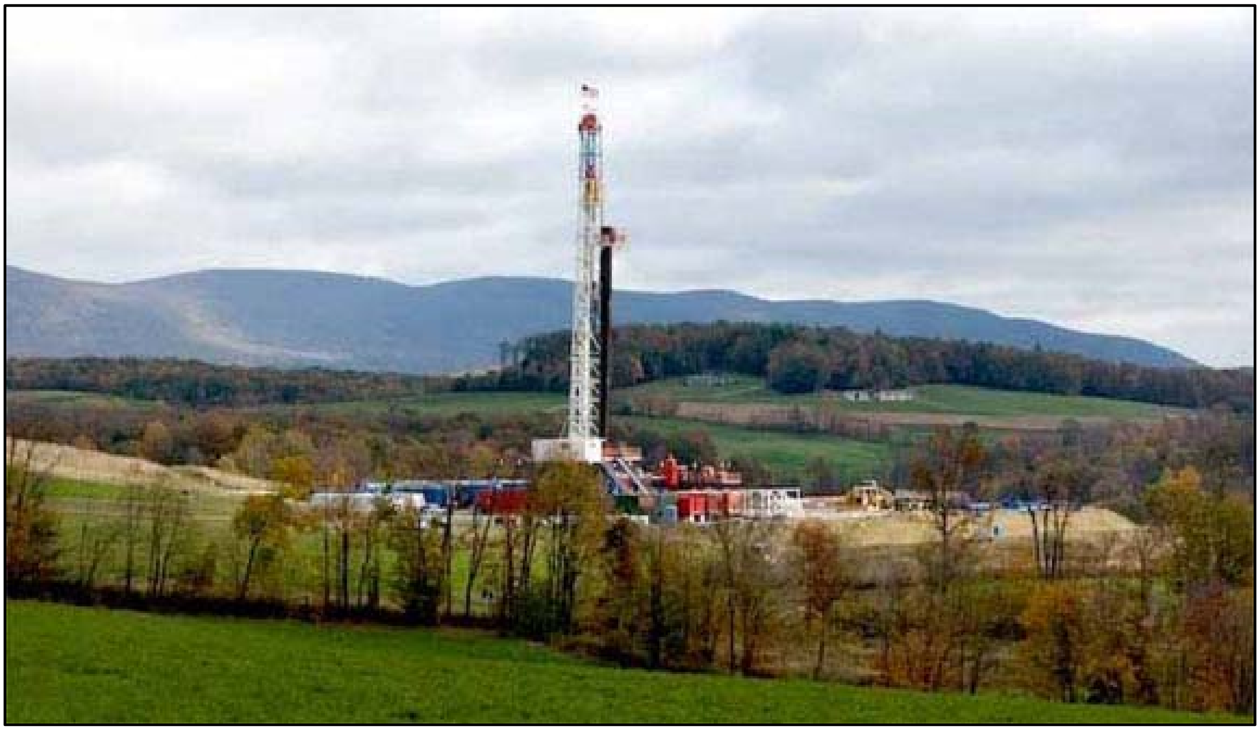

The Economic Impacts of U.S. Shale Gas Production on Ohio Consumers

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January 2012

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EXECUTIVE SUMMARY†

Shale gas has fundamentally changed the U.S. energy picture, providing a boon in an otherwise moribund economy. A decade ago, shale gas and liquids production were inconsequential. As the gas supply "bubble" of the 1990s ended and crude oil prices accelerated, so did wellhead natural gas prices, because of the historic linkage between the prices of the two fuels. In 2005, the damage caused by Hurricanes Katrina and Rita to the U.S. Gulf natural gas supply infrastructure caused a further spike in wellhead prices, and concerns grew that natural gas prices would continue to escalate.

As shale gas production has accelerated, U.S. natural gas prices have plummeted. Although the severe economic recession that began in late 2008 and the resulting decrease in the demand for natural gas have contributed to lower wellhead natural gas prices, much of that price decrease stems from the rapid increase in domestic shale gas supplies, which increased almost tenfold between 2005 and 2010.

The rapid expansion of shale gas production in the United States has created hundreds of thousands of new jobs directly and in supporting industries. The effect of this expansion on people and communities within the geographic areas of the shale plays has received considerable attention. However, domestic shale gas developments have also been the catalyst for far broader economic benefits throughout the country. More specifically, the lower wellhead natural gas prices that have resulted from this expanding shale gas production have lowered businesses' and consumers' energy bills, not only for natural gas, but also for electricity, an increasing percentage of which is generated from natural gas. Without seeking to divert attention away from the important economic development and retention benefits that shale gas development has had or will have on local populations and communities, this report provides information about the broader beneficial dividends that shale development is paying to the public at large.

While conventional natural gas production in the U.S. has decreased over time, shale gas has become a rapidly increasing source of U.S. gas supplies, accounting for about 20 percent of total U.S. onshore domestic natural gas production in 2010. The U.S. Energy Information Administration ("EIA") forecasts that, by 2035, shale gas could account for over 50 percent of onshore natural gas production.

Of greater interest for Ohioans is the Utica Shale, which lies beneath the better-known Marcellus Shale, and extends into the eastern half of the state. Although reserve data is based on preliminary drilling in the Utica Shale, geologists expect the Utica Shale to be relatively rich in

† Funding for this report was secured through the Industrial Energy Users-Ohio (IEU-Ohio), an Ohio-based organization of customers that helps customers address issues affecting the price and availability of energy. Information on IEU-Ohio is available at http://ieu-ohio.org

oil and natural gas liquids that are currently worth significantly more than natural gas on an energy-equivalent basis. Preliminary estimates by Ohio's Department of Natural Resources (ODNR) suggest a recoverable reserve potential of between 1.3 and 5.5 billion barrels of oil as well as 3.8 to 15.7 trillion cubic feet ("Tcf") of natural gas. The overall economic value of the Utica Shale region in Ohio may be especially large, because it lies relatively close to the surface, which reduces exploration and development costs.[1]

Although overall natural gas consumption in Ohio has decreased since 1997 (in part because of reductions in the energy intensity of Ohio's economy), expenditures on natural gas remain significant. In 2009, Ohio consumers and businesses, including electric generators, consumed 724 billion cubic feet ("Bcf") of natural gas, at a cost of $7.46 billion. Thus, lower natural gas prices owing to shale gas production can have real benefits for Ohio energy consumers as well as the public at large.

To estimate how much shale gas has contributed to the decline in wellhead natural gas prices and how those price decreases have flowed through to benefit Ohio's natural gas consumers, Continental Economics developed a model to isolate the impacts of shale gas on wellhead prices. Then, using the results of that model, we determined the savings to different classes of Ohio consumers.[2]

Our analysis showed that, for each Tcf of shale gas produced, the average annual wellhead price is $0.46 per thousand cubic feet ("Mcf") lower that it otherwise would be. Equivalently, the average wellhead price would be $0.46 per Mcf higher for each Tcf of shale gas not otherwise produced. The results of our analysis are shown in Figure EX-1 and Table EX-1 on the following page.

As the table shows, the impact of shale gas production on wellhead gas prices has increased steadily as shale gas supplies have increased relative to total natural gas supplies. For example, in 2010 we estimate that shale gas production, which was over 4.7 Tcf, caused observed average wellhead natural gas prices to be $2.43 per Mcf lower than what they would have otherwise been.

1 The depth of shale gas deposits below the surface is not uniform. All other things equal, the closer to the surface, the lower are exploration and development costs.

2 We will address the impacts of lower wellhead natural gas prices on wholesale and retail electricity prices for Ohio consumers in a subsequent report.

Figure EX-1: Estimated Annual Wellhead Natural Gas Prices Without Shale Gas (1990–2010)

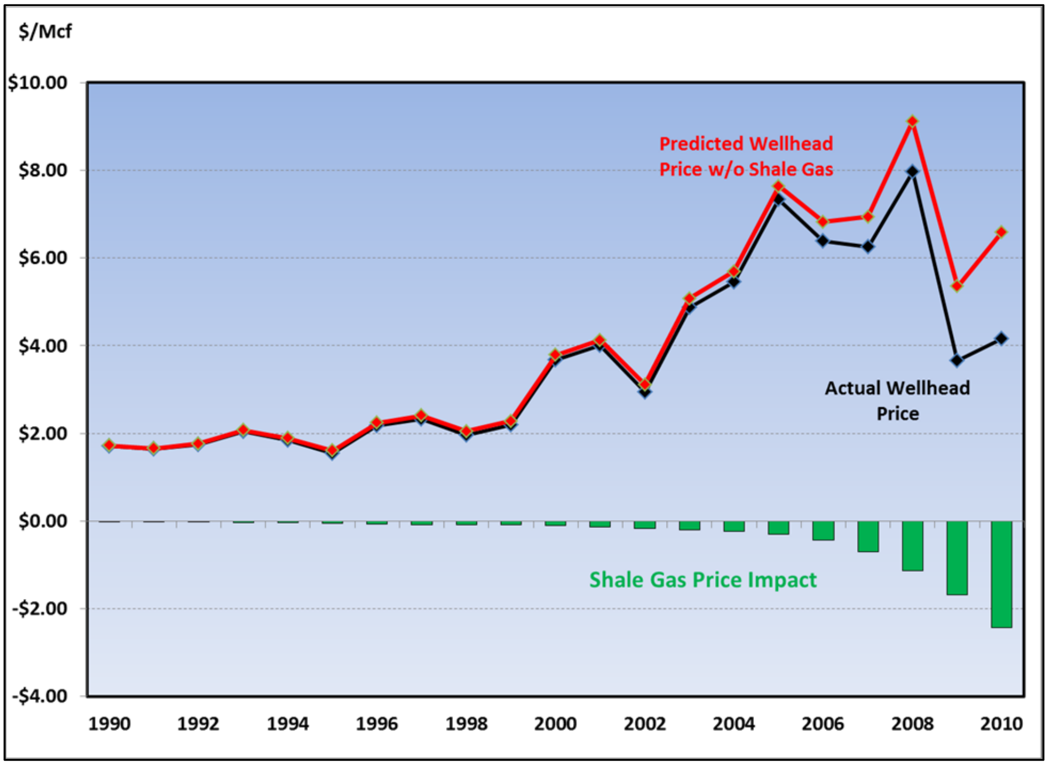

Table EX-1: Estimated Annual Price Impact of Shale Gas Production (1990-2010)

Year	Price Reduction ($/Mcf)	Year	Price Reduction ($/Mcf)
1990	($0.01)	2001	($0.13)
1991	($0.02)	2002	($0.17)
1992	($0.02)	2003	($0.20)
1993	($0.03)	2004	($0.24)
1994	($0.04)	2005	($0.30)
1995	($0.05)	2006	($0.43)
1996	($0.07)	2007	($0.70)
1997	($0.09)	2008	($1.14)
1998	($0.09)	2009	($1.68)
1999	($0.09)	2010	($2.43)
2000	($0.11)		

Based on the results of the analysis described above and average use per customer data for 2010, Table EX-2 provides an estimate of the resulting natural gas energy bill reductions for Ohio commercial, industrial, and residential customers.

