

The Economic Value of Shale Natural Gas in Ohio

Amanda L. Weinstein

Department of Agricultural, Environmental and Development Economics

Mark D. Partridge, Swank Professor of Rural-Urban Policy

Department of Agricultural, Environmental and Development Economics

Swank Program Website: <http://aede.osu.edu/programs/swank/>

Mark Partridge Short Biography



Dr. Mark Partridge is the Swank Chair of Rural-Urban Policy at Ohio State University. He is a Faculty Research Affiliate, City-Region Studies Centre, University of Alberta, an Affiliate of the Martin Prosperity Center at the University of Toronto, and an adjunct professor at the University of Saskatchewan. Professor Partridge is Managing Co-Editor of the *Journal of Regional Science* and is the Co-editor of new the *Springer Briefs in Regional Science* as well as serves on the editorial boards of *Annals of Regional Science*, *Growth and Change*, *Letters in Spatial and Resource Sciences*, *The Review of Regional Studies*, and *Region et Developpement*. He has published over 100 scholarly papers and coauthored the book *The Geography of American Poverty: Is there a Role for Place-Based Policy?* Dr. Partridge has consulted with OECD, Federal Reserve Bank of Chicago, Federal Reserve Bank of Cleveland, and various governments in the U.S. and Canada, and the European Commission. Professor Partridge has received funding from many sources including the Appalachian Regional Commission, Brookings Institution, European Commission, Infrastructure Canada, Lincoln Institute of Land Policy, U.S. National Science Foundation, U.S. National Oceanic and Atmospheric Administration, and Social Science and Humanities Research Council of Canada. His research includes investigating rural-urban interdependence and regional growth and policy. Dr. Partridge served as President of the Southern Regional Science Association in 2004-05 and is currently on the Executive Council of the Regional Science Association International (the international governing board).

Amanda Weinstein Short Biography



Amanda Weinstein is a PhD student in the Department of Agricultural, Environmental, and Development Economics at The Ohio State University. Her research as the C. William Swank Graduate Research Associate includes policy briefs about the employment effects of energy policies and general regional growth and policy issues. She is an OECD consultant advising on the economic impacts of alternative energy policies on rural communities. Her other research interests include women's role in economic development examining women's effect on regional productivity growth. She was awarded the Coca-Cola Critical Difference for Women Graduate Studies Grant to continue her work on gender issues in economics. She is also conducting research on the skills most valued during a recession and the impact of military service on intergenerational mobility. Before starting her PhD at OSU, she was a commissioned officer in the United States Air Force after graduating from the United States Air Force Academy. As a Scientific Analyst in the Air Force and then as a Sr. Management Analyst for BearingPoint, she advised

Air Force leadership on various acquisition and logistics issues. She is currently an adjunct faculty member of Embry-Riddle University and DeVry.



Table of Contents

- 1 Executive Summary
- 4 Introduction
- 7 Hydraulic Fracturing Overview
- 10 Economic Expectations
- 20 The Benefits and Costs of Natural Gas
- 26 Conclusion
- 28 References
- 31 Appendices

We benefited from the careful comments and suggestions made by Jill Clark, Alessandra Faggian, Allen Klaiber, M. Rose Olfert, Dan Rickman, Douglas Southgate, and from the suggestions of the Swank Advisory Committee who heard a preliminary presentation of the report on December 6, 2011. Any errors or omissions are our own fault.

Executive Summary

Increased production of US natural gas in recent years has helped to meet the growing demands of American customers and has reduced natural gas imports. Natural gas is also a cleaner burning fuel when compared to its most realistic substitute, coal. This substantial increase in production has been attributed in large part due to the development of shale gas through a process called hydraulic fracturing. Hydraulic fracturing has enabled the expansion of natural gas extraction into new undeveloped areas. The Marcellus shale in Pennsylvania has experienced impressive growth in its natural gas industry and neighboring Ohio is beginning down the same path. Proponents argue that among the many purported advantages, natural gas production is associated with significant amounts of new economic activity.

Economists have 150 years of experience in examining energy booms and busts throughout the world to form their expectations of how energy development affects regional economies. Generally, economists find that energy development is associated with small or even negative long-run impacts. They refer to a “natural resources curse” phenomenon associated with the surprisingly poor performance of resource abundant economies. There appears to be more examples like Louisiana, West Virginia, Venezuela, and Nigeria of energy economies seemingly underperforming and few examples of places such as Alberta and Norway of relative over performance. This backdrop needs to be considered in forming good policy in Ohio in order to avoid being in the former group.

In supporting energy development, the natural gas industry has funded its own studies of economic performance. For example, utilizing assumptions derived from Pennsylvania economic impact studies, Kleinhenz & Associates (2011) estimate that the natural gas industry could help “create and support” over 200,000 jobs to Ohio and \$14 billion in spending in the next four years. These figures are about the same size as those for Pennsylvania (in industry funded studies). As we outline in this report, impact studies such as those employed by the industry are typically flawed due to the following reasons:

1. Possible double counting economic effects from drilling activities and royalties/lease payments to landowners. Most important, these studies have multipliers well above what independent economists

would normally expect.

2. Including unrealistic assumptions about the percentage of spending and hiring that will remain within the state.
3. Ignoring the costs of natural gas extraction on other sectors through higher wages, and land costs that will make them less competitive (e.g., Dutch Disease), as well as environmental damage that limits tourism and other activities. It will also displace coal mining—i.e. more natural gas jobs come at the expense of fewer jobs in coal mining.
4. Often employing out-of-date empirical methodologies that academic economists have long abandoned for better methodologies in terms of evaluation of economic effects.

Many of the same reasons why alternative energy has not been (will not be) a major job creator also applies to natural gas (Weinstein et al., 2010):

1. The energy industry and specifically the natural gas industry’s employment share is small and by itself is not a major driver of job growth for an entire state the size of Ohio or Pennsylvania. During the one year span October 2010–October 2011, U.S. Bureau of Labor Statistics data reports that Ohio’s unemployment rate fell from 9.7 to 9.0% or 0.7% (without shale development), while Pennsylvania’s unemployment rate only fell from 8.5% to 8.1% or 0.4% (with shale development). Ohio also had faster job growth during the span (1.3% versus 1%), showing that shale development by itself is not shaping their growth.
2. It is a capital-intensive industry versus labor-intensive—or a dollar of output is associated with significantly fewer workers.

The costs of natural gas include the effects it has on other industries. Some of these effects include displacement of other forms of economic activity, the effects of pollution that drive out residents who are worried about its effects and the higher wages and land/housing costs that make other sectors less competitive. For example, the tourism industry will likely be adversely affected by fears of pollution and higher wages and costs as other sectors have to compete for workers with the higher paying natural gas sector. In Pennsylvania, for instance, the tourism industry employed approximately 400,000 in 2010 (though a much smaller number is immediately near the shale development) compared to only 26,000 in

a broad definition of the natural gas industry (Barth, 2010; BLS). Similar concerns should also apply to Ohio across various sectors of the economy.


Our broad analysis shows the expected employment effects of natural gas are modest in comparison to Ohio's 5.1 million nonfarm employee economy. We show this through (1) an assessment of impact analysis, (2) comparison of drilling counties with similarly matched non-drilling counties in Pennsylvania, (3) statistical regressions on the entire state of Pennsylvania, (4) employment comparisons with North Dakota's Bakkan shale region, and (5) an examination of the employment life cycle effects of natural gas and coal per kilowatt of electricity. Specifically, we estimate that Pennsylvania gained about 20,000 direct, indirect, and induced jobs in the natural gas industry between 2004-2010, which is a far cry fewer than the over 100,000 jobs reported in industry-funded studies (and the 200,000 expected in Ohio by 2015). Given the anticipated size of the boom, Ohio is expected to follow the Pennsylvania's experience. We believe 20,000 jobs would be a more realistic starting point for what to expect in Ohio over the next four years and is in line with what other independent assessments have suggested. However, our 20,000 job estimate does not account for displacement losses in other industries such as tourism, and we also note that local economic effects could appear larger in heavily impacted areas. Moreover, we find that mining counties had considerably faster per-capita income growth than their non-drilling peers, which likely results from royalties/lease payments and the high wages in the industry. Thus, we expect the near-term boom to be associated with frothy increases in income but more temperate job effects.

There are several reasons why the industry-funded studies produce employment results that are considerably different from our estimates. Foremost, impact studies are not viewed as best practice by academic economists and would be rarely used in peer reviewed studies by urban and regional economists. Instead, best practice usually tries to identify a counterfactual of what would have happened without the natural gas industries and compare to what did happen (we adopt two of these approaches). One advantage of identifying the counterfactual is that the estimated effects use actual employment data and are not the estimated outcome of an impact computer model. Yet, like virtually every other economic event, there are winners (e.g., landowners or high-paid rig workers) and losers (e.g., those who can no longer afford the high rents in mining communities and communities dealing with excessive demands on their infrastructure).

Moreover, the boom/bust history of the energy economy is that drilling activity usually begins with a wave of drilling and construction in the initial phases, followed by a significant slowdown in jobs as the production phase requires a much smaller number of permanent employees. Indeed Ohio has a long history of energy booms that illustrates that booms too often have few lasting effects. Ohioans need to be aware of this cycle if they are to make prudent decisions and try to gain sustainable gains after the boom has ended. The fundamental problem here is that the time distribution of jobs resulting from a new development is often ignored and it is important. For example it matters whether there are 1,000 jobs distributed as 1,000 for one year and then none, versus 100 additional jobs for 10 consecutive years, or 10 additional jobs for the next 100 years. Yet, 'impact' analysis such as that used by the energy industry typically does not differentiate among these scenarios and the whole topic is usually ignored by the media. Professional economists note that long-term regional economic development requires permanent jobs, and thus independent economists place considerably less weight on the initial construction phase associated with energy development. Policies need to be developed to ensure long-term success.

Natural gas extraction is also associated with potential environmental degradation. Pennsylvania and other areas have reported numerous incidents of water contamination; most notably in Dimock, PA, which was featured in the controversial documentary *Gasland*. Because hydraulic fracturing occurs at levels far below the aquifer level, it is most likely not to blame for contamination, but any contamination is instead likely caused by a casing/tubing failure or other part of the drilling process. Thus, the EPA exempted natural gas extraction using hydraulic fracturing from the Safe Drinking Water Act and Clean Water Act in 2005. However, recognizing increasing concerns over the impact on drinking water and ground water, in 2010 Congress directed the EPA to study the effects of hydraulic fracturing on the environment with results expected by the end of 2012. Until the federal government acts on this issue, state regulations are necessary to ensure natural gas extraction is performed in a safe manner protecting the environment and residents. Yet, coal mining is also associated with high localized environmental costs, indicating that if natural gas mining is not done, there will still be environmental problems that will need to be addressed because more coal mining will be required.

We argue that the focus on whether the industry creates jobs is misguided in assessing its true value



and is not how economists typically evaluate the effectiveness of a program or policy. Rather, the focus should be placed on the true costs and benefits of natural gas especially compared to coal (its main substitute in electricity production). *Compared to coal, natural gas is cheaper and emits less carbon and both industries have their own inherent localized environmental costs in their production.* Independent economists would note that neither industry is associated with large numbers of jobs due to their capital-intensive na-

ture. Making a true assessment of the costs and benefits will require qualified independent analysis. Likewise, ensuring that Ohioans benefit long after the energy boom requires innovative planning that unfortunately, most locations that have experienced such booms have failed to do over the last 150 years. These findings also illustrate that Ohio will need to continue to make economic reforms if it is to prosper in the long term because no one industry—in this case energy development—will be its long-term savior.



Introduction

With the US economy still struggling to recover from the Great Recession, many are looking for a quick fix to create jobs and generate income. Politicians often turn to the latest economic fad to solve unemployment problems, such as aiming to become the next Silicon Valley or, more recently, the next green energy hub. Employment effects are often overstated to justify various policies rather than having a real conversation about the true benefits and costs of a policy.¹ For example, the job creation benefits of green jobs were optimistically asserted while ignoring the high capital intensity of alternative energy and the displacement effect of jobs no longer needed in the fossil fuels industry, especially coal. In response, the fossil fuels energy industry has now put forward its own solution to unemployment and growing energy demands: natural gas from shale, which also provides its own set of environmental costs and benefits.