Table EX-2: Estimated Annual Cost Savings for Ohio End-Use Customers

Customer Class	Average Use Per Customer (Mcf)	Price Reduction ($/Mcf)	2010 Estimated Cost Savings	Number of Customers	Estimated Savings (Millions of $)
Commercial	562.1	($2.43)	$1,366	258,422	$353.0
Industrial	35,266.8	($2.43)	$85,698	5,738	$491.7
Residential	88.2	($2.43)	$214	3,198,883	$685.4
Total					**$1,530.2**

As this table shows, we estimate that Ohio businesses and consumers saved over $1.5 billion on their natural gas bills in 2010 because of lower wellhead natural gas prices. The average residential customer, for example, burned 88 Mcf of natural gas and saved $214 in 2010. The average commercial customer used 562 Mcf and saved $1,366, while the average industrial customer used over 35,000 Mcf and saved almost $87,000. In addition, electric generators reduced their costs because of lower wellhead gas prices. This translated into lower fuel charges levied by electric utilities with fuel cost recovery mechanisms,[3] such as Columbus Southern Power and Ohio Power Company, and also contributed to lower wholesale electric prices paid by retail electric suppliers.

The results of our analysis demonstrate that shale gas production has significantly reduced U.S. wellhead natural gas prices and reduced Ohio consumers' natural gas bills. The estimated savings of $1.5 billion on natural gas bills alone in 2010 affect all sectors of the Ohio economy. As Ohio's Utica Shale gas resource is developed, Ohio businesses and consumers are likely to benefit even more in the future. Furthermore, because of the increasing importance of natural gas used in generating electricity, Ohio consumers are reaping even more benefits from lower electric bills. (In a subsequent report, we will present the estimated savings for Ohio consumers on their electric bills.)

The decreases in natural gas and electricity prices will benefit the Ohio economy, not only by creating jobs directly in the shale gas development and extraction industries as the Utica Shale is developed, but by lowering home energy bills and improving the overall competitiveness of Ohio businesses and industry.

[3] The default generation supply prices of Ohio Power and Columbus Southern Power (sometimes referred to as AEP-Ohio) continue to be administratively set by the Public Utilities Commission of Ohio ("PUCO") based on a rate structure that includes a fuel adjustment clause (FAC). Other Ohio electric distribution utilities ("EDUs") establish default generation supply prices through a competitive bidding process ("CBP") conducted under the PUCO's supervision. The downward pressure that shale gas development has placed on electric prices is observable from the inputs that go into the FAC as well as the pricing results of the CBPs that have been approved by the PUCO.

The Economic Impacts of U.S. Shale Gas Production on Ohio Consumers†

I. INTRODUCTION

Shale gas has fundamentally changed the U.S. energy picture, providing a boon in an otherwise moribund economy. A decade ago, shale gas and liquids production were inconsequential. As the gas supply "bubble" of the 1990s ended and crude oil prices accelerated, so did wellhead natural gas prices, because of the historic linkage between the prices of the two fuels. In 2005, the damage caused by Hurricanes Katrina and Rita to the U.S. Gulf natural gas supply infrastructure caused a further spike in wellhead prices, and concerns grew that natural gas prices would continue to escalate.

As shale gas production has accelerated, U.S. natural gas prices have plummeted. Although the severe economic recession that began in late 2008 and the resulting decrease in the demand for natural gas have contributed to lower wellhead natural gas prices, much of that price decrease stems from the rapid increase in domestic shale gas supplies, which increased almost tenfold between 2005 and 2010.

The rapid expansion of shale gas production in the United States has created hundreds of thousands of new jobs directly and in supporting industries. The effect of this expansion on people and communities within the geographic areas of the shale plays has received considerable attention. However, domestic shale gas developments have also been the catalyst for far broader economic benefits throughout the country. More specifically, the lower wellhead natural gas prices that have resulted from this expanding shale gas production have lowered businesses' and consumers' energy bills, not only for natural gas, but also for electricity, an increasing percentage of which is generated from natural gas. Without seeking to divert attention away from the important economic development and retention benefits that shale gas development has had or will have on local populations and communities, this report provides information about the broader beneficial dividends that shale development is paying to the public at large.

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Much attention has been paid to the jobs created by the shale gas industry, both directly and indirectly.[1] Much less has been focused on these broader economic benefits provided by shale gas stemming from lower natural gas and electricity prices.[2] The purpose of this report, therefore, is two-fold. First, we estimate the magnitude of the decrease in wellhead natural gas prices that has been caused by increased shale gas production. Second, we estimate how this decrease in wellhead natural gas prices has reduced natural gas expenditures by Ohio businesses and consumers.[3]

II. HISTORICAL OVERVIEW

In the late 1960s, the conventional wisdom was that natural gas supplies would soon be exhausted. Wellhead natural gas prices were regulated and capped. Supplies began to diminish as the incremental cost of production exceeded the revenue available from regulated prices and production from existing wells declined. Growth in the natural gas industry came to a standstill because there was little economic incentive to undertake new, more costly exploration. By 1967, estimated domestic reserves had peaked and actual production began to fall steadily. Natural gas supply shortages on peak usage days began to occur. As these gas supply shortages became more common, in states like Ohio new customer hookups were unavailable, supplies for industrial and commercial customers were interrupted and curtailed, and predictions that "the spigot would run dry" within a decade became prevalent.

By 1978, proved natural gas reserves had dropped by 30%. Something had to be done and policy makers turned to market-based strategies to balance natural gas supply and demand. First, as part of comprehensive energy legislation that year, Congress passed the Natural Gas Policy Act ("NGPA"), which began to dismantle the complex historic system of natural gas price regulation that stemmed from a 1954 decision by the United States Supreme Court decision regarding the meaning of the Natural Gas Act passed in 1938.[4] For example, Ohio initiated the Natural Gas

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1 *See, e.g.*, Kleinhenz and Associates, "Ohio's Natural Gas and Crude Oil Exploration and Production Industry and the Emerging Utica Gas Formation," (Sept., 2011). http://www.oogeep.org/downloads/file/Economic%20Impact%20Study/Ohio%20Natural%20Gas%20and%20Crude%20Oil%20Industry%20Economic%20Impact%20Study%20September%202011.pdf. For a different viewpoint on job creation impacts, and the costs and benefits of shale gas development in Ohio, see A. Weinstein and M. Partridge, "The Economic Value of Shale Natural Gas in Ohio," Department of Agricultural, Environmental, and Development Economics, Ohio State University, December 2011. http://go.osu.edu/shalejobs.

2 In this report, we do not analyze employment impacts, which are not benefits *per se*. However, businesses and consumers clearly do benefit from lower energy prices.

3 We will address the impacts of lower wellhead natural gas prices on wholesale and retail electricity prices in a subsequent report.

4 The Natural Gas Act ("NGA") of 1938 allowed the Federal Power Commission ("FPC"), the precursor to the Federal Energy Regulatory Commission ("FERC"), to regulate the prices charged by interstate natural gas pipelines. From 1938 to 1954, the FPC did not regulate wellhead natural gas prices. Instead, independent producers sold natural gas to interstate pipelines at unregulated prices,

Self-Help Program[5] that allowed retail customers to develop and obtain their own natural gas supply and then use the unbundled delivery capabilities of natural gas companies to transport the gas supply from the wellhead to the point of utilization. The NGPA provided for the gradual elimination of a labyrinth of price rules, and full decontrol of prices was achieved by 1993.[6]

Not surprisingly, eliminating price controls and creating a truly competitive market for natural gas supplies created the economic incentives needed for renewed natural gas exploration and development. Coupled with FERC's severing of the traditional connection between production, pipeline transportation, and distribution in 1992,[7] by the early 1990 the natural gas market was vibrant; the predicted shortages had turned into a gas supply "bubble" that led to much lower prices. Those lower prices, in turn, spurred development of competitive wholesale electricity markets that were envisioned under the Energy Policy Act of 1992, as well as calls for electric industry restructuring, because of advances in gas-fired generating technologies, such as combined-cycle units that were energy efficient and could be constructed more quickly than traditional coal-fired or nuclear baseload generating plants. As a result of the increasing reliance on natural gas-fired generation, the demand for natural gas has increased since the mid-1990s. Between 1997 and 2010, for example, total natural gas consumption increased by about six percent, whereas natural gas consumption for electric power generation increased by 80%.[8]

(cont.)

with any subsequent sales for resale being regulated by the FPC. Advocates who sought to keep consumer prices low through price regulation went to the FPC to close what they alleged was a regulatory "loophole," because the FPC exempted wellhead sales from price regulation as "production and gathering" activities. The FPC rejected this claim, but in 1954, the U.S. Supreme Court, in *Phillips Petroleum v. Wisconsin*, 347 U.S. 672 (1954), reversed the FPC, ruling that the NGA applied not only to pipelines, but also to natural gas producers. This led to the FPC regulating natural gas wellhead prices and creating the natural gas "shortages" beginning in the late 1960s.

5 Ohio's Self-Help Program was one of the first unbundled natural gas transportation programs in the Nation and during the 70's it sparked a surge of exploration and development activities in Ohio. It also served as a model for other unbundled open access transportation programs that evolved to provide the foundation for the natural gas industry structure that is in place today.