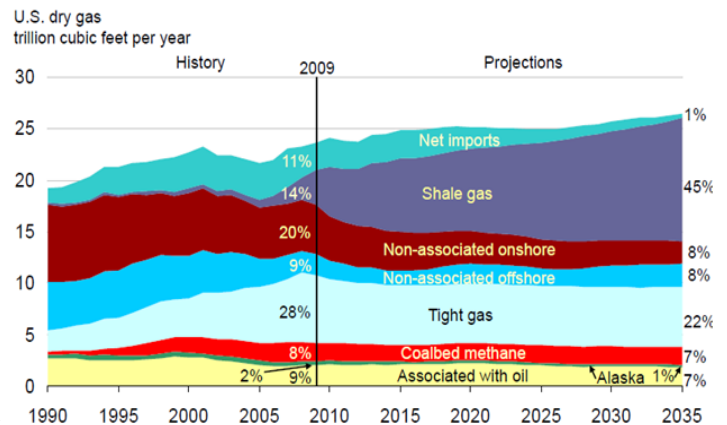
In their "Short-Term Energy Outlook," the US Energy Information Administration (EIA) expects that total natural gas consumption will grow by 1.8% in 2011. Despite the increase in consumption, recent increases in natural gas production have met these demands and reduced natural gas imports. Thus, shale gas proponents claim that newly accessible reserves could provide a new level of energy independence for the US. The 2010 EIA "Annual Energy Outlook" found that natural gas production reached its highest levels since 1973 at 21.9 trillion cubic feet (Tcf). This increase in production is mainly attributed to the increase in natural gas extraction from shale resources. From 2009 to 2010 shale gas production more than doubled from 63 billion cubic meters to 137.8 billion cubic meters. This trend in rising natural gas production, especially shale gas production, is likely to continue. Figure 1 below shows the increasing shale gas production the US has experienced, along with future expectations.

The dramatic increase in shale gas production since 2005 is shown below in Figure 2 separated by the area where shale gas has been developed. Recent technological advancements in a method called hydraulic fracturing, or "fracking", have made extracting natural gas from shale more efficient and cost effective. This has brought natural gas potential to new areas as evidenced by the increased drilling in Pennsylvania. Although still a small percentage compared to Texas, growth in shale gas production in Pennsylvania is growing rapidly and

provides a roadmap for how production in Ohio will evolve.

With these innovations, shale gas potential is now growing in neighboring Ohio, which shares the same Marcellus shale with Pennsylvania. Many have already begun to speculate what this could mean in terms of the job benefits to Ohio. An industry-funded study by Kleinhenz & Associates (2011) suggests that new Ohio natural gas production could "create and support" over 200,000 jobs

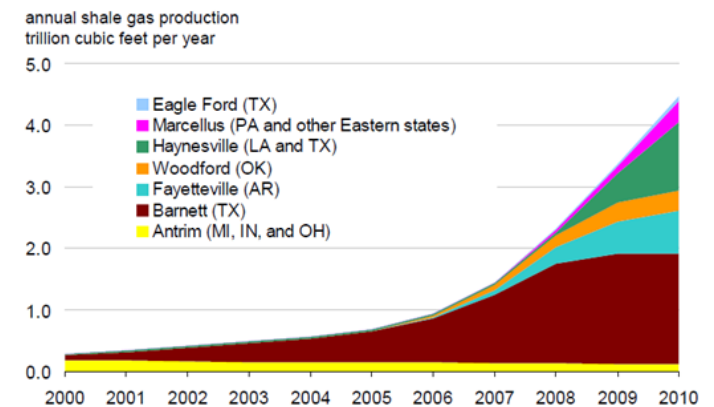
Shale gas offsets declines in other U.S. supply to meet consumption growth and lower import needs



Source: US EIA Annual Energy Outlook 2011

Figure 1: Shale Gas Prospects

U.S. shale gas production increased 14-fold over the last decade; reserves tripled over the last few years



Source: US EIA Annual Energy Outlook 2011

Figure 2: Shale Gas Areas of Production

1. Independent economists have long complained about hyped up numbers from various industry impact reports. For a tongue-in-cheek look see Leach (2011). <http://www.theglobeandmail.com/report-on-business/economy/economy-lab/the-economists/who-needs-pipelines-the-oil-bucket-brigade-is-ready/article2268015/>

and \$14 billion injected into the state economy over the next 4 years (Gearino, 2011).² In this manner, Chesapeake Energy CEO Aubrey McClendon stated, “This will be the biggest thing in the state of Ohio since the plow” (Vardon, 2011). Obviously, there is considerable hype surrounding the economic effects of shale oil production

To see if these expectations are realistic, we examine the impacts that natural shale gas has had on Pennsylvania to draw comparisons to Ohio. Many industry funded studies of the economic impacts of the Marcellus shale development in Pennsylvania are consistent with the Kleinhenz & Associates (2011) predictions, which is reasonable in the sense that the early stages of Ohio’s development is expected to mimic what happened in Pennsylvania.

Unlike the industry funded reports, Barth (2010) doubts whether there is any net positive economic impact of drilling in Pennsylvania. She contends that previous industry-funded reports have focused on the benefits while ignoring the costs and risks associated with natural gas extraction. She claims industry funded studies haven’t properly accounted for other impacts, including the costs of environmental degradation. Although replacing coal or oil with natural gas can significantly reduce carbon emissions, rising concerns have mounted, most notably in the controversial 2010 documentary *Gasland*, about the potential environmental impacts of natural gas mining on nearby water sources. This has become more of a concern as hydraulic fracturing and natural gas extraction occurs closer to both water sources and population centers in Pennsylvania and Ohio. These concerns have not yet been fully alleviated by the US EPA or the natural gas industry. In 2005, hydraulic fracturing methods were exempted from the Safe Drinking Water Act and Clean Water Act. However, recognizing increasing concerns over the impact on drinking water and ground water, in 2010 Congress directed the U.S. Environmental Protection Agency (EPA) to study the effects of hydraulic fracturing on the environment.

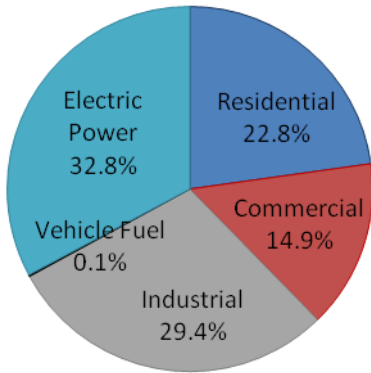
Barth (2010) also argues that previous industry-funded studies have not properly accounted for the impact on infrastructure, property values, and the “displacement” impact pollution can have on other

industries such as tourism and fishing. In 2010, tourism employed approximately 400,000 people in Pennsylvania whereas the natural gas industry employed closer to 26,000 (Barth, 2010; BLS). If tourism suffers as a result of the natural gas industry, then a bigger industry could be put at risk from expansion of the natural gas industry, though we note that much of Pennsylvania’s tourism industry is not near the mining activity.

Economists have long argued that energy development has limited overall impacts on the economy. There is a longstanding literature that refers to a “natural resources curse” that limits growth from energy development. One reason for the limited effects of energy development is Dutch Disease, which broadly refers to the higher taxes, wages, land rents, and other costs associated with energy development that make other sectors less competitive (including currency appreciation at the national level). These higher costs also reduce the likelihood new businesses will locate in the affected location. Previous research has found evidence of a natural resources curse and Dutch Disease suggesting that a natural resource boom can occur at the cost of other sectors and general long-run economic growth. For example, Papyrakis and Gerlagh (2007) found that US states with a higher degree of reliance on natural resources experience lower economic growth.³ Kilkenny and Partridge (2009) and James and Aadland (2011) also found evidence of this resource curse at the US county level.

Figure 3 on the next page shows that most natural gas is still used to supply electricity. Thus, with rising electricity demands, increasing natural gas production will lower the need for electricity generation from coal—i.e., we will have more natural gas jobs that are offset by fewer coal jobs. Only 0.1% of natural gas is used as vehicle fuel, which is derived from oil as opposed to coal. Thus, new natural gas will not significantly decrease US reliance on foreign oil unless, as publicly suggested by T. Boone Pickens, the US considers converting more buses, trucks and other vehicles to natural gas. Thus, its effects on “energy security” are rather limited in the foreseeable future as increased electrical demand and the growing reliance on US natural gas will primarily be at the expense of US coal.⁴

2. Kleinhenz & Associates (2011) specify that over 200,000 jobs will be *created or supported* but they do not clearly define the difference between “created” and “supported” jobs. In terms of long-term economic development, permanent job creation would be necessary—or does natural gas development create more permanent jobs than what would have happened without the energy development? The latter counterfactual question is not addressed in that report.
3. Dutch Disease refers to natural gas development in the Netherlands in the 1960s and 1970s. The ensuing boom raised costs and appreciated the Dutch currency, rendering Dutch manufacturers less competitive on international markets. After the initial boom settled down, not only were there less employment in the natural gas industry, but Dutch manufactures found it hard to regain their market share on international markets, producing a permanent cost on their economy.
4. The recent expansion of shale development did reduce natural gas imports, but going forward, its main influence will be as a substitute for other sources of electricity, primarily coal.



Source: US EIA

Figure 3: 2010 Natural Gas Consumption by End Use

Even with a significant conversion of vehicles to natural gas, the energy sector as a whole has an employment share that is simply too small to significantly impact the high unemployment rates the US is experiencing. In 2010, the natural gas industry accounted for less than 0.4% of national employment, so even if the sector doubled in size—which is quite a stretch—overall U.S. employment would only be marginally effected (BLS).⁵ This is not surprising as natural gas like much of the energy sector (including alternative

energy) is quite capital intensive, which reduces the employment effects of natural gas compared to the broader economy.

The pursuit of economic fads is often justified by overpromising jobs while ignoring the displacement effects on other sectors of the economy as well as other costs on the economy. The benefits should be appropriately weighed against the costs, but this requires a better understanding of both the benefits and costs. It should not be based on the overblown hype of either side. Using previous experience from Pennsylvania, we will produce realistic estimates what Ohio should expect from shale gas development over the next four years. We find that although the employment advantages of shale gas have generally been overstated by the industry, there are clear benefits of natural gas production when compared to coal (which has its own environmental risks). The biggest advantages are that natural gas is more cost-effective than coal and can reduce carbon emissions. Coal forms the natural benchmark because in the medium term, natural gas production would displace coal production as the alternative source for electricity.



5. The calculation of total natural gas employees uses the methodology of IHS Global described in more detail in note 7 and we use U.S. Bureau of Labor Statistics Data to derive the employment figures.

Hydraulic Fracturing Overview

Innovations in hydraulic fracturing are the reasons natural gas extraction has recently been developing in the Marcellus shale regions in Pennsylvania and Ohio and now expanding to the Utica shale regions in Ohio. Before investigating the impacts of shale gas development, it is important to understand the hydraulic fracturing method that has made natural gas extraction from shale economically feasible.

Shale is a fine-grained sedimentary rock that can trap petroleum and natural gas well below the surface. Horizontal drilling and hydraulic fracturing now allow the energy industry to extract this trapped gas. Commercial hydraulic fracturing began in 1949, though it took decades of use for innovations to make shale gas extraction more cost effective. Horizontal drilling can cost 3 to 4 times more than conventional drilling, but has the potential of reaching substantially more reserves. Figure 4 from the EIA compares horizontal drilling and hydraulic fracturing to conventional methods of natural gas extraction. Figure 5, further depicts the hydraulic fracturing process.

Horizontal wells and hydraulic fracturing in conjunction with advances in micro-seismic technology aiding both exploration and the drilling process have allowed the energy industry to extract natural gas at greater depths. According to the EPA (Jun., 2010), horizontal wells are drilled to a depth between 8,000 and 10,000 feet. Hydraulic fracturing extracts natural gas from shale using a pressurized injection of fluid composed mostly of water and a small portion of sand and chemical additives that vary by site. This pressure causes the shale to fracture, requiring sand or other propping agents to keep the fissures open and allow gas to escape. Between 15 to 80% of the fluids are recovered from the well before the natural gas is collected. This water called "produced water" can be reused in other wells, but will need to be treated or disposed of at some point.

Natural Gas Development in the US:

In the 1980s, the Barnett shale in Texas became the first natural gas producing shale. More than a decade of production from the Barnett shale in Texas has helped improve the hydraulic fracturing process, leading the way for it to be used in other areas such as the Marcellus shale in Pennsylvania and the Utica Shale in Ohio. The Marcellus shale is more than 60 million acres and is significantly larger than the Barnett. The EIA esti-

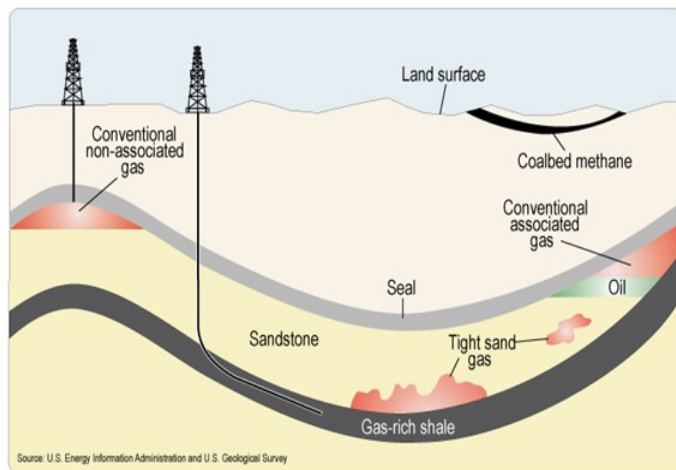
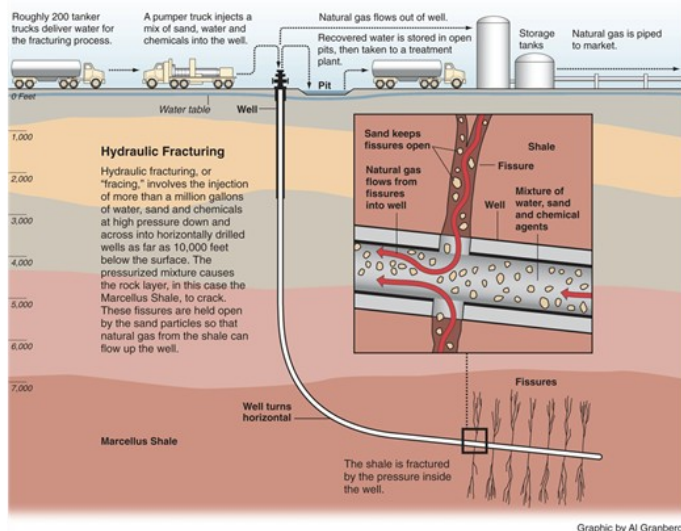


Figure 4: Natural Gas Mining Methods



Source: ProPublica

Figure 5: Hydraulic Fracturing

mates that there are 410 Tcf of recoverable gas in the Marcellus shale alone. Figure 6 on the next page shows the location of US shale plays including the Barnett in Texas and the Marcellus and Utica in Pennsylvania and Ohio. Figure 6 clearly shows that shale natural gas is a national phenomenon that will dramatically alter natural gas availability and pricing nationally. Indeed, EIA data further documents that shale plays are a global phenomenon that will likely reduce world-wide natural gas prices.