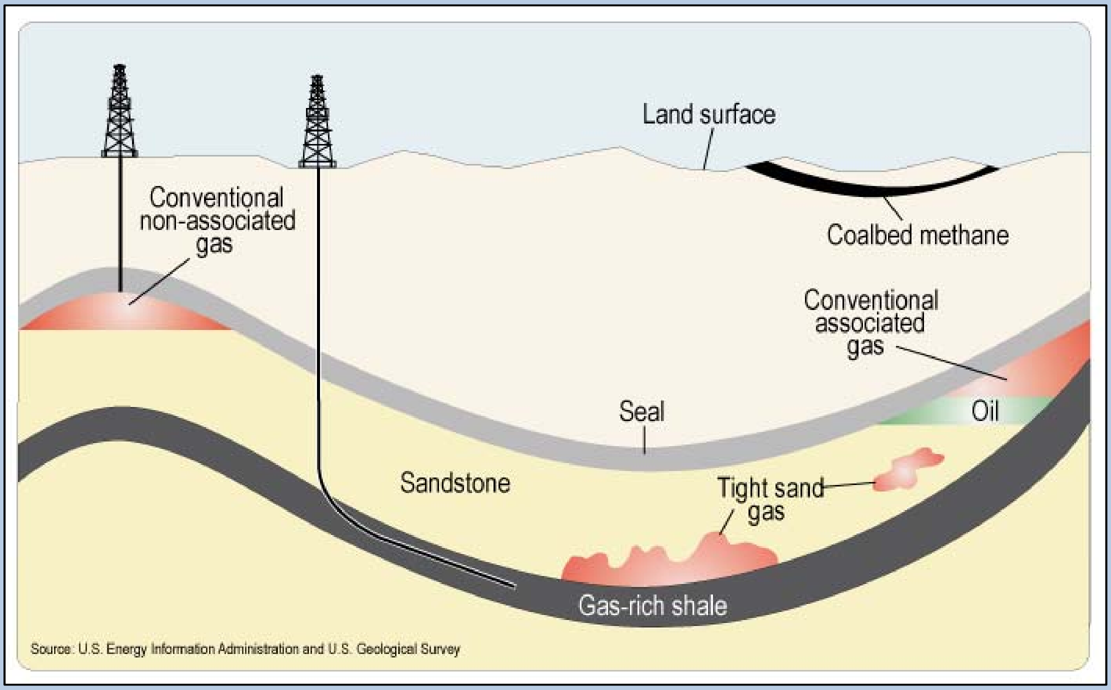
6 In 1989, Congress passed the Natural Gas Wellhead Decontrol Act, which fully decontrolled wellhead prices as of January 1, 1993.

7 *Pipeline Service Obligations and Revisions to Regulations Governing Self-Implementing Transportation Under Part 284 of the Commission's Regulations*, *Regulation of Natural Gas Pipelines After Partial Wellhead Decontrol*, FERC Order No. 636, 59 FERC ¶ 61,030 (1992).

8 Source: U.S. Energy Information Administration, *Natural Gas Annual*, 2011.

The Many Sources of Natural Gas

Natural gas is produced from a number of sources. The diagram below is a schematic of the different types of gas and their relative locations underground.



Nearest the surface is coalbed methane, which is just natural gas found in coal seams.[9] Associated gas is natural gas that is found on top of crude oil deposits. Often, crude oil wells produce both crude oil, natural gas, and so-called "natural gas liquids" ("NGLs"), which are valuable types of hydrocarbons, such as propane and butane. In other cases, natural gas is found in separate deposits, called non-associated gas. Further below the surface, one finds "tight-gas." Tight gas is natural gas that has migrated upwards into sandstone formations and which, because sandstone has low permeability,[10] cannot migrate further. Further below still lies shale gas.

Although market forces had eliminated fears of natural gas shortages, wellhead prices remained linked to world crude oil prices. Thus, when the events of September 11, 2001, and the subsequent invasions of Afghanistan and Iraq, led to a rapid increase in crude oil prices, natural gas prices followed; the gas supply "bubble" had burst. Natural gas prices increased, spiking in 2005 because of the damage caused by Hurricanes Katrina and Rita to the Gulf Coast gas supply

[9] Coal seams are often saturated with water, and the pressure of that water forces methane (natural gas) into the coal. When the water is removed, the pressure drops, and natural gas can be extracted.

[10] "Low permeability" means that gas molecules do not flow easily. For shale gas, that is the reason producers use hydraulic fracturing techniques to release the natural gas and let it easily flow to their wells.

infrastructure, and causing renewed fears that U.S. natural gas production once again faced inexorable decline and that consumers would face increasing prices.[11]

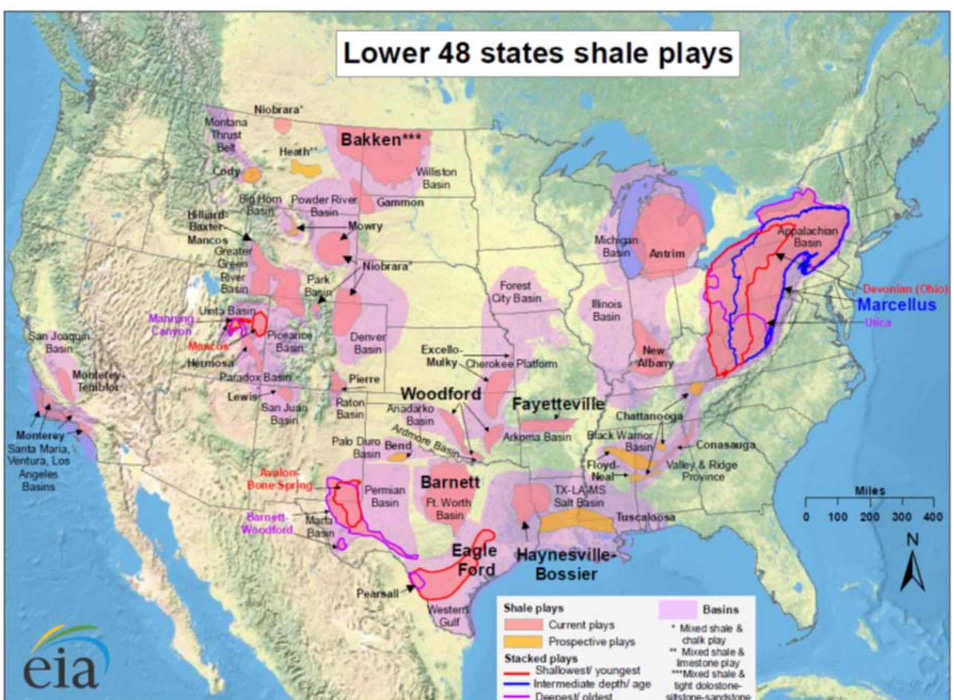
The search was on for new sources of natural gas. One of the first was liquefied natural gas (LNG) that could be imported from the Middle East, where gas was still considered a waste by-product from crude oil production and simply flared (burned) off. Plans for huge new facilities capable of receiving LNG were developed, but many such facilities faced intense siting opposition because of the perceived risks, such as explosions.

Other "unconventional" domestic natural gas supplies also emerged. By the mid-1990s, for example, production of coal-bed methane ("CBM") had increased to about 1 trillion cubic feet ("Tcf") per year, or about four percent of total U.S. natural gas production. In 2008, coal-bed methane production peaked at just under 2 Tcf. The other unconventional resource—and the one that has already provided huge economic benefits—is shale gas, which now accounts for over 20 percent of all total domestic natural gas production.

A. The Emergence of Shale Gas

By the late 1970s, natural gas was already known to exist in deep shales, such as the Barnett in Texas and Marcellus in Pennsylvania (Figure 1).

Figure 1: U.S. Shale Gas Plays



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

[11] The same was true for natural gas supplies exported to the U.S. from western Canada, which had also increased over the previous decade.

However, the technology to retrieve gas from such "low-permeability" areas did not exist. It was not until the 1980s that improvements in hydraulic fracturing, a drilling technique that had been widely used since the 1940s to enhance production in existing oil and gas wells, began to change the economics of shale gas.

The U.S Energy Information Administration ("EIA") has tracked shale gas production for each of the major shale gas plays since 1990 (Figure 2). As can be seen in Figure 2, shale gas production began to accelerate rapidly after the year 2000, as production ramped up in the Barnett shale of Texas. By the middle of the decade, production in the Fayette and Haynesville regions began to increase. Most recently, production in the Marcellus region, which is estimated to have far larger reserves, has begun to accelerate.

Figure 2: U.S. Annual Shale Gas Production, (1990 – 2010)

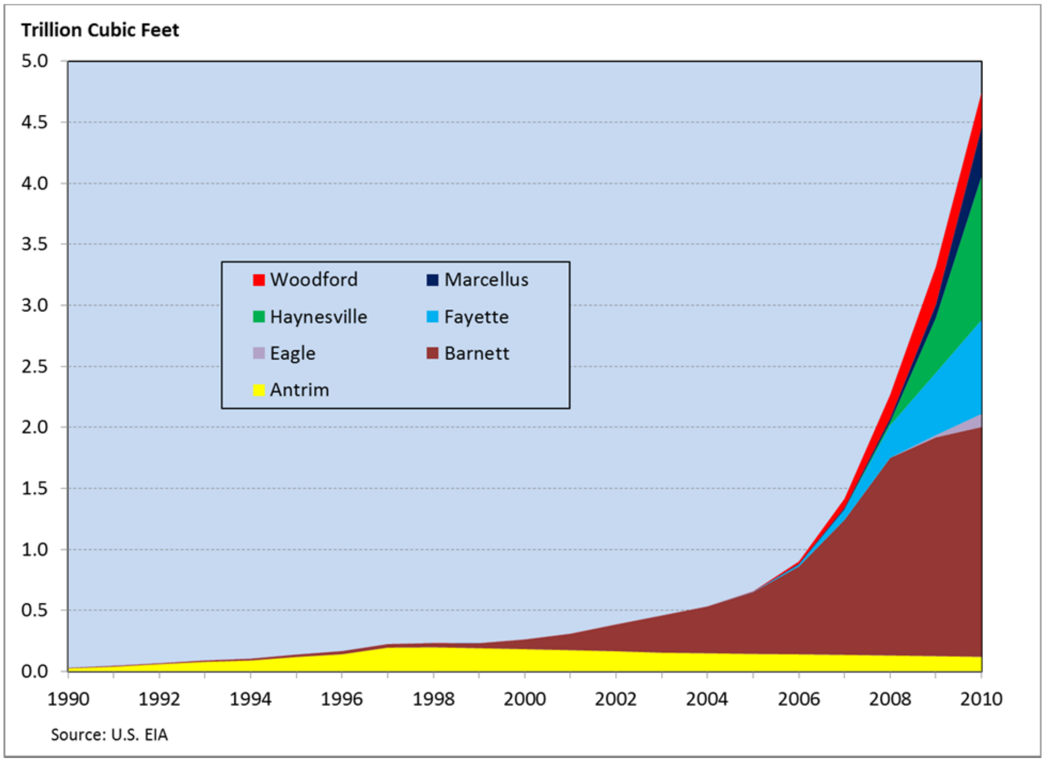
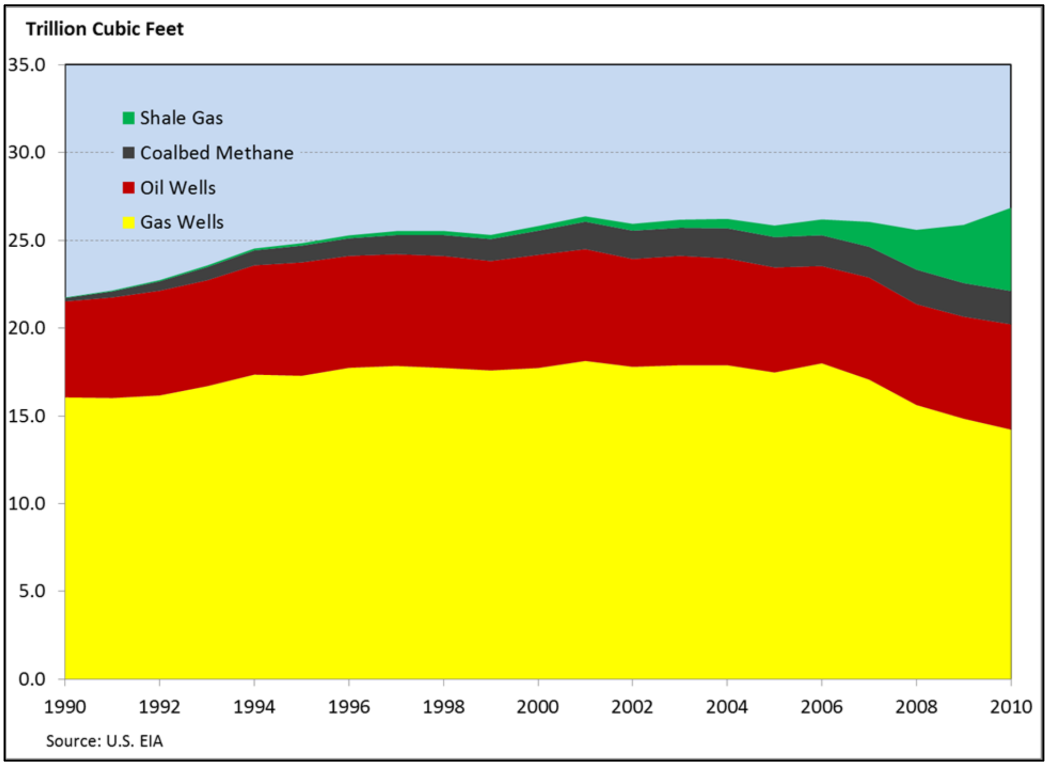