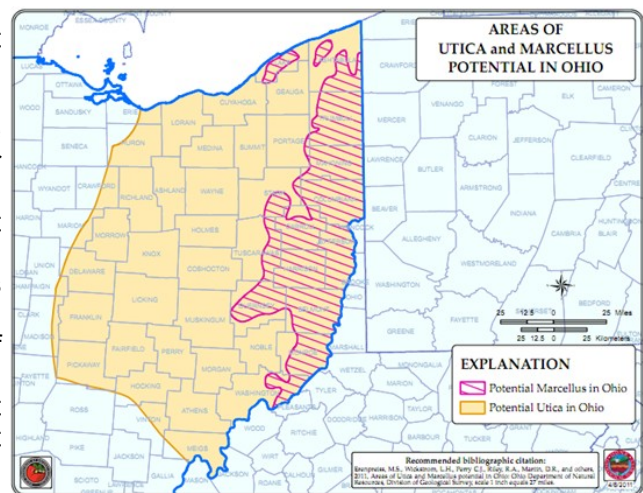


Source: US EIA

Figure 6: US Shale Resources

The large potential of the Marcellus shale, and more recently the Utica shale, has made Pennsylvania and Ohio highly attractive for mining of natural gas reserves. Figure 7 below provides a more detailed look at areas in Ohio that may be directly affected by natural gas resources. In an interview, Douglas Southgate of The Ohio State University's Subsurface Energy Resource Center states that shale resources in Ohio can provide a reliable, cheap, and local source of energy for Ohio. He explains that much of the attention has been on the Marcellus formation, though it is becoming clear that the Utica is more important. In the long term, the latter is expected to supply oil in significant quantities (Dezember and Lefebvre, 2011). It is also an important source of natural gas liquids (NGLs) such as ethane, which is converted into the ethylene used to manufacture a wide array of chemical products (American Chemistry Council, 2011). Thus, Southgate and others argue that shale deposits in and around Ohio are an important source of various hydrocarbons, not just the methane used to heat homes, generate electricity, and so forth.

Ohio shale development is just beginning. Figure 8 on the next page shows specific Marcellus and Utica well activity in Ohio from 2006 through August, 2011. It was recently reported that Chesapeake Energy has its first 4 active Utica shale wells in Ohio producing between 3 and 9.5 million cubic



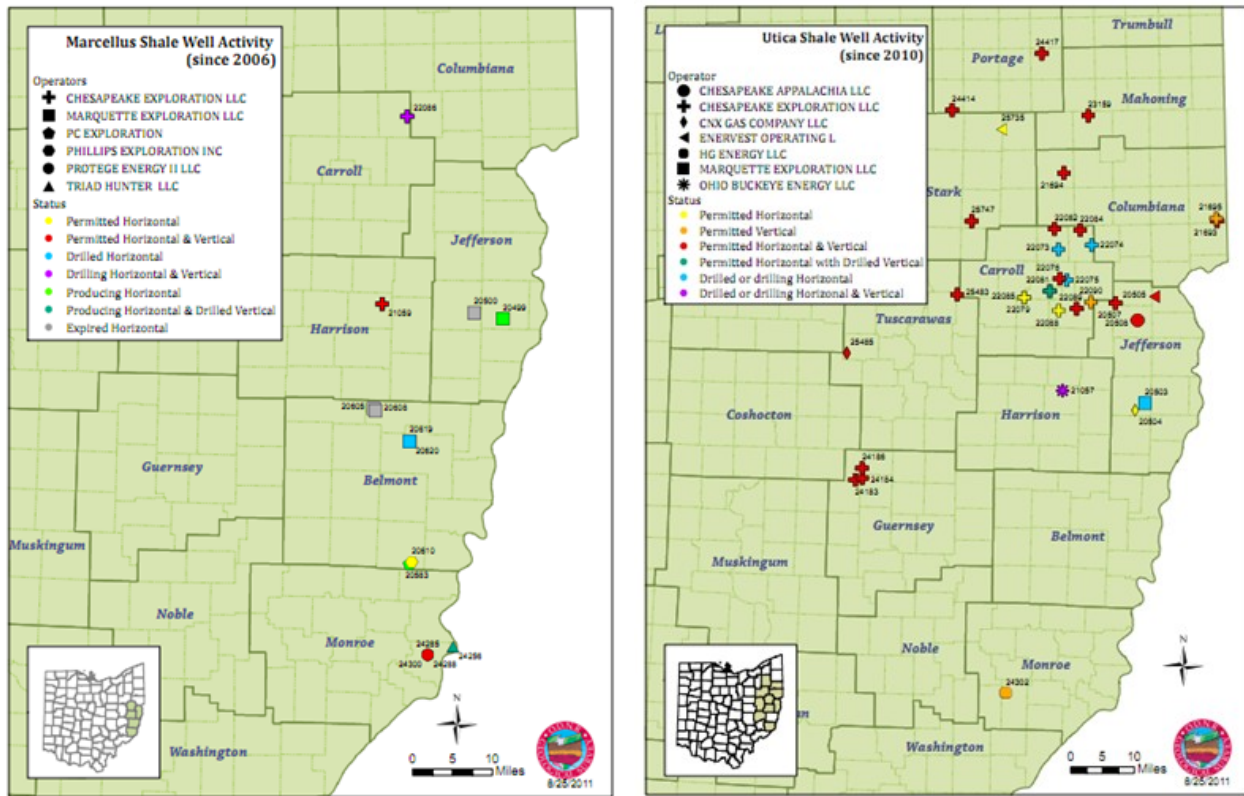
Source: ODNR

Figure 7: Ohio Shale Resources

feet of natural gas per day (Gearmino, 2011). A conventional well might produce between 100,000 and 500,000 cubic feet per day, but the Marcellus and Utica shale wells are expected to produce between 2 to 10 million cubic feet of natural gas per day. Chesapeake plans to increase the number of wells to 20 by the end of 2013.

Although shale development has already begun in Ohio, it is still nascent compared to Pennsylvania. The projected impacts on Ohio are still being de-

bated. For example, Kleinhenz & Associates (2011) projected natural gas development in Ohio would lead to 200,000 jobs and \$14 billion in spending. Much of their analysis uses assumptions derived from recent Pennsylvania impact studies such as Considine et al. (2009; 2010; 2011). Kleinhenz & Associates (2011) projected that 4,000 wells will be drilled in Ohio by 2015. Overall, they produced economic results that are similar to the industry-funded estimates for Pennsylvania.



Source: ODNR (Aug, 2011)

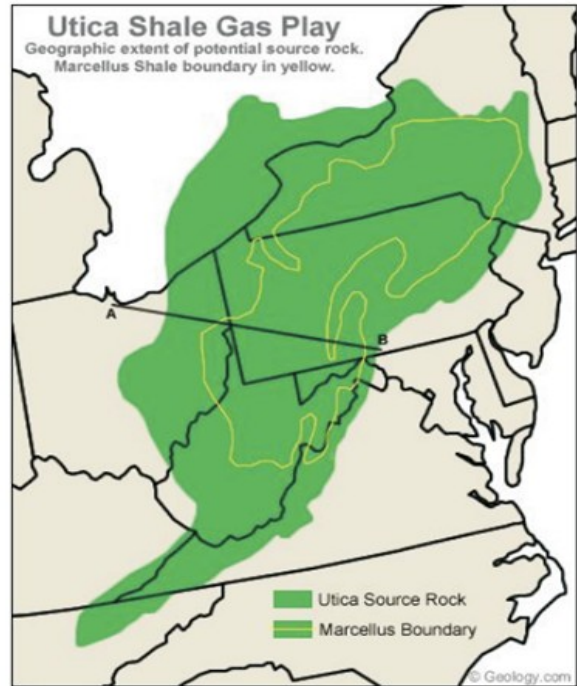
Figure 8: Marcellus and Utica Well Activity in Ohio

Economic Expectations

Pennsylvania is a particularly good gauge to predict what the impacts of shale gas will be on Ohio because they share much of the same natural resources. They are also very proximate and have similar economic structures. Figure 9 shows the Marcellus and Utica shale running through both states. Besides being neighbors, Pennsylvania and Ohio are the 6th and 7th most populous states. For both states, the shale resources are mainly located in rural areas, though there are larger population centers that are affected.

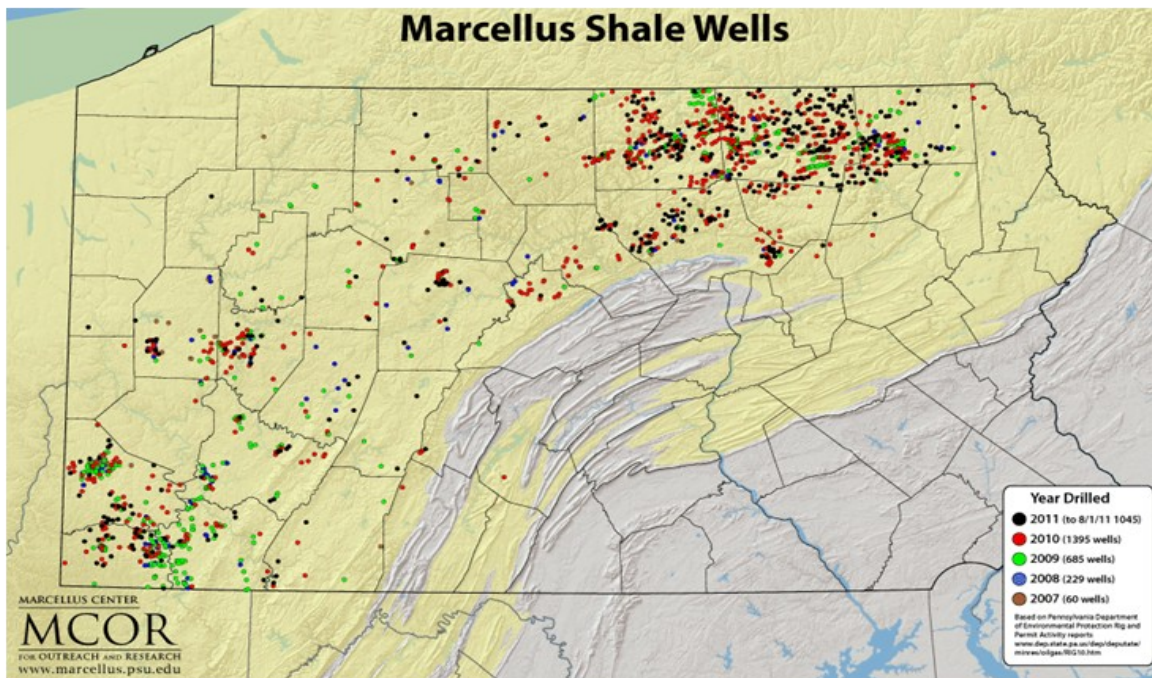
In 2005, the first well in the Marcellus shale in Pennsylvania began producing natural gas. Since then, most of the wells have been located in the northeast and southwest in Pennsylvania. Figure 10 shows the location of wells across the state by year. The number of shale wells drilled grew from 60 in 2007 to 1,395 in 2010. Considine (2010) finds that 36% of the 229 wells drilled in 2008 were horizontal and that percentage is expected to rise.

As the number of wells drilled dramatically increased, so did natural gas production in Pennsylvania, especially in the northeast region. Figure 11 on the next page shows the notable increase in production.



Source: Ohio EPA

Figure 9: Marcellus and Utica Shale Plays



Source: PSU

Figure 10: Marcellus Shale development 2007-2011

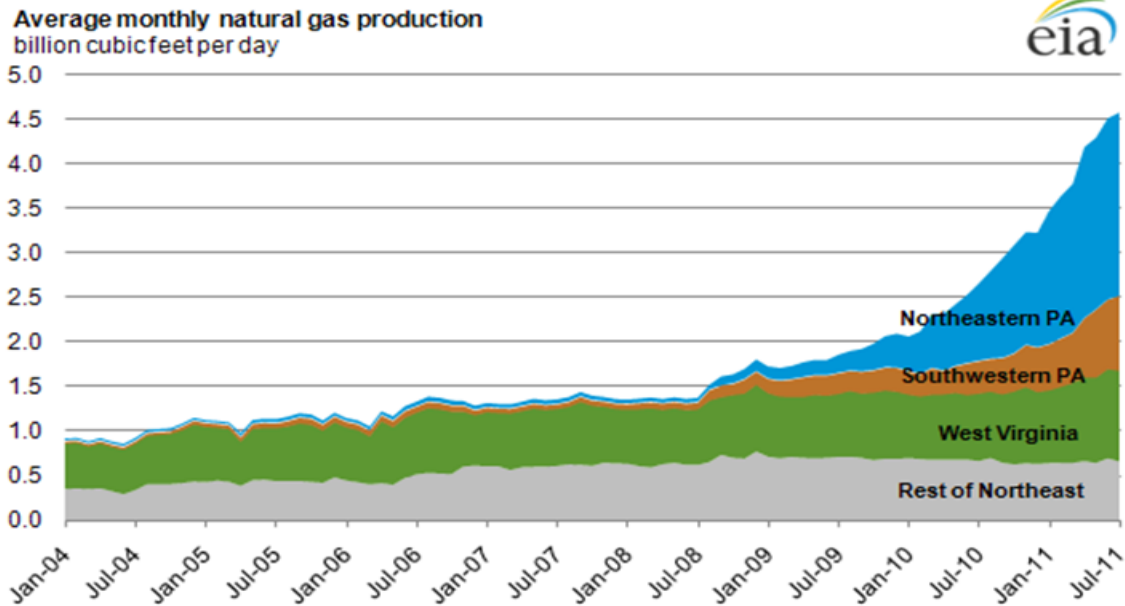


Figure 11: Northeast Natural Gas Production

Pennsylvania Natural Gas Employment:

Studies of natural gas's role in national and regional economies typically use impact studies (though this is not considered best practice for evaluating economic effects). Impact studies, such as the ones we describe, typically estimate three types of employment effects: (1) direct effects of the jobs directly employed in the activity (in this case natural gas mining); (2) indirect effects that would include inputs to the direct activity (such as pipeline construction); and (3) induced effects due to the added household income (e.g., workers purchasing items in the local economy) (see IMPLAN.com for more details). Summing across the three categories, if done correctly, would produce the total number of jobs "supported" by the industry (not new jobs created). As we describe below, estimating the number of new jobs created would need to assess what would have happened in the absence of natural gas mining—i.e., develop the counterfactual—which is not done in standard impact analysis.

One source of confusion is that impact studies do not produce continuous employment numbers. If an impact study says there are 200,000 jobs, this does not mean 200,000 workers are continuously employed on a permanent basis. For example, there are workers who do site preparation. Then there is another group who do the drilling followed by another group who maintains the well when it is in

production. Finally, there is an entirely different group doing pipeline construction, and so on. So, while the public is likely more interested in continuous ongoing employment effects, impact studies are producing total numbers of supported jobs that occur in a more piecemeal fashion.

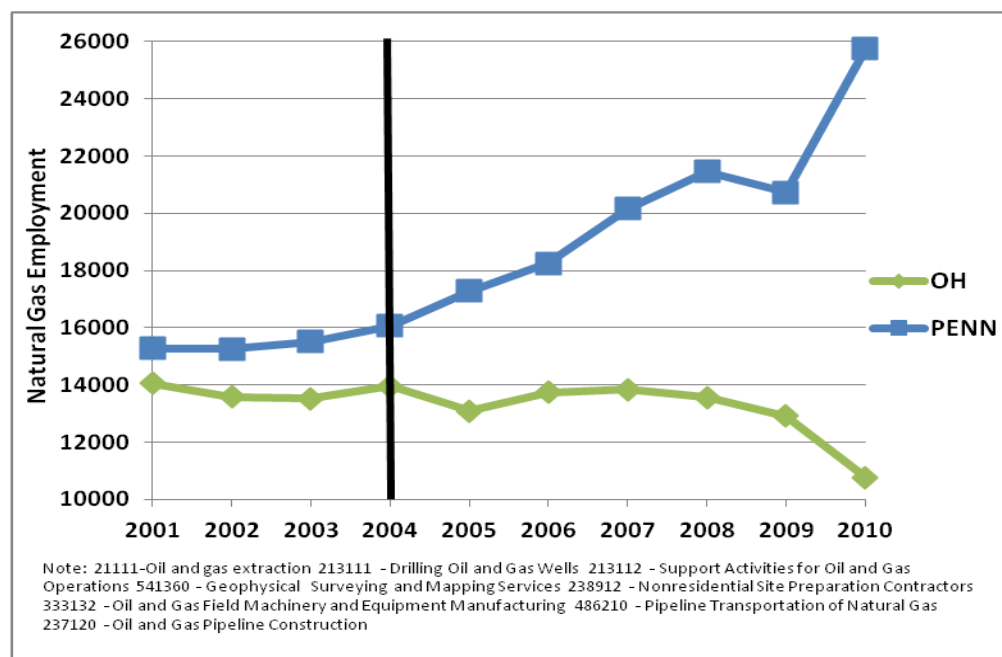
Impact analysis is usually based on an old input-output technology that is typically not used today by economists to estimate actual economic effects. Impact studies do not include various displacement effects and do not reflect the true counterfactual of comparing what would have happened without natural gas drilling. For example, oil and natural gas drilling would lead to higher local wages and land costs, which reduce employment that would have occurred elsewhere in the economy. Likewise, the environmental effects may reduce activity in the tourism sector and other residents may not want to live near such degrading activity. Finally, greater natural gas employment means that there are fewer jobs in coal that would have occurred without the increase in natural gas employment. As described below, best practice economics uses other approaches that try to adjust for displacement effects to derive more accurate estimates of actual effects (see Irwin et al. (2010) for a discussion of the weaknesses of impact studies).

Figure 12 on the next page shows the direct and much of the indirect employment in natural gas and other related sectors in Ohio and Pennsylvania.⁶

6. For the direct effect of natural gas mining, we also include some indirect suppliers that are related to natural gas drilling, which overstates the direct effects. However, not all of the indirect industries are included in Figure 12. When we use a multiplier below, because we already include some indirect effects, we would overstate the total number of supported jobs for the industry.

Since some of the sectors reported in Figure 12 include other sectors—primarily oil—we assume that all of the gain in Pennsylvania employment is due to new natural gas production. Also, we do not include “energy related” sectors in Figure 12 if they showed a large decrease in employment because we believe that would understate the importance of new natural gas production in Pennsylvania (those declines would likely be due to other factors). Thus, if anything, we believe that any measurement “errors” would work to overstate the importance of new gas production employment.⁷ From Figure 12, with these assumptions, we assume that from 2004-2010, there was a gain of about 10,000 direct and indirect jobs in the natural gas industry in Pennsylvania.

The typical multiplier would take direct employment and multiply it by the multiplier to arrive at the total effects, including indirect and induced effects. Since the 10,000 number derived above includes some of indirect effects such as pipeline construction, using the standard multiplier would likely lead to an overstatement of the total employment effects of new production. Nonetheless, assuming the standard multiplier of 2 (which is on the high end), the natural gas industries would still have led to about 20,000 direct, indirect, and induced jobs from 2004 to 2010 in Pennsylvania, though this ignores employment losses in other sectors displaced by natural gas.⁸ By comparison, Considine et al.’s (2011) industry funded study suggested that natural gas was associated with 140,000 Pennsylvania jobs during 2010.



Source: BLS

Figure 12: Ohio and Pennsylvania Natural Gas Employment⁹

- IHS Global Insight (2009) notes that employment in these sectors also includes employment in the oil sector and other sectors (not just natural gas). They calculate some national estimates of natural gas’s share of overall employment in each sector. For example, they estimate natural gas’s employment share for the following industries as follows: (1) 2111-Oil and gas extraction, 213111 - Drilling Oil and Gas Wells, and 213112 - Support Activities for Oil and Gas was 74% in 2008; (2) 237120 - Oil and Gas Pipeline Construction was 68% in 2008; (3) 333132 - Oil and Gas Field Machinery and Equipment Manufacturing was 65% in 2008 and (4) 238912 - Nonresidential Site Preparation Contractors was 16% in 2008). We could have used IHS Global Insight’s shares in our calculations, but we believe this would understate the increase in the size of the natural gas sector in Pennsylvania because some of the gains would be attributed to other sectors.
- Academic economists generally use a multiplier of 2 as an upper bound multiplier. For example, Stabler and Olfert (2002) describe a range of employment multipliers in the 1.1 to 1.5 range. Hughes (2003) describes that *output* multipliers above 2.5 are likely very questionable. Likewise, Kelsey et al. (2009) found an output multiplier for natural gas in Pennsylvania to be in the 1.86 to 1.90 range, further showing that our 2.0 multiplier is reasonable. Indeed, as the economy becomes more global, fewer employment gains are on-shore or local, which would reduce employment multiplier effects. Likewise, with outsourcing and increasingly fragmented supply chains, firms are further shifting their purchases outside the firm, which further reduces the amount purchased locally. Further, keep in mind that the energy sector is highly capital intensive which would work to reduce the employment effects and increase the output effects in a multiplier. Thus, we believe our use of an employment multiplier of 2 would be viewed as “generous” by independent academic economists.
- The direct effects would commonly include the drilling and extraction activities while indirect effects would normally include inputs such as pipeline construction and field equipment manufacturing. Hence, this is why we state that we are already including some of the key inputs as direct employment in Figure 12.

We believe that independent and academic economists in regional and urban economics would view our 20,000 employment estimate as reasonable and some may view it on the high end of actual job creation.¹⁰ For example, Barth (2010) notes that other studies found a multiplier for oil and gas as low as 1.4. She also notes that in similar input-output studies, other industries were found to have higher multipliers than oil and gas, with agriculture having one of the highest multipliers. If shale development adversely affects employment in (say) coal mining, agriculture, and tourism, then those numbers should be subtracted from these numbers to derive the actual employment effects (including any multiplier effects in those sectors). To be sure, we only calculate an impact style estimate to give a feel of the overestimated effects produced by industry consultants (and others who produce impact studies). There are much better approaches than impact studies to calculate actual effects, which we describe below.

One other issue is that proponents of natural gas expansion in Ohio often claim that lower natural gas prices will provide a major stimulus to overall employment, especially in manufacturing. While we will not assess whether natural gas prices are a sufficient share of a typical firm's cost structure to make a tangible difference, we do note that there are reasons to be skeptical of those claims (though we hope we are wrong). Foremost, to make a difference on Ohio's relative competitive edge compared to the rest of the United States and the rest of the world, it would have to be an event that helps Ohio's businesses much more than in the rest of the world. However, as we note in the discussion surrounding Figure 6, shale natural gas is a global phenomenon, meaning that falling natural gas prices will benefit a significant share of Ohio's global competitors. Thus, there is no "edge" given to Ohio's businesses that would make them tangibly more competitive than their national and international competitors.

Economists typically subject their forecasts to "smell tests" by making comparisons to similar events. In our case, comparing energy develop-

ment around North Dakota's Bakken shale formation in the far northwestern part of the state is good benchmark to assess whether our 20,000 job forecast for Ohio makes sense. Specifically, development of North Dakota's Bakken shale region has been about the same magnitude as the energy development in Pennsylvania and should produce somewhat comparable job effects on both states.¹¹ During the October 2007-October 2011 period (or a four year period that corresponds to Kleinhenz & Associates' Ohio study), the entire state of North Dakota added about 39,000 jobs. It is highly unlikely that this is all due to energy as high commodity prices (for example) have supported North Dakota's relatively large farm economy. Further, we would expect that the Bismarck metropolitan area (which is relatively close to the mining activity) to be more impacted by the energy boom, while the Fargo and Grand Forks metropolitan areas that are hundreds of miles away on the Minnesota border to be considerably less affected. In this comparison, Bismarck added 4,600 jobs during this four-year period, while Fargo and Grand Forks metropolitan areas respectively added 4,400 and 1,600 jobs. These figures strongly suggest that North Dakota's relative prosperity is more widespread than just an energy boom in the Bakken region. So, even if all 39,000 North Dakota jobs were due to energy (which we have already shown is highly unlikely), this would be a far cry short of the 200,000 jobs that have been forecasted for Pennsylvania and Ohio despite the comparable size of the three states' energy booms.¹² Thus, our forecast of 20,000 jobs over the next four years is further supported as a reasonable forecast based on the North Dakota experience.