Figure 3: U.S. Annual Natural Gas Production, by Source (1990–2010)



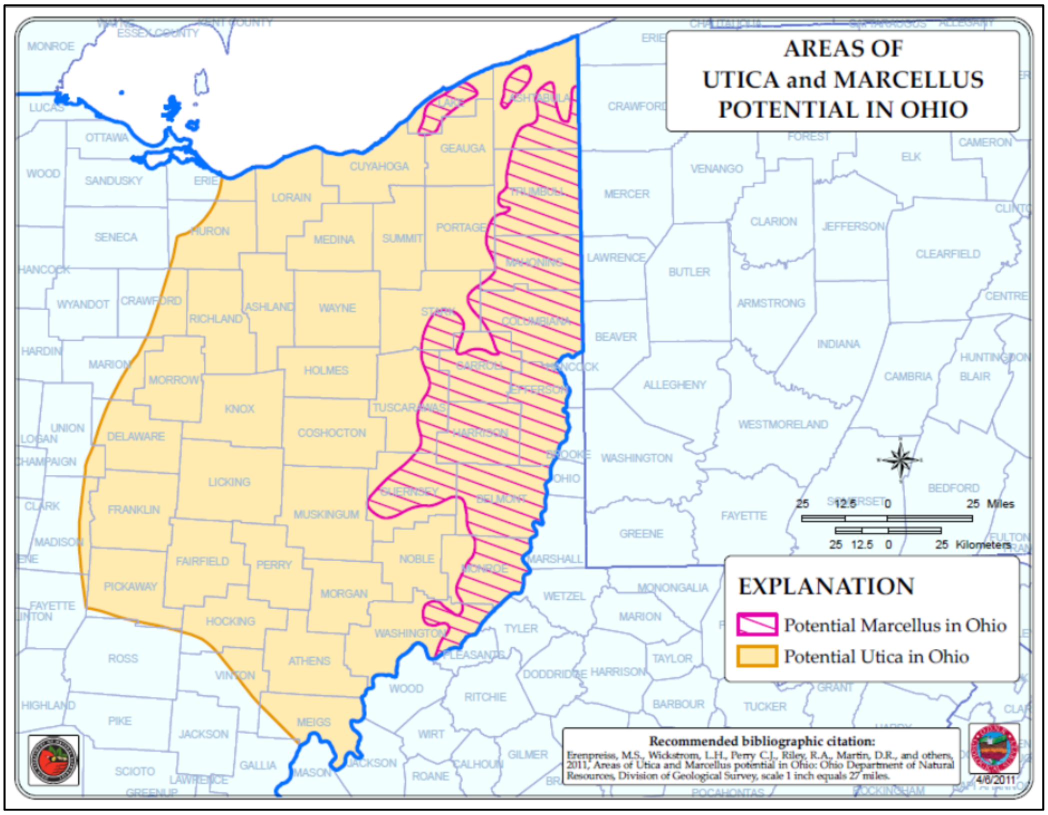
While conventional natural gas production in the U.S. has decreased over time, shale gas has become a rapidly increasing source of U.S. gas supplies (Figure 3), and now accounts for about 20 percent of total U.S. onshore domestic natural gas production. The EIA forecasts that, by 2035, shale gas could account for over 50 percent of onshore natural gas production.[12]

Of greater interest for Ohioans is the Utica Shale, which lies beneath the better-known Marcellus Shale, and extends into the eastern half of the state. Although reserve data is based on preliminary drilling in the Utica Shale, geologists expect the Utica Shale to be relatively rich in oil and natural gas liquids that are currently worth significantly more than natural gas on an energy-equivalent basis. Preliminary estimates by Ohio's Department of Natural Resources (ODNR) suggest a recoverable reserve potential of between 1.3 and 5.5 billion barrels of oil as well as 3.8 to 15.7 trillion cubic feet ("Tcf") of natural gas. The overall economic value of the Utica Shale region in Ohio may be especially large, because it lies relatively close to the surface, which reduces exploration and development costs.[13]

[12] http://www.eia.gov/forecasts/aeo/IF_all.cfm#prospectshale.

[13] The depth of shale gas deposits below the surface is not uniform. All other things equal, the closer to the surface, the lower are exploration and development costs.

Figure 4: Marcellus and Utica Shale Plays in Ohio



B. Overview of Shale Gas Production Economics

As we discuss in the next section, shale gas production has helped reduce wellhead natural gas prices. But what factors affect shale gas production? It turns out, there are a number of factors, including not only day-to-day production costs, but also the costs of leasing land, the productivity of the wells drilled, and the mix of natural gas and NGLs produced.

The economic benefits of drilling an oil or gas well—and, often, the same well produces both—depend on a number of factors. Broadly, these are the expected future revenues from what the well produces, and the fixed and variable production costs of drilling and operating the well.

Expected future revenues depend on how much a typical well is likely to produce over its lifetime and future prices. For example, wells that produce both crude oil and NGLs tend to be more profitable than wells producing just natural gas, given current and expected prices. The reason is that world crude oil prices are much higher (on a Btu basis, i.e., the price per million Btus, based on the relative heat content of oil and natural gas) than the price of natural gas. Similarly, some NGLs, such as propane and butane, tend to sell at higher market prices than methane, which is the major component of what we term “natural gas.” Thus, all else equal, a developer is more likely to drill where natural gas is likely to be found with crude oil and natural gas liquids.

Production costs can be broken down into fixed and variable costs. Fixed costs are those that do not change with the quantity of oil or gas produced, such as the cost of obtaining a lease. For example, recent data shows that leases for land in Athens County are costing developers $2.500 per acre.[14] The costs of these leases, together with the cost of leasing the actual drilling equipment, are the largest fixed costs associated with well-drilling.

Variable costs of production are those that depend on how much oil and natural gas is produced. For example, the state of Ohio levies a severance tax on crude oil and natural gas producers of$0.10 per barrel of oil and $0.0025 per thousand cubic feet of natural gas produced, regardless of the market prices.[15] Landowners typically assess a royalty fee on producers that, unlike the state severance tax, is based on the value of natural gas produced. Finally, there are the direct variable production costs, such as the cost of operating the well equipment every day. Because a significant portion of the overall production costs are fixed, drillers will often continue to produce oil and natural gas from wells even when the average production costs are greater than market prices, which can tend to further decrease market prices.

Estimates of the overall average production cost of shale gas wells vary widely, because shale gas plays differ in their characteristics, such as depth. Typically, drilling costs are reported on a per-foot basis. Thus, the equivalent cost per MMBtu of natural gas produced depends on how deeply a well is drilled, and the well's average daily production.

Publicly available data on the costs of shale gas wells, and production costs per MMBtu, are difficult to obtain. Moreover, because of technological advances, production costs continue to decrease. A 2010 report by the World Energy Council states that estimates of average shale gas production costs in North America range between $4 per Mcf and $8 per Mcf.[16] However, in 2010, Chesapeake Energy estimated average direct production expenses, including taxes, of just over $1 per Mcf.[17] It reports another $0.44 per Mcf in administrative and general costs, and $1.56 per Mcf in depreciation and amortization costs, for an overall average cost of about $3 per Mcf. Moreover, because shale gas resources tend to be located near demand centers, transportation costs on natural gas pipelines can be less than for natural gas sourced from traditional supply basins, such as the Rocky Mountains, Western Canada, and the Gulf Coast.

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[14] "County oil and gas leasing just goes on & on," *The Athens* (OH) *News*, December 15, 2011.

[15] http://codes.ohio.gov/orc/5749. One thousand cubic feet ("Mcf") is approximately 1.04 million Btus (MMBtu). One barrel of oil has an average heat content of 5.6 MMBtus. Thus, on a per-Btu basis, Ohio levies a slightly higher severance tax on oil than natural gas.

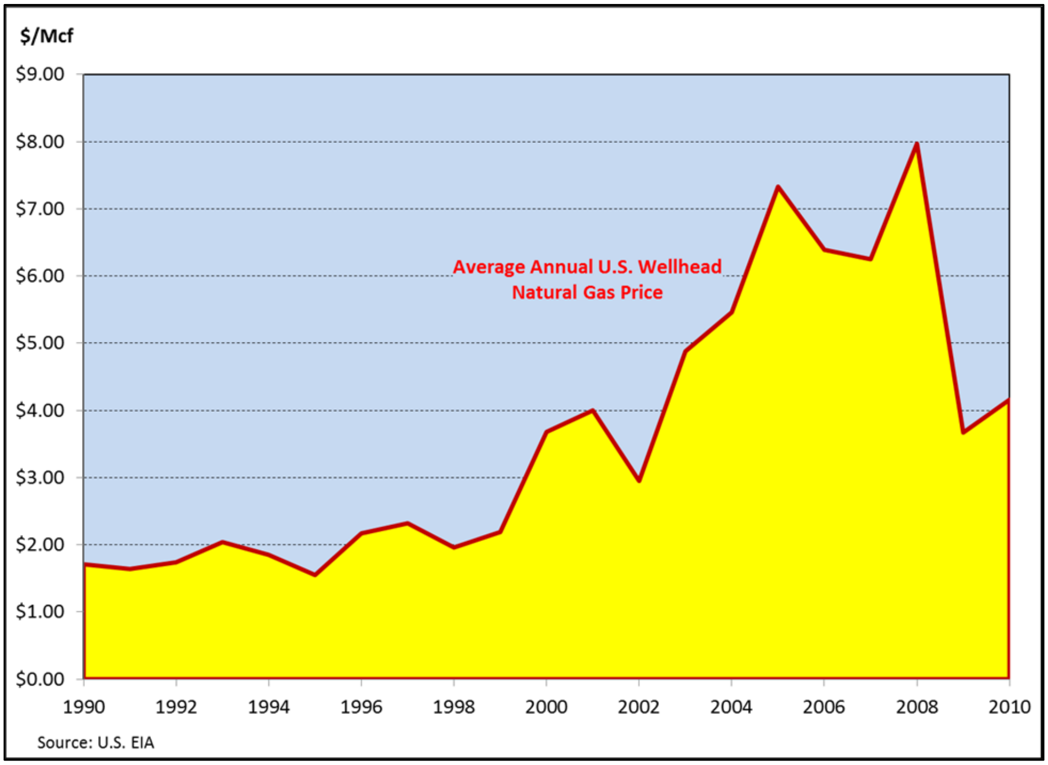
[16] World Energy Council, "Survey of Energy Resources: Focus on Shale Gas," 2010, page 14. http://www.worldenergy.org/documents/shalegasreport.pdf

[17] Chesapeake Energy, *2010 Annual Report*, page 4. http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9OTEzODB8Q2hpbGRJRD0tMXxUeXBlPTM=&t=1

C. Natural Gas Prices and Demand

The gas supply "bubble" of the 1990s caused an extended period of low natural gas prices, with prices generally less than $2 per Mcf (Figure 5). Starting in 2001, however, gas prices, which were historically linked closely with crude oil prices, began to increase rapidly, in response to the events of September 11, 2001, and the subsequent invasions of Afghanistan and Iraq, which caused crude oil prices to increase rapidly (Figure 6). Wellhead natural gas prices peaked in 2005 at an average of over $7 per Mcf, in part because of the damage to the production and gathering infrastructure along the U.S. Gulf Coast caused by Hurricanes Katrina and Rita, and continued increases in natural gas demand, especially for generating electricity. Prices then decreased to about $6 per Mcf in 2006 and 2007. However, in 2008, prices spiked to their highest annual level ever, about $8 per Mcf, caused by increased demand and surging crude oil prices.[18]

Figure 5: Average Annual U.S. Wellhead Natural Gas Prices (1990–2010)



The rapid increase in U.S. shale gas production has more than compensated for decreases in conventional natural gas production from oil and gas wells, because advances in drilling technology have made the economics of shale gas production so favorable. In fact, according to

[18] The June 2008 wellhead price was $10.79 per Mcf, the highest nominal value ever. Historically, U.S. natural gas prices and crude oil prices were closely linked, owing to the substitutability of oil and natural gas. As discussed below, because of shale gas, that historic link is much weaker.

IHS CERA, the cost of producing shale gas is now less than the cost of producing "conventional" natural gas.[19]

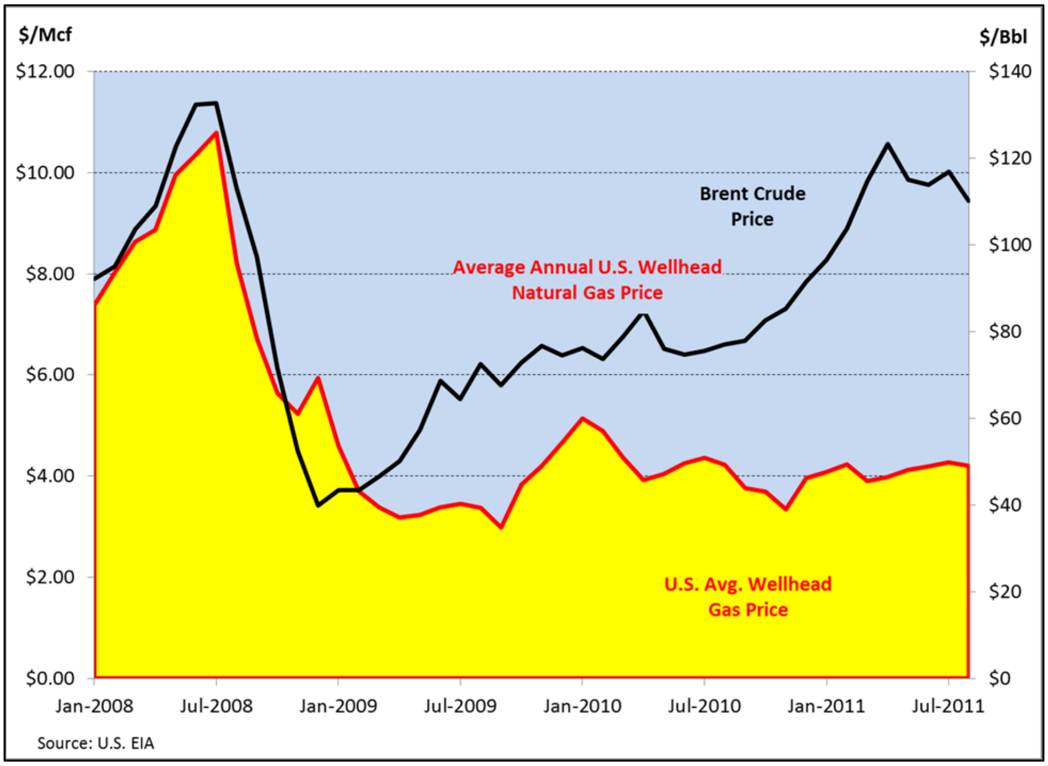
Another important benefit of the rapid increase in shale gas production has been to weaken the historical link between wellhead natural gas prices and volatile world crude oil prices. Because of the limited ability to export natural gas overseas, increased domestic production has reduced wellhead natural gas prices, even though world crude oil prices remain in the $100 per barrel ("Bbl") range.[20] For example, between January 2009 and August 2011, the price of Brent crude (one of the world's benchmark oil prices) tripled, rising from under $40 per Bbl to almost $120 per Bbl. During that same period, U.S. wellhead natural gas prices remained relatively constant (Figure 6).[21] Thus, while natural gas prices and crude oil prices in Europe and Asia continue to move in tandem, the weakening of the historic link in the U.S. is providing consumers with the economic benefits of lower and more stable natural gas prices.

19 "Fueling America's Energy Future," IHS Cambridge Energy Research Associates Report, 2010. A copy of the Executive Summary may be found at: http://groundwork.iogcc.org/sites/default/files/IHS%20CERA%20Executive%20Summary%20Fueling%20North%20America%27s%20Energy%20Future%20The%20Unconventional%20Natural%20Gas%20Revolution%20and%20the%20Carbon%20Agenda.pdf.

20 LNG facilities were developed to import natural gas, not export it. Today, some of these facilities are being modified so that natural gas can be delivered to them, and then exported, but the cost is high.

21 A portion of the increase in the Brent crude price can be explained by decreases in the value of the U.S. dollar relative to other major world currencies. According to data published by the U.S. Federal Reserve, between January 2009 and August 2011, the dollar declined in value by 15% relative to these other currencies.

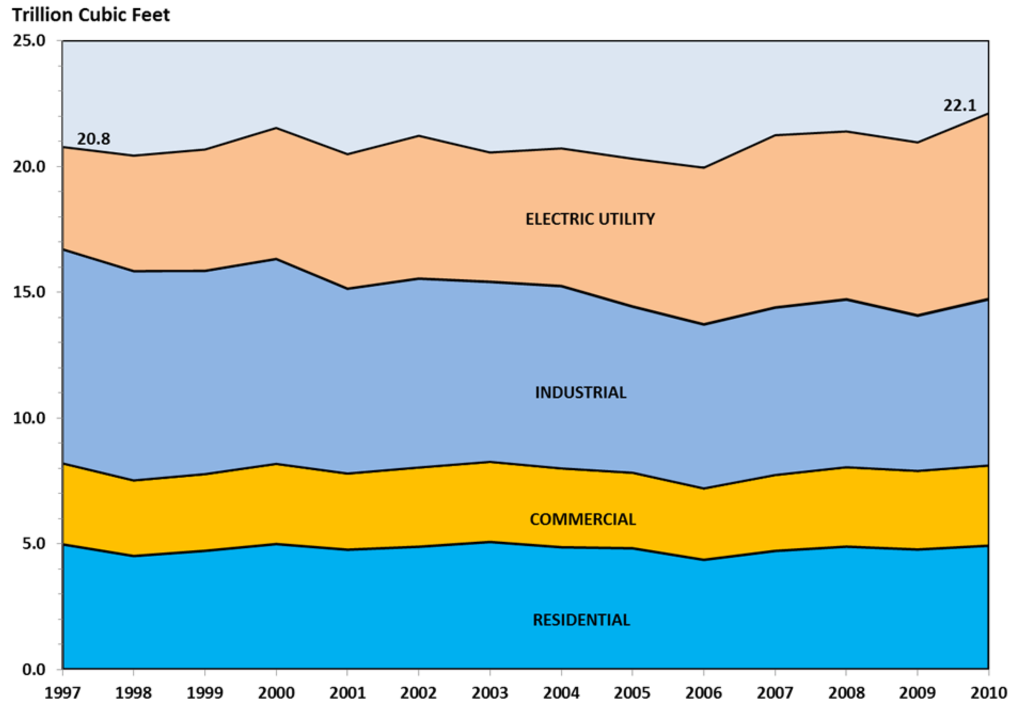
Figure 6: U.S. Monthly Wellhead Natural Gas Prices and Brent Crude Price (2009–2011)



D. Trends in U.S. and Ohio Natural Gas Demand

The increase in the production of shale gas has also outstripped the overall growth in the demand for natural gas (Figure 7). This has also contributed to the decrease in wellhead natural gas prices since 2008 and provided greater price certainty. As shown in Figure 7, between 1997 and 2010, total natural gas delivered to domestic customers increased from 20.8 Tcf to 22.1 Tcf. Between 1997 and 2010, residential and commercial sector demand remained essentially constant, despite increases in the number of customers, because of increases in the energy efficiency of space and water heating equipment. Industrial demand during this same time period decreased by just over 22%, owing to a general decrease in manufacturing output, as well as improved energy efficiency. However, the demand for natural gas by electric generators increased over 80% between 1997 and 2010, reflecting the rapid increase in gas-fired generating capacity.