Although Pennsylvania's natural gas employment gains are impressive, they still represent just a small share of total state employment. From 2004 to 2010, the employment share of oil and natural gas related sectors shown in Figure 12 increased from 0.30% to 0.48% (see Figure 13). This small employment share is simply not enough to have a significant effect on total jobs and on unemployment for the state.¹³ Despite the significant increase in natural gas jobs from 2009 to 2010,

10. For example, there are many factors affecting the actual employment number. If there are workers from out of state, Ohio's employment number would be lower. Conversely, if more landowners are in state compared to Pennsylvania, that would increase the employment number. Other factors are harder to predict such as mining's effect on agriculture and timber.

11. U.S. Bureau of Labor Statistics Data (Current Employment Statistics) suggests that between October 2007 and October 2011, mining employment (which is due to the direct energy production) increased by about 12,000 in both states. The other employment numbers referred to here are from the same source.

12. U.S. Bureau of Labor Statistics Data shows that North Dakota had an October 2011 unemployment rate of 3.5%, which seems quite low compared to the 9.0% national rate. However, North Dakota always has very low unemployment rates due to long-term structural reasons (Partridge and Rickman, 1997a, 1997b). For example, it was an even lower 3.0% in October 2001, well before the energy and commodity price boom of recent years, illustrating that the energy boom is only a partial reason for North Dakota's current low unemployment rate.

13. To give a further feel for the size of the natural gas sector in Pennsylvania, Barth (2010) finds that in January 2010 there were 48,777 Walmart employees in Pennsylvania (almost double that of the natural gas industry broadly defined) and approximately 400,000 jobs in the tourism industry.

Pennsylvania's unemployment rate still increased from 8.0% to 8.7% during this time (BLS: U.S. Department of Labor, Bureau of Labor Statistics). At most, natural gas employment effects would be localized. Conversely, Ohio's unemployment rate remained unchanged at 10.1% from 2009 to 2010 (BLS) despite a loss in the energy sector jobs in Figure 12, illustrating that natural gas employment is not driving either state's economy.

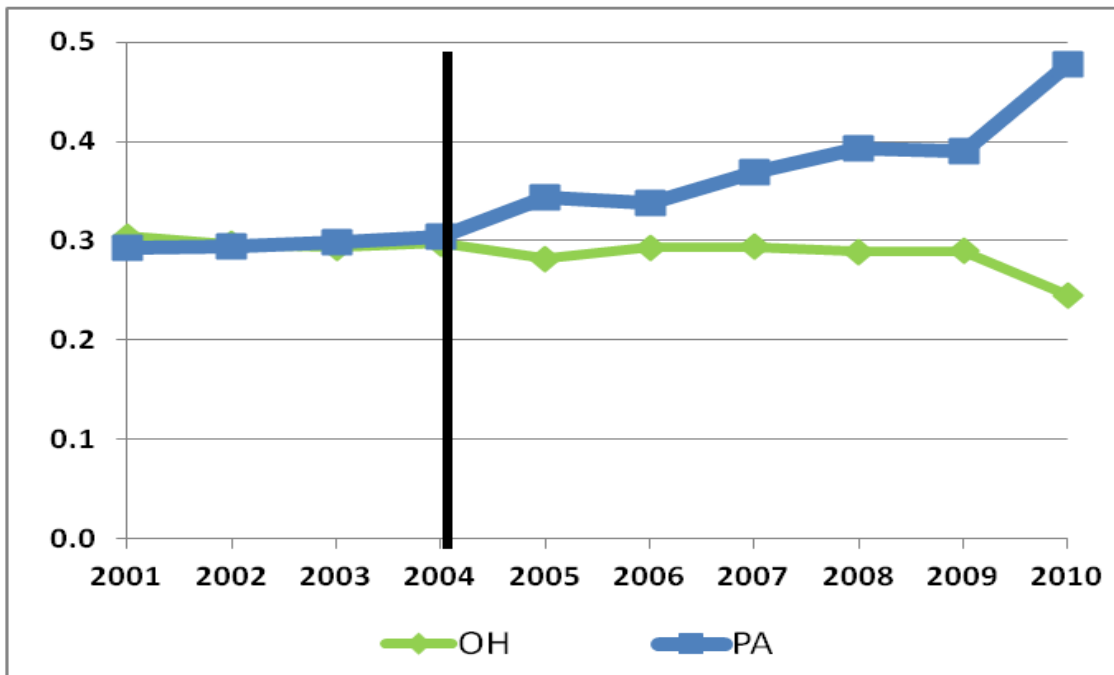
Concerns with the Economic Impact Studies of Natural Gas Development:

Impact studies are typically associated with overstatements of the employment effects of new development. For example, the Considine et al. (2011) study appears to include indirect and induced jobs before applying the multiplier effect, which double-counts effects and blows up the estimated effects. Direct jobs should include those jobs directly associated with drilling the wells and extracting the natural gas. Indirect jobs include the jobs associated with various inputs required by the industry such as pipelines. Induced jobs should include those jobs

and services required by the workers such as restaurants and entertainment.¹⁴ The final two categories should be the outcome of the multiplier process.

Second, Considine et al. assumes that 95% of natural gas industry spending will occur in Pennsylvania. Kleinhenz & Associates assumes a slightly more conservative 90% of all spending will be spent in Ohio. In global economies in which state economies are integrated with national and international economies, such assumptions would not be credible for independent economists. Moreover, because the industry is relatively new and undeveloped, more of the inputs would be brought in from outside of the state, e.g., from Texas.¹⁵

There are other problems with impact studies because, in reality, more of the money leaks out. For example, Kelsey et al. (2011) found 37% of the Marcellus employment has gone to non-Pennsylvania residents and that landowners save or invest approximately 55% of the money they make from royalties/lease payments rather than spending it in the local economy. They use these



Source: BLS

Figure 13: Ohio and Pennsylvania Natural Gas Employment Shares of Total State Employment

14. Examples of jobs that should not be categorized as direct to natural gas mining are Finance & Insurance, Educational Services, Health, Arts & Entertainment, Hotel & Food Services, etc. By including these jobs as direct jobs, Considine et al. is essentially double counting the employment effects. While we do not have Considine et al.'s programming we believe one source of the double counting derives from how household spending from lease payments/royalties are treated. Even using the job estimates of Considine et al., it is still not a significant portion of the total employment in Pennsylvania.

15. We believe a more reasonable approach would have been to use the default state spending shares from the IMPLAN software (i.e., Considine et al. overruled IMPLAN's default numbers and incorporated 95%). In the absence of detailed and regional I-O data, other shortcuts have been used such as payroll to sales ratios (Oakland et al., 1971; Rioux and Schofield, 1990; Wilson, 1977) or Value-added to gross outlays by industry (Stabler and Olfert, 1994).

	Population 2005	Per Capita Income 2005	Employment Growth Rate 2001-2005	Employment Growth Rate 2005-2009	Income Growth Rate 2001-2005	Income Growth Rate 2005-2009
Non-Drilling Counties	255,508	\$32,187	5.3%	-0.4%	12.6%	13.6%
Drilling Counties	124,928	\$27,450	1.4%	-0.6%	12.8%	18.2%

Source: BEA

Table 1: Pennsylvania County Descriptive Statistics

more realistic findings to develop a better estimate of the economic impacts of shale development in Pennsylvania. Using IMPLAN, Kelsey et al. (2011) find that in 2009, Marcellus shale development economic impact was over 23,000 jobs and more than \$3.1 billion. Our estimate of 20,000 jobs then closely corresponds to Kelsey et al.'s estimates (2011).

Finding Counterfactuals to Assess Growth:

The key problem with impact studies is that they do not estimate the actual number of jobs created by mining because of all of the displacement effects. They are not the true counterfactual and economists have not viewed them as best practice for decades (Irwin et al., 2010). Economists have developed other more credible approaches in developing a counterfactual, such as difference in difference approaches. One of these approaches is to match drilling counties to non-drilling counties that otherwise would have had similar employment patterns if there was no drilling. Thus, the goal is to find counties that would have looked similar to the drilling counties in the absence of drilling. We describe this approach below.

Although natural gas employment does not seem to have had a significant impact on the state as a whole, it may still have a sizeable impact on the specific counties, many of them rural. Table 1 presents data for Pennsylvania counties before and after drilling. Table 1 shows that before 2005, drilling counties are notably struggling more than non-drilling counties. Drilling counties on average are less populated, more rural, have lower per capita income and less employment growth. Natural gas leases also provide an additional source of income for landowners. Landowners that choose to lease their land to natural gas companies generally re-

ceive an upfront payment per acre and royalties on the gas produced from the well. Although the payout varies, it can be quite sizeable. From Table 2, it seems natural gas development is positively related to per capita income growth rates for drilling counties.

Table 1 highlights the fact that drilling counties on average look very different than most non-drilling counties. Thus, we look specifically at 3 significant high-drilling counties in the northeast (Tioga, Bradford, and Susquehanna) and 3 in the southwest (Washington, Greene, and Fayette).¹⁶ We then match each of these two sets of mining counties to similar non-mining counties (as of 2009) based on population and similar employment and income dynamics *before* 2005 and the advent of shale drilling.¹⁷ Figure 14 shows the mining and non-mining counties that were chosen. Figure 14 shows that the matches are divided into the Northeast quadrant of the state and the southern part of the state. The appendix provides additional graphs directly comparing each drilling county with its matched

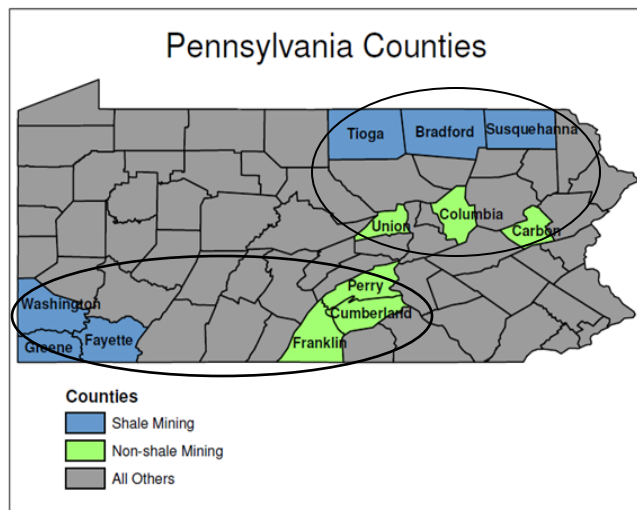


Figure 14: 2009 Matched Drilling and Non-drilling Counties

16. Drilling counties were matched to non-drilling counties on the basis of population and general urbanization as well as region (either north or south).

17. Matching studies can employ other mathematical approaches to finding matches. As will be apparent, our choice of non-drilling counties will appear to be good matches.

non-drilling county.

Using BEA employment and income data, the shale mining counties are compared to the non-mining counties with 2004 marking the point immediately before drilling activities began. One of the key features of the employment and income data is that both mining and non-mining counties are on similar growth paths prior to drilling, suggesting there they are good comparisons (see Figures 15-18 in the next pages). Figure 15 suggests that mining counties may have had faster job growth in the Southern region, but Figure 16 shows that the opposite applies in the Northeastern region. Overall, there are no clear employment effects for heavily drilled counties. We are not saying there are no drilling employment effects, but that they are not large enough to be detected in this commonly used matching approach. One reason may be that many of the new jobs may go to people outside the state who have previous experience in natural gas extraction.¹⁸ Conversely, the positive impacts on incomes are more clear. Figures 17 and 18 show the per capita income impact of natural gas drilling appears to be positive in both Southern and Northeastern regions. While the effects may differ in longer-run periods, our four year window conforms to Kleinhenz & Associates' four year forecast for Ohio.

To be sure, there are many things happening in these county economies, but such efforts to form the true counterfactual are more in line with best economic practice than the impact studies that are often used by economic consultants. In particular, one especially appealing feature is that our approach is based on actual employment and income data and not based on the assumptions of computer software.

For further comprehensive analysis to appraise whether our previous matched results

are correct, we now perform a statistical analysis on all counties within Pennsylvania. To control for county-specific effects, we use a difference-in-difference approach to find the impact of drilling on the change in employment after drilling compared to the change in employment before drilling. Details of the difference-in-difference methodology are provided in the appendix, but essentially we are examining whether having more natural gas wells is associated with more job and income growth, but this time we are considering all Pennsylvania counties. This approach accounts for the fact that drilling and non-drilling counties may have systematic differences (fixed effects) for a variety of reasons - and we are adjusting for these differences. Table 2 shows that the number of wells drilled since 2005 has no statistically significant effect on employment.¹⁹ Overall, we believe that there have been modest employment effects in drilling counties, but they are not large enough to statistically ascertain (most likely due to some of the offsetting factors we just described). The upshot is decision makers who are interested in the actual job creation effects of natural gas need to take much more seriously the displacement effects throughout the economy.