Figure 7: U.S. Annual Natural Gas Deliveries, by Customer Class



Source: U.S. EIA

Unlike the U.S. as a whole, natural gas consumption in Ohio decreased during this period, especially in the industrial sector, where demand fell by about one-third between 1997 and 2009, reflecting the loss of heavy manufacturing industry in the state during this period.

E. Natural Gas Prices and Ohio Consumers' Energy Costs

Although overall natural gas consumption in Ohio has decreased since 1997 (in part because of reductions in the energy intensity of Ohio's economy), expenditures on natural gas remain significant. In 2009, Ohio consumers and businesses, including electric generators, consumed 724 billion cubic feet ("Bcf") of natural gas, at a cost of $7.46 billion, as shown in Table 1.[22] Thus, lower natural gas prices owing to shale gas production can have real benefits for Ohio energy consumers as well as the public at large.

22 Source: EIA, State Energy Data System. http://www.eia.gov/state/seds/seds-states.cfm?q_state_a=OH&q_state=Ohio.

Table 1: Summary of Ohio 2009 Natural Gas Consumption and Expenditures

Sector	Consumption (Bcf)	Cost (Millions of $)	Average Price ($/Mcf)
Residential	292	$3,708	$12.70
Commercial	161	$1,676	$10.41
Industrial	233	$1,908	$8.19
Electric Power	38	$166	$4.36
Totals	**724**	**$7,458**	**$10.30**

Of the total expenditure, residential customers spent $3.7 billion, about half of the total, and paid an average delivered retail price of $12.70 per Mcf. That delivered price includes the wholesale cost of gas, which reflects the wellhead price, plus the cost of transportation via pipeline and the cost of retail distribution. The reason that the average price for electric generators is so much lower than other customers is that most electric generators are directly interconnected to interstate pipelines, thus avoiding all of the costs associated with retail distribution.

III. ESTIMATING THE IMPACTS OF SHALE GAS PRODUCTION ON U.S. WELLHEAD NATURAL GAS PRICES AND OHIO CONSUMERS' ENERGY BILLS

Shale gas has contributed to the decline in wellhead natural gas prices, but by how much? And, how does the wellhead price decrease caused by shale gas translate to savings for Ohio natural gas consumers? To answer these questions, we developed a model to isolate the impacts of shale gas on wellhead prices. Then, using the results of that model, determined the savings to different classes of Ohio consumers.

A. The Impacts of Shale Gas on Wellhead Natural Gas Prices

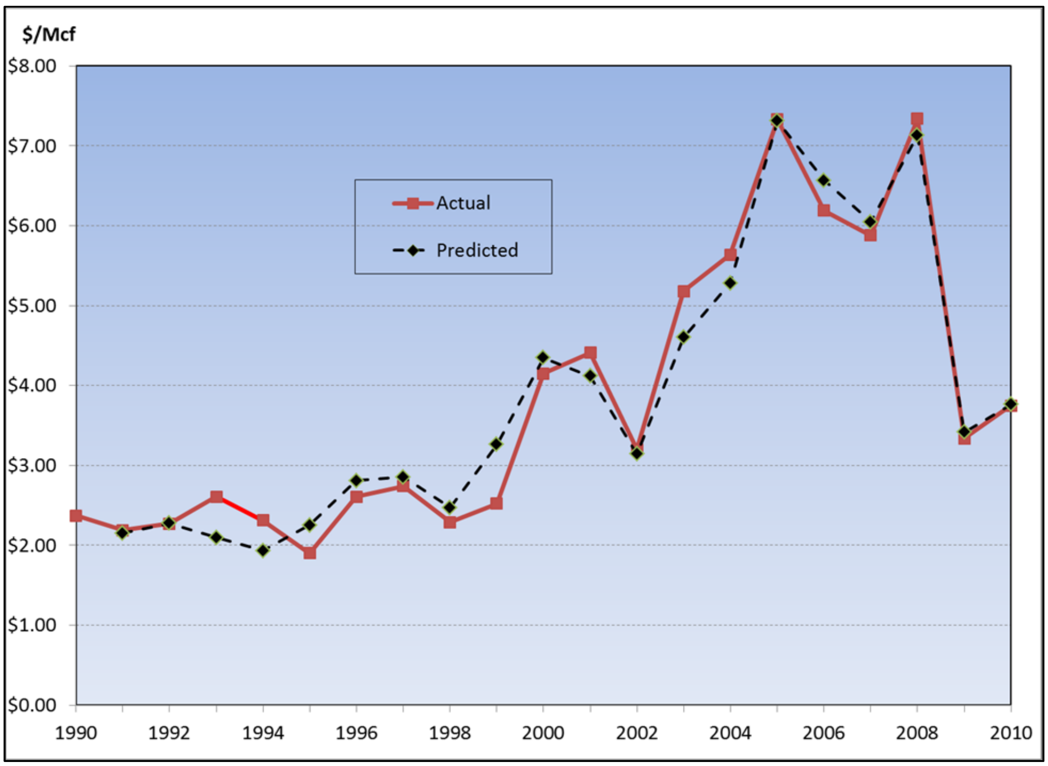
Natural gas supplies reflect complex relationships between expectations of future demand, market prices, and technology. Moreover, because significant quantities of natural gas are produced from oil wells, supplies are also influenced by expectations about crude oil markets. The U.S. EIA, for example, uses a complex set of interdependent models to prepare forecasts of natural gas production and prices.[23] The EIA models combine engineering relationships, such as exploration costs per drilled foot, with econometric models and economic projections, to determine the economic returns from exploration and development. These factors further interact with demand projections, which are based on macroeconomic forecasts of the U.S. and world economies.

23 The EIA crude oil and natural gas supply model ("OGSM") is part of its larger National Energy Modeling System ("NEMS"). Documentation for the OGSM can be downloaded at: http://www.eia.gov/FTPROOT/modeldoc/m063(2011).pdf

For the purposes of this report, however, it would be difficult to modify this type of modeling approach to determine what historic natural gas prices would have been without production from shale gas. Thus, we developed an econometric framework that models annual natural gas supply, demand, and average wellhead prices, and which isolates the impacts of shale gas production on wellhead prices. (A detailed description of the model can be found in the Appendix.) The advantages of an econometric approach include its relative transparency: factors that influence natural gas supply and demand, such as the price of crude oil and the delivered price of coal used by electric generators, are easily modeled and evaluated. The disadvantages of the econometric framework used here is that it cannot incorporate all of the variables that affect natural gas supply and demand.[24]

Once the model was estimated, we evaluated how well it predicted wellhead natural gas prices (Figure 8). As this figure shows, the model predicted natural gas prices that closely follow the actual annual prices.

Figure 8: Actual v. Predicted Wellhead Natural Gas Price (1990 – 2010)



To estimate the impact of shale gas production on average wellhead prices, we used the estimated relationship between wellhead prices and the quantity of natural gas produced. Specifically, our analysis showed that, for each Tcf of shale gas produced, the average annual

24 In economic terms, we have developed a "partial equilibrium" model, rather than a "general equilibrium" one.

wellhead price would be $0.46 per Mcf lower. Equivalently, the average wellhead price would be $0.46 per Mcf higher for each Tcf of shale gas not otherwise available. The results of the analysis are shown in Figure 9 and Table 2.

Figure 9: Estimated Annual Wellhead Natural Gas Prices Without Shale Gas (1990 – 2010)

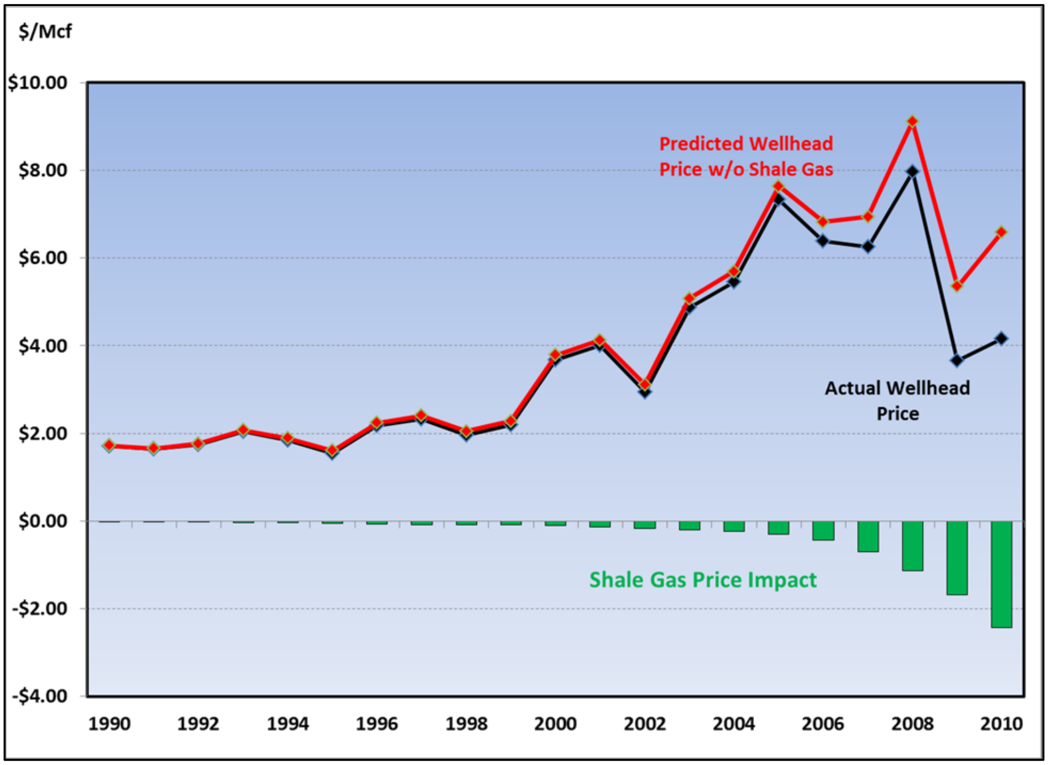


Table 2: Estimated Annual Price Impact of Shale Gas Production (1990-2010)

Year	Price Reduction ($/Mcf)	Year	Price Reduction ($/Mcf)
1990	($0.01)	2001	($0.13)
1991	($0.02)	2002	($0.17)
1992	($0.02)	2003	($0.20)
1993	($0.03)	2004	($0.24)
1994	($0.04)	2005	($0.30)
1995	($0.05)	2006	($0.43)
1996	($0.07)	2007	($0.70)
1997	($0.09)	2008	($1.14)
1998	($0.09)	2009	($1.68)
1999	($0.09)	2010	($2.43)
2000	($0.11)		

As Table 2 shows, the impact of shale gas production on wellhead gas prices has increased steadily as shale gas supplies have increased relative to total natural gas supplies. In 2010, for example, we estimate that shale gas production, which was over 4.7 Tcf, caused observed average wellhead natural gas prices to be $2.43 per Mcf lower than what they would have otherwise been.

To gauge the reasonableness of this price impact, we reviewed a 2004 analysis prepared by the EIA at the request of Representative Barbara Cubin, Chairman of the Subcommittee on Energy and Mineral Resources of the U.S. House Committee on Resources. The EIA analysis examined the projected impacts on U.S. natural gas production and wellhead prices under three different "low-supply" scenarios, and a combination of all three scenarios:[25]

- No increased availability of Alaska natural gas;
- No significant increase in production of tight sands natural gas (or other nonconventional sources); and
- Inability to permit more than three additional average-sized liquefied natural gas off-loading facilities.

The EIA study estimated that, in 2010, the combination of these three restrictive supply assumptions would increase the average wellhead price of natural gas by $0.47 per Mcf (2002$) and reduce production in the lower 48 states by 0.96 Tcf. This implies an average increase of $0.49 (2002$) per Tcf of reduced production. Adjusting for inflation to 2010 dollars, this translates into an average price impact of $0.59 per Mcf for each Tcf reduction in natural gas production in the lower 48 states. As discussed above, we estimated a somewhat smaller price impact, $0.46 per Mcf for each Tcf reduction in gas supplies.

B. Impacts on Ohio Natural Gas Consumers

Natural gas retail distribution customers typically pay for natural gas on a pass-through basis. Thus, if the wholesale price increases by, say, 10 cents per Mcf, the retail customer will see an additional 10 cent charge on his bill. Thus, we believe it reasonable to assume that the full impacts of the wellhead price reductions stemming from increased production of shale gas would be fully reflected on customers' bills.

Based on the analysis described above, Table 3 provides an estimate of the resulting natural gas energy bill reductions for commercial, industrial, and residential customers, using average use per customer data from 2010.

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[25] EIA, Office of Integrated Analysis and Forecasting, "Analysis of Restricted Supply Cases," February 2004. http://www.eia.gov/oiaf/servicerpt/ngsupply/pdf/sroiaf%282004%2903.pdf . There do not appear to be any more recent EIA analyses that have estimated wellhead prices and production related specifically to unconventional gas.

Table 3: Estimated Annual Cost Savings for Ohio End-Use Customers

Customer Class	Average Use Per Customer (Mcf)	Price Reduction ($/Mcf)	2010 Estimated Cost Savings	Number of Customers	Estimated Savings (Millions of $)
Commercial	562.1	($2.43)	$1,366	258,422	$353.0
Industrial	35,266.8	($2.43)	$85,698	5,738	$491.7
Residential	88.2	($2.43)	$214	3,198,883	$685.4
Total					**$1,530.2**

As this table shows, we estimate that Ohio businesses and consumers saved over $1.5 billion on their natural gas bills in 2010 because of lower wellhead natural gas prices. The average residential customer, for example, burned 88 Mcf of natural gas and saved $214 in 2010. The average commercial customer used 562 Mcf and saved $1,366, while the average industrial customer used over 35,000 Mcf and saved almost $87,000. In addition, electric generators reduced their costs because of lower wellhead gas prices. This translated into lower fuel charges levied by electric utilities with fuel cost recovery mechanisms,[26] such as Columbus Southern Power and Ohio Power Company, and also contributed to lower wholesale electric prices paid by retail electric suppliers.[27]

The results of our analysis demonstrate that shale gas production has significantly reduced U.S. wellhead natural gas prices and reduced Ohio consumers' natural gas and electric bills. The estimated savings of $1.5 billion in 2010 affect all sectors of the Ohio economy. As Ohio's Utica Shale gas resource is developed, Ohio businesses and consumers are likely to benefit even more in the future. The decreases in natural gas and electricity prices will benefit the Ohio economy, not only by creating jobs directly in the shale gas extraction industry as the Utica Shale is developed, but by improving the overall competitiveness of Ohio businesses and industry.

26 The default generation supply prices of Ohio Power and Columbus Southern Power (sometimes referred to as AEP-Ohio) continue to be administratively set by the Public Utilities Commission of Ohio ("PUCO") based on a rate structure that includes a fuel adjustment clause or FAC. Other Ohio electric distribution utilities ("EDUs") establish default generation supply prices through a competitive bidding process ("CBP") conducted under the PUCO's supervision. The downward pressure that shale gas development has placed on electric prices is observable from the inputs that go into the FAC as well as the pricing results of the CBPs that have been approved by the PUCO.

27 A subsequent report will estimate how much Ohio consumers saved on their electric bills because of the lower wellhead natural gas prices.

Appendix 1: Econometric Model Specification

This appendix provides supporting detail on the econometric model used to estimate the impact of shale gas production on U.S. wellhead natural gas prices. The appendix first discusses general issues in estimating econometric models of supply and demand, and how those issues affected the specification of the model we developed. We then present the details of the model itself, the data used to estimate it, and the results of the estimation.

The Identification Problem

One well-recognized problem in modeling supply and demand is called the "identification" problem.[28] What this means is that, when modeling supply and demand, observed data can reflect changes in both, as shown in Figure A-1.

Figure A-1: Identifying Supply and Demand Curves

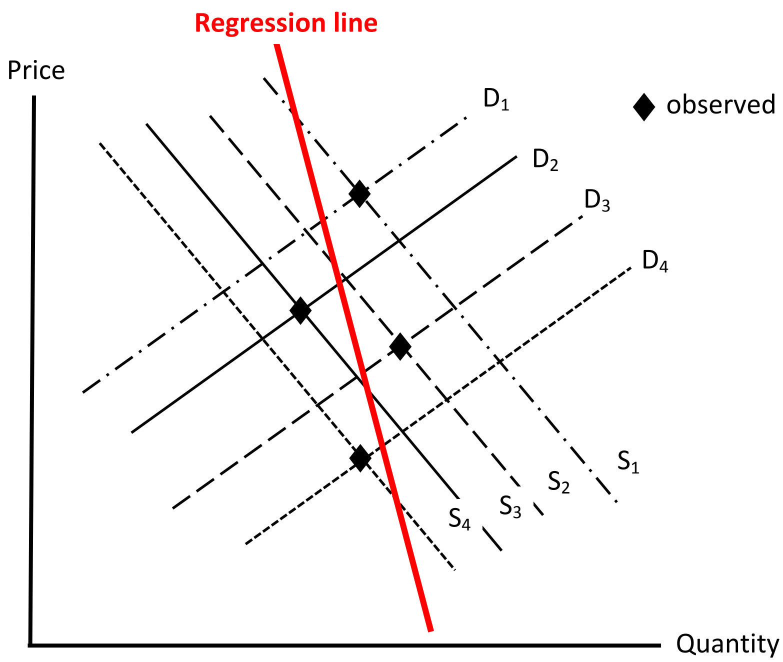
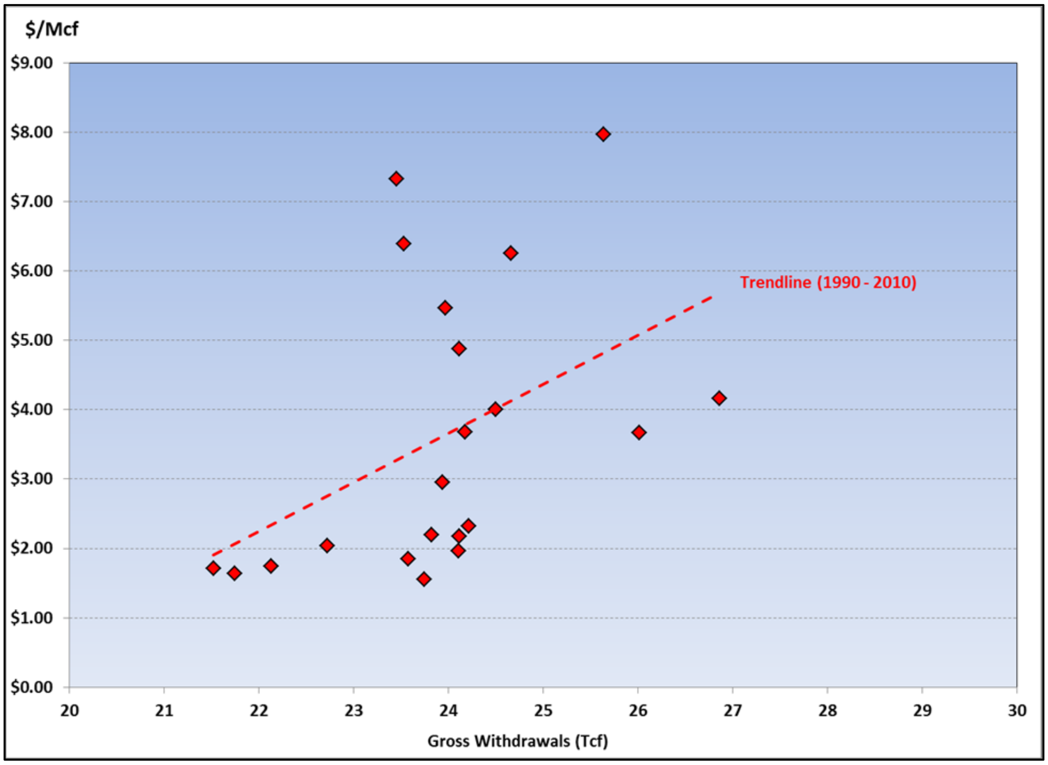


Figure A-1 illustrates four annual supply-demand equilibrium points, each corresponding to a different supply-demand curve combination. In this example, the four observed points do not trace out a single demand or supply curve. Thus, if we performed a simple linear regression of price on quantity, the resulting regression line (shown as the bright red line in Figure A-1), would not correspond to either a supply or demand curve.

28 For a discussion, see P. Kennedy, *A Guide to Econometrics*, 6th Ed., (Malden, MA: Blackwell Publishing 2009), pp. 173-76.

If we graph the annual average natural gas wellhead prices and total natural gas withdrawals, we see a similar problem. This is shown in Figure A-2.

Figure A-2: Average Annual Wellhead Natural Gas Prices and Gross Withdrawals (1990–2010)



In Figure A-2, we have graphed the supply-demand combinations for the years 1990 through 2010. Although the trendline shown <u>looks</u> like an upward sloping supply curve, it is far more likely that it reflects changes in demand and supply curves over time, as in Figure A-1.

Model Specification

To address this simultaneity issue, we developed a 4-equation model reflecting the supply and demand for natural gas, as well as the supply and demand of coal for electric generating purposes, because natural gas is increasingly being substituted for coal to generate electricity.[29] Thus, we write the general model structure as:

[29] We assume the world crude oil price (measured as the published price of Brent crude) as independent of the U.S. natural gas market and the market for coal used to generate electricity.

$$\begin{aligned} P_t^G &= f_1(Q_t^G, P_t^O, P_t^C) \\ Q_t^G &= f_2(P_t^G, P_t^O, P_t^C) \\ P_t^C &= f_3(Q_t^C, P_t^G, P_t^O) \\ Q_t^C &= f_4(P_t^C, P_t^O, P_t^G) \end{aligned} \tag{A-1}$$

where:

P_t^C = Average annual price of coal delivered to electric generating plants, year *t*.