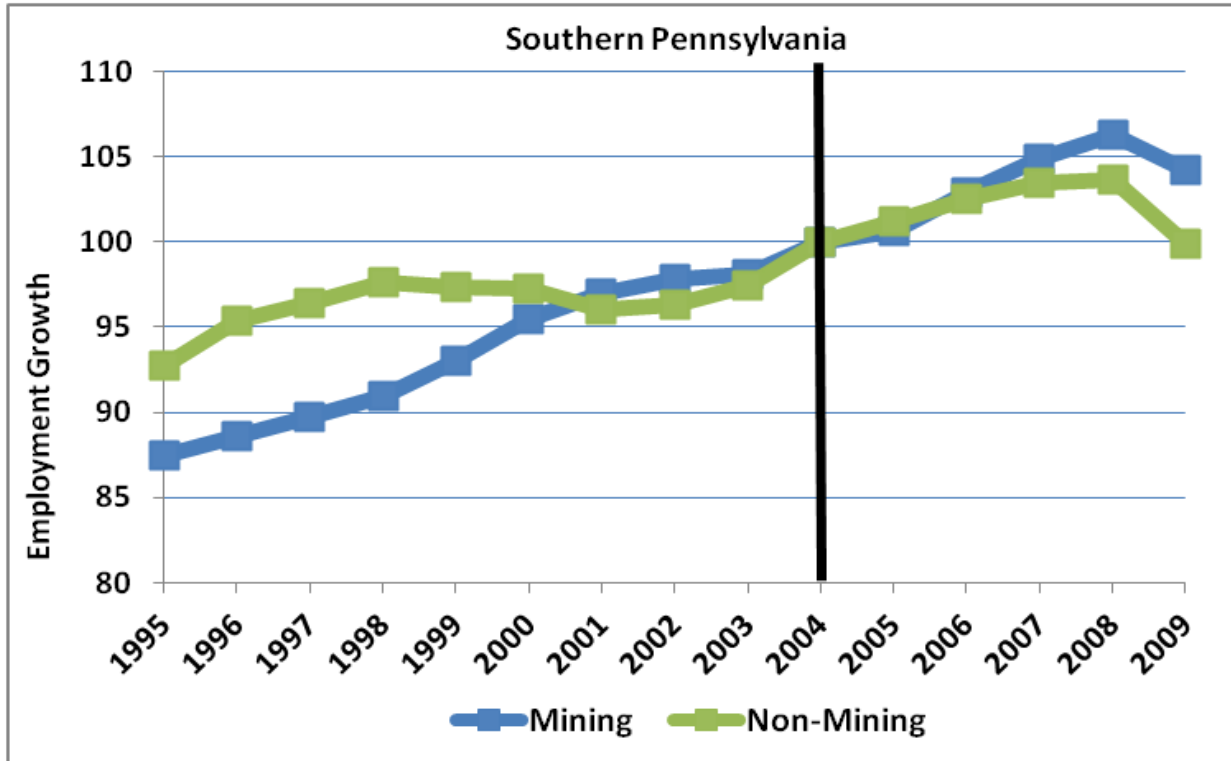
There are many important reasons why we would expect natural gas' impact on employment to be small or insignificant, which explains the findings in Figures 15 and 16 and in Table 2. Besides displacement, one reason is the production technology of natural gas. Like other fossil fuel energy industries, natural gas is rather capital intensive.

	Change in Percent Employment Growth 2005-2009 Compared to 2001-2005	
	Parameter Estimate	t-value
Total Wells 05-09	1.769E-05	1.14
2001 Log Population	0.023	2.64
2001 Log Per Capita Income	-0.096	-1.55
N	67	
R2	0.118	
Adjusted-R2	0.076	

Source: BEA and Pennsylvania DEP Data. See the appendix for more details.

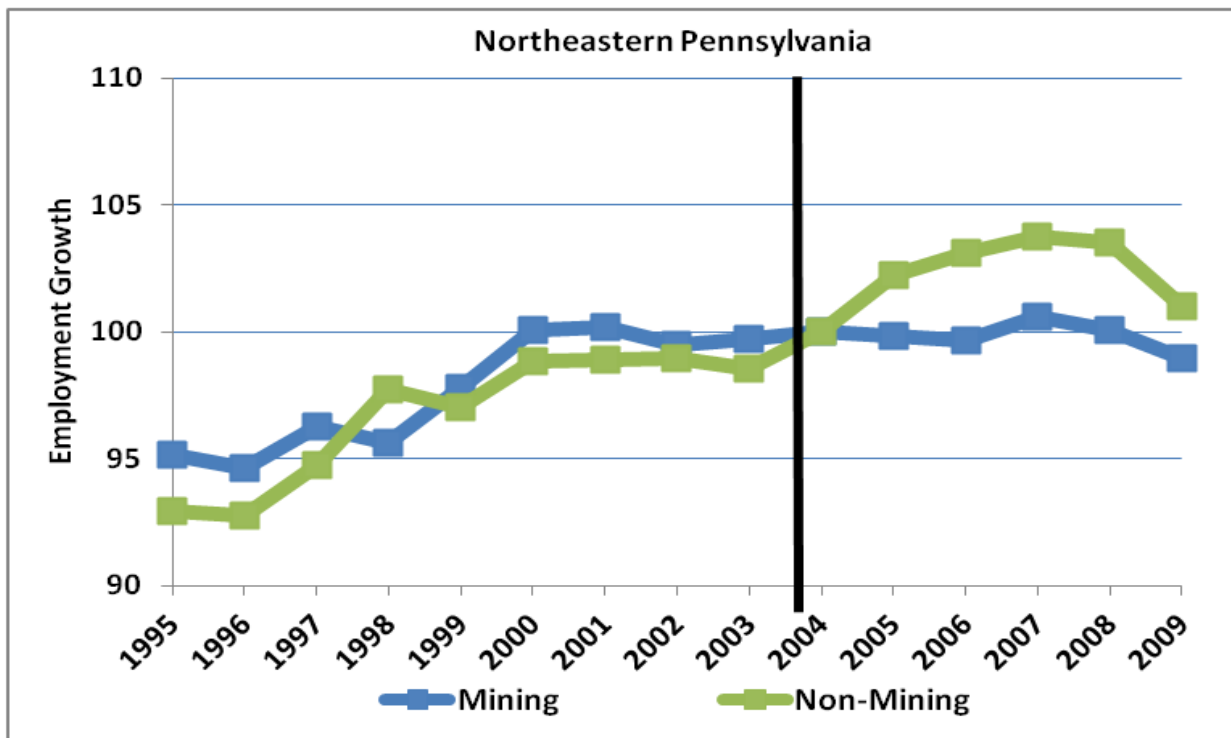
Table 2: Employment Effects of Drilling

18. Pennsylvania and Ohio residents may not have the skills and experience needed to meet the demands of the natural gas industry and royalty/lease monies may not be spent locally. Similarly with natural gas spending, Pennsylvania may not have the services and supply chain the energy industry requires initially. Along with other displacement effects, this may explain the lack of employment response.
19. We also considered that possibility that there are threshold effects (or other nonlinearities) in which drilling does not affect economic growth until a certain number of wells are drilled. We did this by adding a number of wells drilled squared term to the model. This variable's coefficient was negative and statistically insignificant in both the income and employment growth models, suggesting that there are no nonlinear effects. Additionally, these numbers don't account for people switching from part time to full time employment.



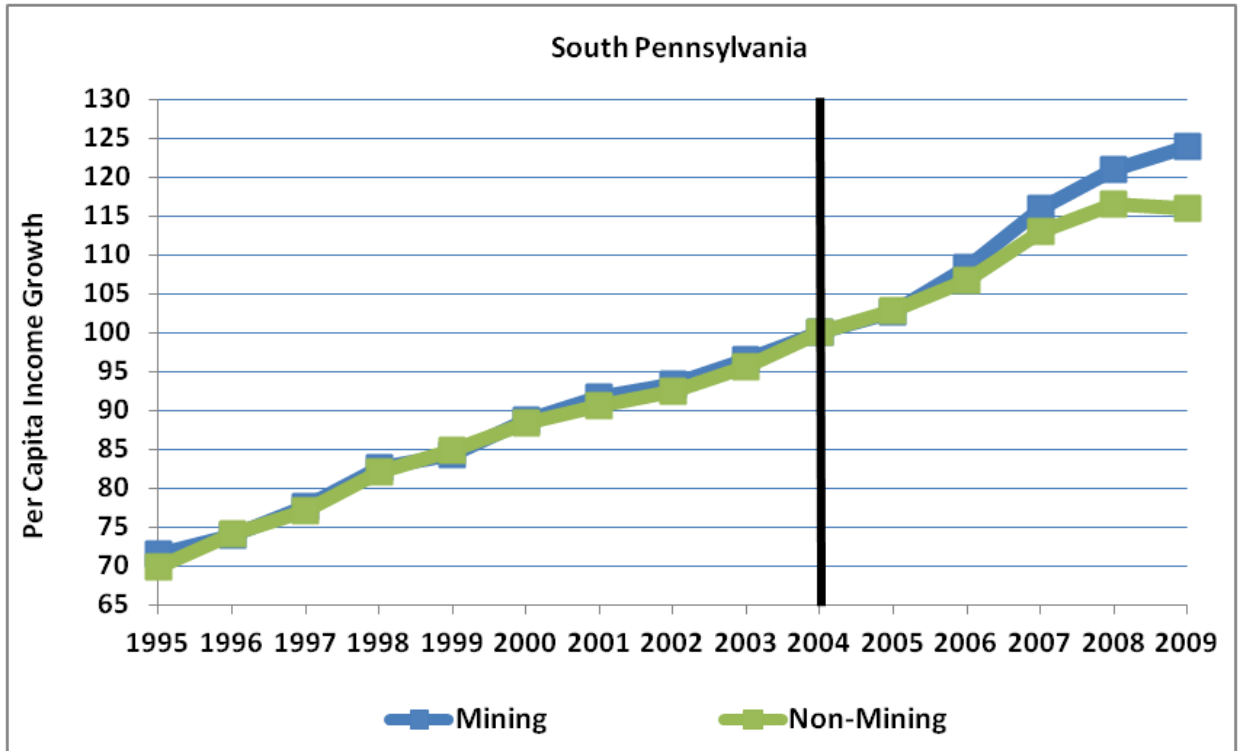
Source: BEA Mining counties (Washington, Greene, and Fayette) Non-mining counties (Perry, Franklin, Cumberland)

Figure 15: Drilling and Non-drilling Employment Comparison (2004=100)



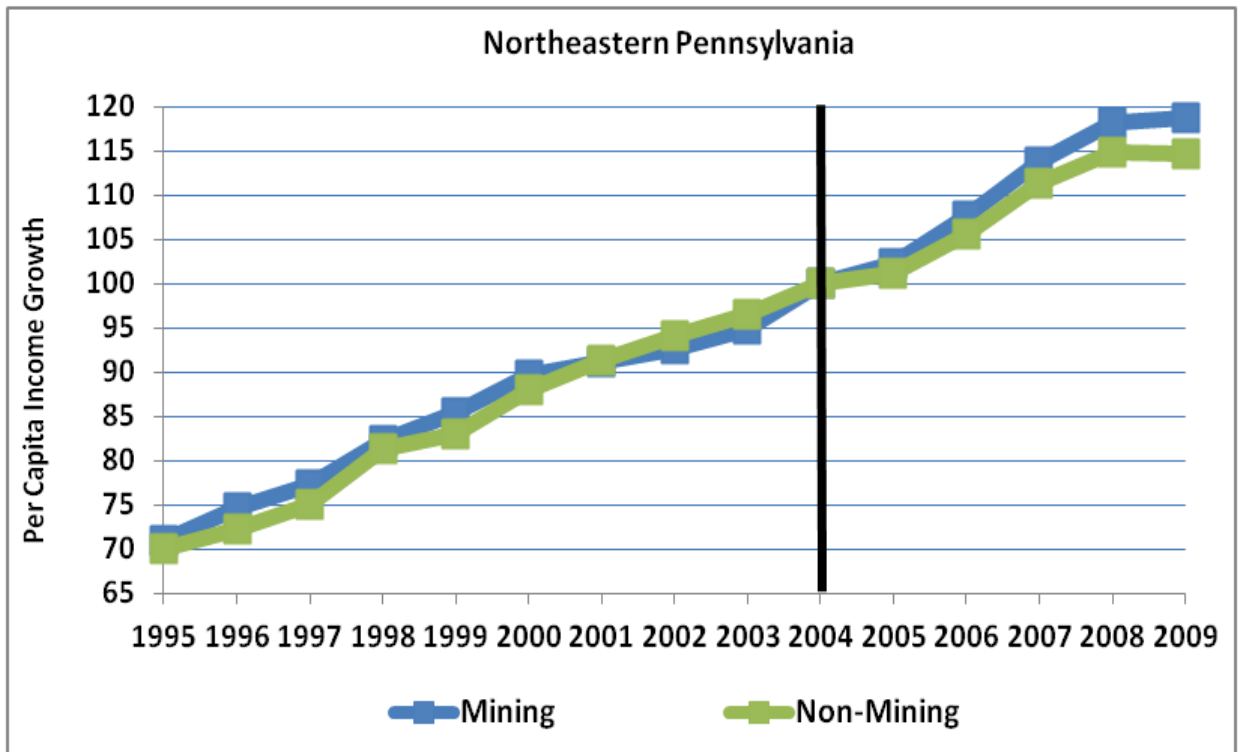
Source: BEA. Mining counties (Tioga, Bradford, and Susquehanna) Non-mining counties (Union, Columbia, Carbon)

Figure 16: Drilling and Non-drilling Employment Comparison (2004=100)



Source: BEA. Mining counties (Washington, Greene, and Fayette) Non-mining counties (Perry, Franklin, Cumberland)

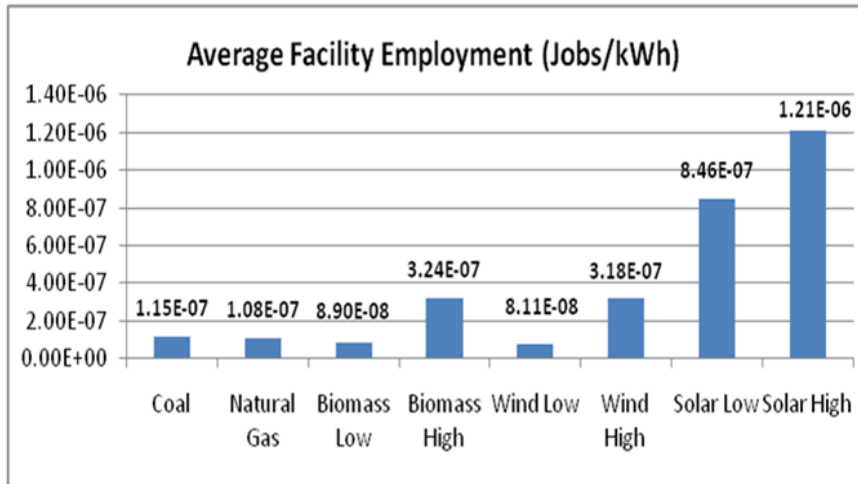
Figure 17: Drilling and Non-drilling Per Capita Income Comparison (2004=100)



Source: BEA. Mining counties (Tioga, Bradford, and Susquehanna) Non-mining counties (Union, Columbia, Carbon)

Figure 18: Drilling and Non-drilling Per Capita Income Comparison (2004=100)

Figure 19 shows the estimated number of jobs required to produce a kWh of electricity. Natural gas actually requires fewer jobs to produce a given amount of electricity than coal. The job requirements for natural gas electricity production are low because it is efficient at producing a kWh. In this case, fewer jobs created is actually a good thing for the overall competitiveness of the economy because that implies low-cost electricity, but it means that natural gas drilling has smaller employment impacts.



Source: Weinstein et al. (2010) chart using data from Kammen et al. (2004)

Figure 19: Jobs Requirements to Produce a kWh by Energy Source

As figure 3 shows, most natural gas resources (32.8%) are used for electricity. When switching from coal to natural gas, there will be significant displacement effects in addition to the effects of natural gas being more productive than coal in producing a kWh. Using the same technique shown in Weinstein et al. (2010), Table 3 shows the approximate employment effects of even large shifts (25% of the kWh produced from coal to kWh generated from natural gas) are rather small. In both cases, there are small employment losses with Ohio having more employment losses due to a higher percentage of electricity being generated from coal.

	Total kWh from Coal 2009	Change in Jobs	Change in Energy Costs (millions)	Change in Emissions (lbs)
Ohio	113,711,997,000	-195	-\$491,804	-23,822,663,372
Pennsylvania	105,474,534,000	-181	-\$456,177	-22,096,914,873

Source: EIA and Weinstein et al. (2010)

Table 3: Effects of Displacing Coal with Natural Gas

	Change in Percent income Growth	
	Parameter Estimate	t-value
Total Wells 05-09	2.515E-05	2.11
2001 Log Population	0.084	2.53
2001 Log Employment	-0.086	-2.76
N	67	
R2	0.205	
Adjusted-R2	0.167	

Source: BEA and Pennsylvania DEP Data

Table 4: Income Effects of Drilling

Table 4 shows the regression results for a difference-in-difference for county per-capita income. In this case, the income injected into the economy by the natural gas industry through leases and wages appears to have a significant positive effect on per capita income. These results, along with the employment regression results, verify our previous analysis using matched drilling and non-drilling counties. Drilling seems to have a positive and significant effect on income in drilling counties - but not on employment.

The Benefits and Costs of Natural Gas

Once the realistic expectations of the employment and income effects of shale natural gas development are properly assessed, these impacts can be included when weighing the benefits and costs of shale gas.

The Benefits of Natural Gas:

Other than the income effects and modest employment impacts, additional benefits to natural gas include lower energy prices, natural gas imports, and carbon emissions (especially compared to coal). First, Figure 20 below shows the average levelized cost to produce a kWh. As shown in Table 3, natural gas decreases electricity costs for end users. However, if natural gas prices are too low it will be less economical to pursue shale gas.²⁰

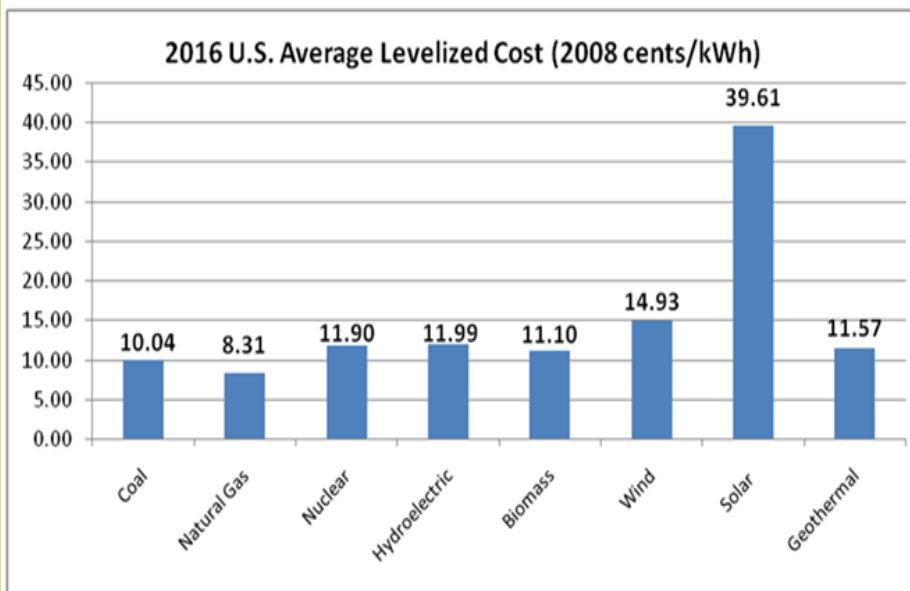
Pennsylvania and Ohio are also good locations to produce natural gas as there is significant natural gas infrastructure in the area and large population and industry centers that require natural gas as shown in Figure 21 on the next page. This proximity further decreases energy costs by reducing transportation costs.

Increasing domestic sources of natural resources are

reducing the demand for foreign gas. The EIA reports that 87% of the natural gas consumed in 2009 was produced domestically. Figure 22 on the next page shows that since 2007, natural gas imports have been declining. However, as already noted, future increases in natural gas production will have very little effect on “energy security” as our largest problem relates to oil imports.

The potential benefits of natural gas have been touted by both the industry and the US EIA. However, the ability to supply the country’s energy’s needs may have been overstated. In the 2011 Annual Energy Outlook, the EIA estimates that 2,543 Tcf of potential natural gas resources could supply the U.S. for approximately 100 years at the 2010 level of annual consumption. However, this does not account for the increasing trends in consumption. Accounting for the trend in consumption from 1974 to 2010, this estimate falls to 65 years. Using a more recent trend from 1986 to 2010, the estimate falls to 52 years. Despite the significant reserves, natural gas energy strategies still suffer from typical fossil fuels problems such as nonrenewability.

The Environmental Benefits and Costs:



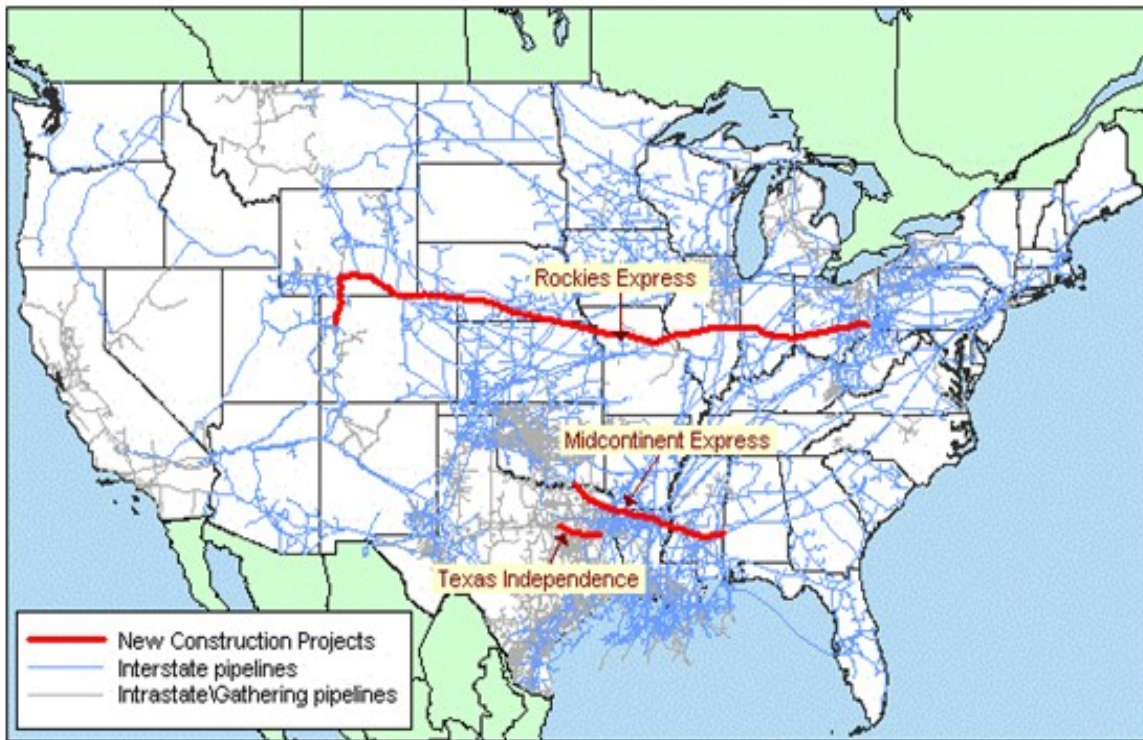
Source: Weinstein et al. (2010) using data from the EIA

Figure 20: Energy production costs by energy source²¹

Natural gas is often viewed as a bridge between a reliance on carbon emitting fossil fuels and an energy industry comprised of some mix of alternative energy sources with far less reliance on foreign energy and carbon emitting energy sources. Figure 23 on page 22 shows the life cycle emissions rates for various sources of electricity generation. Although natural gas emits significantly more carbon than nuclear and alternative energy sources, it does emit far less than coal. Thus, as table 3 showed, switching from coal to natural gas will not only save money on energy costs it will also reduce carbon emissions. Natural gas combustion emits lower levels of carbon dioxide, nitrogen oxide, and sulfur dioxide than both coal and oil. Yet,

20. It should also be noted that a decoupling of natural gas prices from oil prices has realigned markets (Southgate and Daniels, 2011).

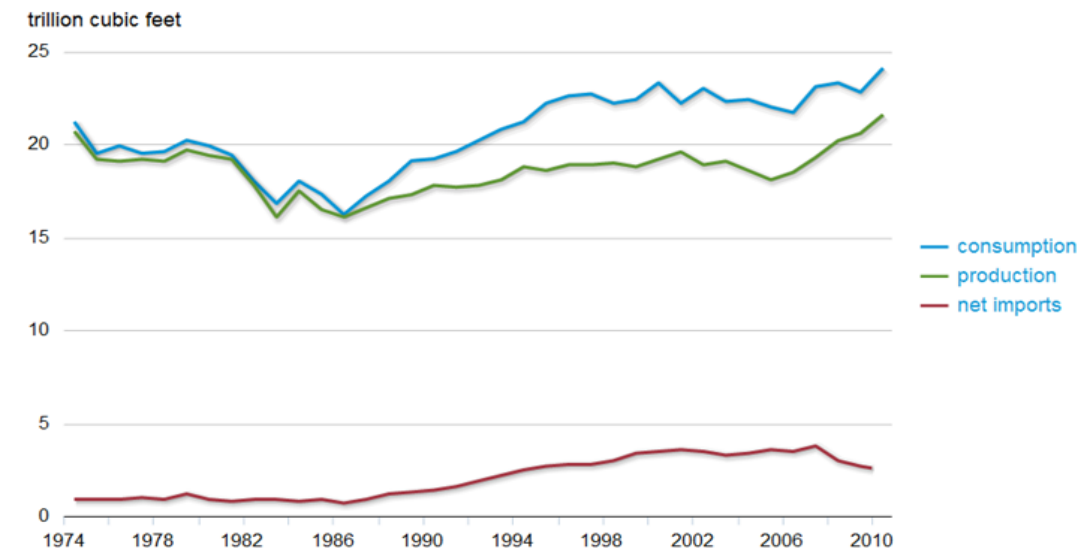
21. The average levelized cost is the present value of all costs including building and operating the plants.