P_t^G = Average annual wellhead price of natural gas, year *t*.

P_t^O = Average annual price of Brent crude, year *t*.

Q_t^G = Gross withdrawals of U.S. natural gas from all sources, year *t*.

Q_t^C = Receipts of coal at electric generating plants, year *t*.

Thus, the model consists of demand and supply equations for natural gas and coal delivered to electric generating plants. The specification treats the wellhead price of natural gas, gross withdrawals of natural gas, the quantity of coal delivered to electric generators, and the price of coal delivered to electric generators as endogenous variables. The price of Brent crude is treated as exogenous.

To address the data shown in Figure A-2, we evaluated a number of functional forms for the general model structure in (A-1), ultimately settling on the following specification, (*t*-1 subscripts indicate one-year lagged values).

$$Q_t^C = \beta_0^2 + \beta_1^2 P_t^C + \beta_2^2 P_{t-1}^O + \beta_3^2 P_{t-1}^C + \beta_4^3 GDP_t + \varepsilon_t^2 \tag{A-2}$$

$$P_t^C = \beta_0^3 + \beta_1^3 P_{t-1}^C + \beta_2^3 P_t^G + \beta_3^3 P_{t-1}^O + \varepsilon_t^3 \tag{A-3}$$

$$P_t^G = \beta_0^4 + \beta_1^4 Q_t^G + \beta_2^4 P_t^O + \beta_3^4 P_{t-1}^C + \beta_4^4 D_{2002} + \beta_5^4 D_{2005} + \varepsilon_t^4 \tag{A-4}$$

$$Q_t^G = \beta_0^5 + \beta_1^5 P_t^G + \beta_2^5 P_{t-1}^G + \beta_3^5 P_{t-1}^C + \beta_4^5 P_{t-1}^O + \varepsilon_t^5 \tag{A-5}$$

where:

D_{2002} = Dummy variable for the year 2002.

D_{2005} = Dummy variable for the year 2005.

GDP_t = Real U.S. gross domestic product, year *t*.

ε_t^j = Random error term, equation *j*.

The inclusion of lagged price variables reflects the fact that gas and coal production and consumption decisions are influenced by observed historic prices, as well as contemporaneous prices. The inclusion of a "dummy" variable for the year 2002 reflects the economic downturn brought on by the events of September 11, 2001. The inclusion of the dummy variable for the year 2005 reflects the damages caused by Hurricanes Katrina and Rita to the natural gas drilling and gathering infrastructure off the U.S. Gulf coast.

To estimate the impact of shale gas production on wellhead natural gas prices, we note that

$$Q_t^G = Q_t^{Shale} + Q_t^{Non-shale} \tag{A-6}$$

where Q_t^{Shale} and $Q_t^{Non-shale}$ represent production shale gas and gas from all non-shale sources, respectively. Thus, the estimated wellhead price of natural gas without shale gas, $P_{t,NS}^G$ is

$$P_{t,NS}^G = P_t^G - \beta_1^4 Q_t^{Shale}, \tag{A-7}$$

where the minus sign in equation (A-7) reflects the fact that total wellhead production is reduced by the quantity of shale gas produced.

Data Sources

All of the data used to estimate the model is publicly available and published by the U.S. EIA. The specific data sources are as follows:

- P_t^C *Electric Power Annual*. Available at: http://www.eia.gov/electricity/data.cfm
- P_t^G Available at: http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm
- P_t^O Based on daily spot prices, as published by EIA from ThomsonReuters.
- Q_t^G *Natural Gas Annual*. Available at: http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_nus_a.htm
- Q_t^C Electric Power Annual

Analysis Results

Equations (A-2) – (A-5) were modeled using the three-state least-squares (3SLS) method in STATA.[30] The results are summarized in Table A-1.

[30] See Kennedy (2009), pp. 180-81.

Table A-1: Three-stage Least-squares Regression Summary[31]

Equation	No. of Obs	Parameters	RMSE	"R-sq"	Chi-square	Significance
(A-2) Qcoal	20	3	50662.89	0.7064	50.17	0.0000
(A-3) Pcoal	20	4	0.6913167	0.9783	909.27	0.0000
(A-4) Pgas	20	5	0.3771036	0.8931	167.70	0.0000
(A-5) Qgas	20	5	0.3141652	0.9670	584.57	0.0000

The estimated coefficients for all of the equations are shown in Table A-2.

Table A-2: Three-Stage Least Squares Regression Results

Equation	Dep. Variable	Coef.	Std. Err.	z	P>|z|	[95% Confidence	Interval]
(A-2)	**Pcoal(t)**						
	Qcoal(t)	-5.01E-06	3.95E-06	-1.27	0.205	-0.0000128	2.73E-06
	Pcoal(t-1)	0.9101757	0.0439476	20.71	0	0.82404	0.9963114
	Pgas(t)	0.6102044	0.1782589	3.42	0.001	0.2608233	0.9595854
	Poil(t-1)	0.0627027	0.0122623	5.11	0	0.0386691	0.0867364
	Constant	2.756187	3.41147	0.81	0.419	-3.930172	9.442546
(A-3)	**Qcoal(t)**						
	Pcoal(t)	-2065.633	4251.958	-0.49	0.627	-10399.32	6268.052
	Poil(t)	2004.676	1515.881	1.32	0.186	-966.3957	4975.748
	Real_GDP	24.01612	16.67534	1.44	0.15	-8.666949	56.69919
	Constant	625558.4	253000.7	2.47	0.013	129686.1	1121431
(A-4)	**Pgas(t)**						
	Qgas(t)	-0.4617642	0.0873941	-5.28	0	-0.6330535	-0.290475
	Poil(t)	0.0809128	0.0047686	16.97	0	0.0715666	0.0902591
	Pcoal(t-1)	-0.2108965	0.0164349	-12.83	0	-0.2431083	-0.1786848
	Dummy_2005	0.7724999	0.3563397	2.17	0.03	0.0740869	1.470913
	Dummy_2002	-1.175227	0.3269946	-3.59	0	-1.816125	-0.5343296
	Constant	18.91655	2.210884	8.56	0	14.5833	23.2498
(A-5)	**Qgas(t)**						
	Pgas(t)	-0.2000595	0.0905154	-2.21	0.027	-0.3774665	-0.0226526
	Pgas(t-1)	-0.6352557	0.1392652	-4.56	0	-0.9082104	-0.362301
	Pcoal(t-1)	-0.0856178	0.0413864	-2.07	0.039	-0.1667337	-0.004502
	Poil(t-1)	0.0523611	0.0178196	2.94	0.003	0.0174353	0.0872869
	Year	0.2041171	0.0379631	5.38	0	0.1297108	0.2785235
	Constant	-380.1301	76.49281	-4.97	0	-530.0532	-230.2069

31 Note that the "R-sq" is not the same as the traditional "goodness-of-fit" measure in OLS regressions, because with 3SLS "R-sq" can be negative. For comparison purposes, Appendix 1 provides the results of OLS regressions of each of the four equations (A-2) – (A-5).

The regression results for the coal equations are consistent with economic theory. For example, equation (A-2) shows that the delivered price of coal to electric generators increases as the price of natural gas and oil increase, which would be expected for substitute fuels. Equation (A-3) shows that the quantity of coal deliveries increases as the price of oil increases, but decreases as the price of coal increases. It also shows that coal deliveries increase as economic growth, measured by real GDP, increases.

Equation (A-4) shows that the wellhead price of gas tends to increase as the price of oil increases, as was generally the case until 2005. Equation (A-4) also includes the two dummy variables for the years 2002 and 2005, respectively. The coefficients for both dummy variables have the expected signs.

Equation (A-4) also shows that the wellhead price of gas is strongly related to the previous year's price of utility coal receipts. However, the coefficient is negative. That is, an increase in last year's utility price of coal tends to decrease this year's wellhead price of natural gas. We hypothesize that this initially counterintuitive result stems from the response by natural gas producers to anticipated increases in the demand for natural gas. In other words, producers respond to higher coal prices and, hence, expected increases in the demand for natural gas, by increasing production. These production increases more than offset the expected increase in demand. In fact, this phenomenon has clearly contributed to the reductions in natural gas prices generally; technological improvements in drilling technology have enabled rapidly increasing quantities of shale gas to be produced, more than compensating for the general increase in natural gas demand.

Equation (A-5) yields the expected results for the coefficients on the prices of natural gas and crude oil. Thus, we expect increases in the price of crude oil to increase production of natural gas. Not only does this stem from increased demand for gas, but higher oil prices encourage additional exploration of development of domestic oil resources, and significant quantities of natural gas are produced from oil wells (so called "wet gas"). Equation (A-5) also shows the same counterintuitive result with respect to coal prices.

Impacts of Shale Gas Production on Wellhead Prices

Equation (A-7) and the coefficient β_1^4 from equation (A-4) are used to estimate the impacts of shale gas production on wellhead natural gas prices. Thus, the impact of shale gas production in year *t* on the average wellhead natural gas price in year *t* is

$$P_{t,NS}^{G} = P_t^G - (0.4617642)\, x\, Q_t^{Shale},$$

which implies that, for each Tcf of shale gas produced, the wellhead price decreases by just over $0.46 per Mcf.

Limitations of the Model Specification

As discussed in Section II of the report, econometric modeling has both advantages and disadvantages, with a specific disadvantage being the partial equilibrium framework that we have used. Such a framework necessarily trades off accuracy for greater simplicity. The model estimated presumes there is a linear relationship between shale gas production and wellhead prices.

In fact, the relationship may be nonlinear, especially as shale gas production accounts for an increasing proportion of total U.S. natural gas production. In 2010, for example, shale gas accounted for almost 20% of total gross production in the U.S., and that percentage is expected to increase over time, barring environmental regulations that restrict or curtail shale gas production in the future. To the extent the relationship is nonlinear, the predicted impacts of shale gas production on wellhead natural gas prices may be overstated. Moreover, additional shale gas production, to the extent it reduces wellhead prices, may reduce production of conventional natural gas. The impact will be a function of the market price and the production cost of conventional gas: the higher the cost to produce conventional gas, the larger the likely reduction in conventional production, and the smaller will be the net price impact. Finally, higher natural gas prices could have other macroeconomic impacts that are not considered in the econometric model, such as reductions in economic growth that would reduce overall natural gas demand and temper such price increases. Thus, a recommended next step in researching the impacts of shale gas on wellhead prices is to use more complex econometric specifications that test for and account for these potential nonlinearities.