Source: EIA, GasTran Natural Gas Transportation Information System.

Figure 21: Natural Gas Infrastructure

U.S. natural gas consumption, production, and net imports



Source: EIA

Figure 22: Increasing Production Reduces Imports

Howarth et al. (2011) find that the carbon emission benefits of natural gas are less when it extracted using hydraulic fracturing compared to conventional methods because of the water and wastewater transportation.

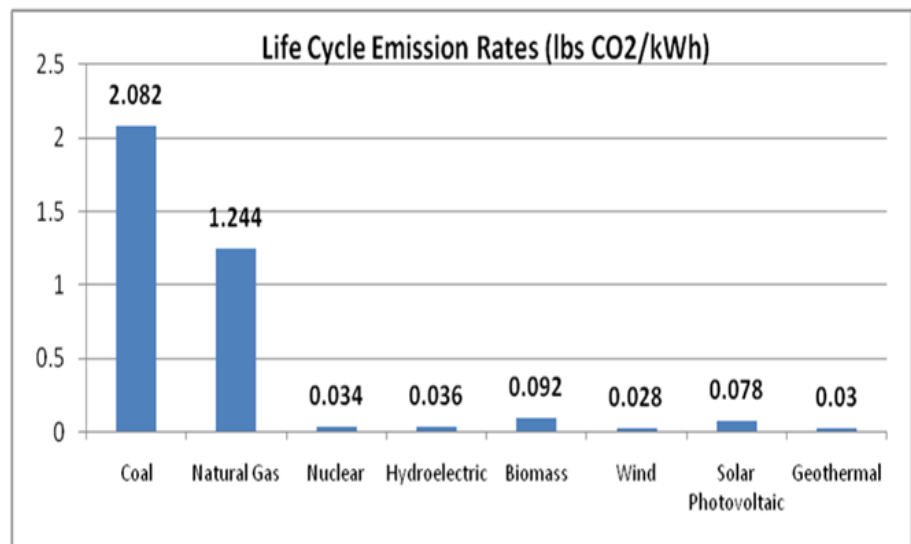
Despite the potential emissions advantages of natural gas, significant concerns have been raised about the environmental impact of natural gas extraction with a Duke University study finding elevated levels of methane in water near drilling sites (Osborn et al., 2011) and the EPA's recent announcement that hydraulic fracturing chemicals polluted water sources in Wyoming (The Associated Press).

The environmental concerns with natural gas have been focused on the hydraulic fracturing process and its impact on water sources. The importance of understanding the hydraulic fracturing process is essential in understanding its potential environmental effects. If cracks aren't able to be controlled or predicted during hydraulic fracturing or somehow disturb the ground, then natural gas or fracturing fluid containing toxic chemicals may shift or migrate to aquifers affecting drinking water. However, hydraulic fracturing typically occurs at depths well below the level of aquifers and drinking water. At thousands of feet below water sources, it is unlikely that hydraulic fracturing would contaminate water sources in Ohio. A 2004 EPA report found that, although fluids migrated unpredictably, hydraulic fracturing did not affect underground drinking water and posed no health risk. Representatives of the natural gas industry have made similar claims that hydraulic fracturing has never contaminated drinking water sources. These claims were used to exempt the natural gas industry from the Clean Water Act and the Safe Drinking Water Act when Congress enacted the 2005 Energy Policy Act.

Although the hydraulic fracturing method of injecting fluids deep below the aquifer level may not be a source of contamination, this level and aquifers themselves must be drilled through. Casing failures in the drilling process may

cause fracturing fluids or natural gas to escape and pollute aquifers and local water sources. There are also concerns over spills that can occur during transport or impoundment failures. Thus, whether hydraulic fracturing has contaminated water sources becomes an issue of semantics as to whether the cause is the actual hydraulic fracturing or the drilling, extracting, and spills. Because of the potential impacts on water sources, it is important to be aware of the location of water sources compared to the location of shale resources. Figures 24 and 25 on the next page show the water resources of the US (aquifers are differentiated by various colors). US water resources and shale resources are clearly geographically overlapping though they are at different depths (including in Ohio and Pennsylvania).

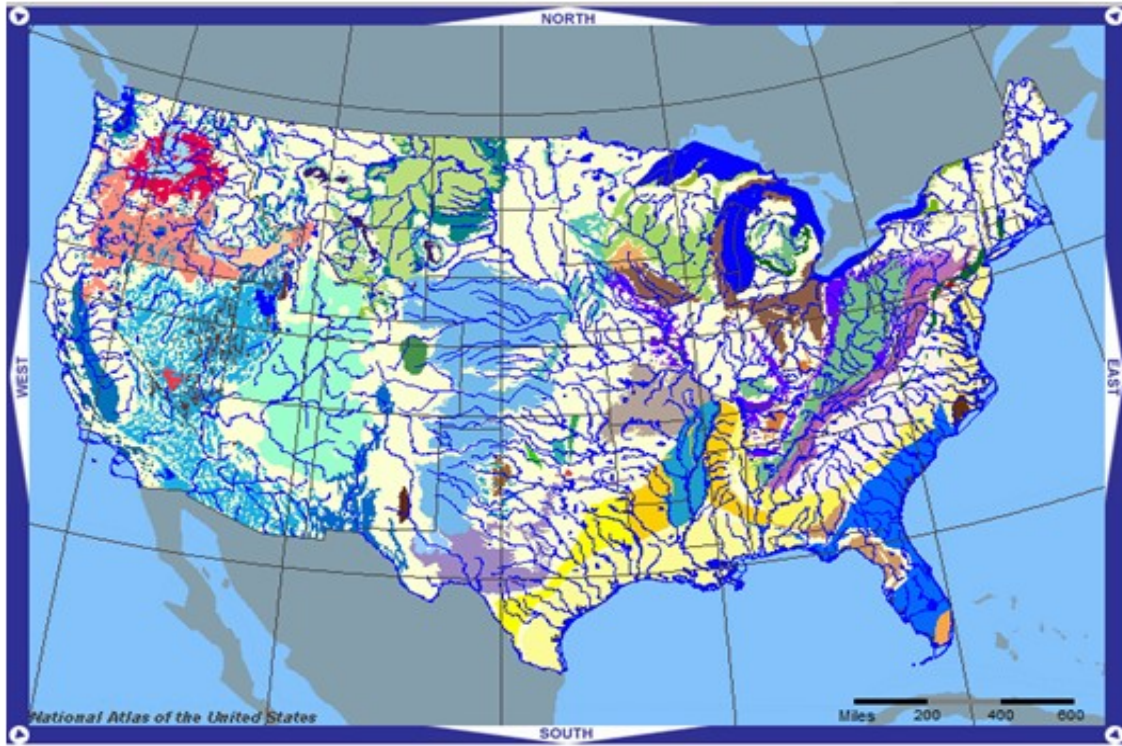
In addition to accidental contamination in the drilling and extraction process, water use and disposal are also concerns. The hydraulic fracturing method requires at least a million gallons of water per well that is combined with chemicals and sand. Sapien (2009) notes that approximately 9 million gallons of wastewater per day were produced from Pennsylvania wells in 2009, and this amount is expected to increase. This water by-product contains elements and chemicals such as cadmium and benzene that are known to cause cancer. There may be other toxic chemicals in the hydraulic fracturing fluid mix though energy companies have continually refused to disclose these chemicals for proprietary reasons. Water byproducts also contain Total Dissolved Solids (TDS) that can make the water five times as salty as



Source: Weinstein et al. (2010) using data from Meier (2002)

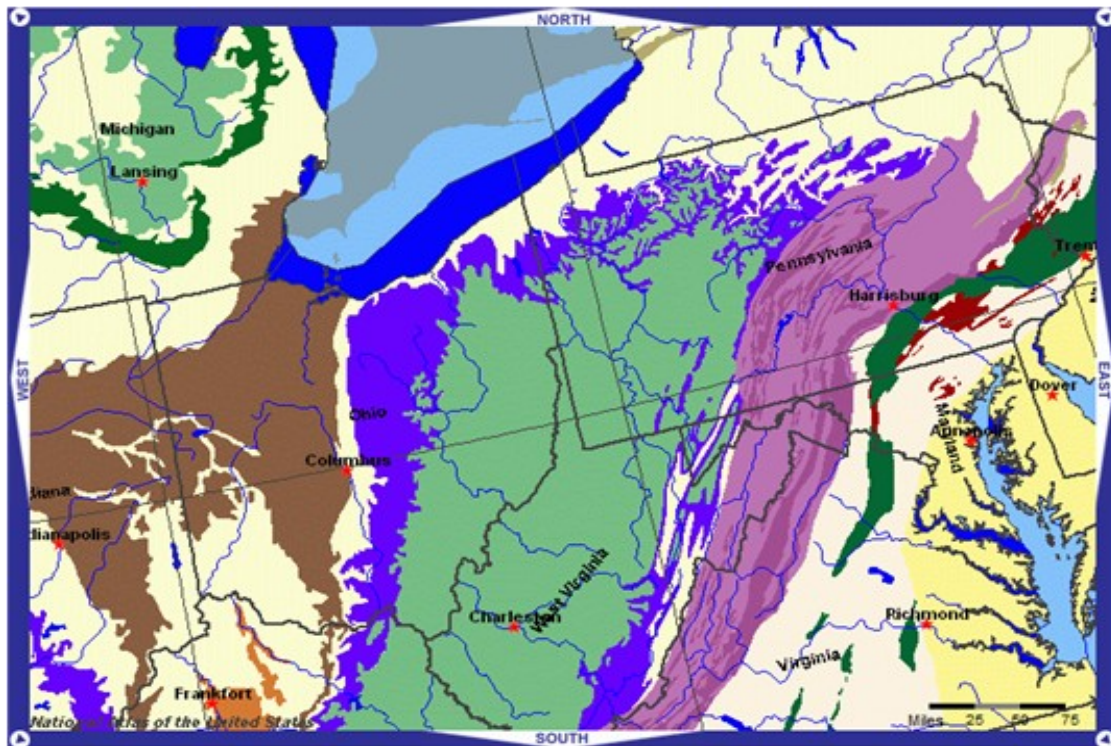
Figure 23: Carbon Emissions by Electricity Source²²

22. Life cycle emissions rates include the total aggregated carbon emissions over the life cycle of the fuel, including extraction, production, distribution, and use.



Source: NationalAtlas.Gov

Figure 24: US Aquifer, Stream, and Waterbed Resources



Source: NationalAtlas.Gov

Figure 25: Ohio and Pennsylvania Aquifer, Stream, and Waterbed Resources

seawater. Although some of this water is left behind and some can be reused, there is still a significant amount that must be treated and disposed. Water byproducts must be stored in either open wells, closed containment wells, or injected back into the ground. Open wastewater wells can lead to air pollution as it evaporates and water contamination if the lining fails, but this method is less expensive than other methods. There are additional air pollution concerns with the increased traffic resulting from water transportation, flaring, etc.

There are also environmental costs in the form of noise pollution. Ohio residents may simply not want to look at or hear natural gas rigs in their backyard or heavy equipment driving through the countryside. Hydraulic fracturing does limit the number of rigs used compared to conventional methods.

The potential environmental impact of hydraulic fracturing on water in Ohio needs to be accounted for when estimating the economic costs of natural gas. Just as the employment and income effects for Ohio were estimated using Pennsylvania as a case study, the potential environmental impacts of hydraulic fracturing and natural gas drilling on Ohio can be approximated by examining incidents in Pennsylvania. Whether the source of contamination is from the migration of fluids and gas underground, drilling or extraction accidents, or improper disposal of water byproducts, it is important to understand what Pennsylvania residents have experienced. After gaining a better understanding of the environmental impacts, then it is important to determine the source of the contamination, how it can be prevented, and whether new regulations are needed to protect the Ohio environment and its drinking water.

Pennsylvania Environmental Concerns:

In 2008, Lustgarten noted that more than 1,000 cases of suspected contamination have been documented in Colorado, New Mexico, Alabama, Ohio, and Pennsylvania. Incidents of contamination have been most publicized in Dimock, PA. Dimock is located in Susquehanna County in northeastern Pennsylvania where natural gas development is most pronounced. Dimock is a struggling rural area with approximately 1,300 residents and nearly 1 in 7 is unemployed. Residents hoped the natural gas industry would turn their economy around. Instead, the controversial documentary *Gasland* contends it environmentally turned it upside down.²³ The documentary begins and ends in Dimock and includes

footage of residents lighting their tap water on fire. After natural gas drilling began in Dimock, Lustgarten notes that several of the residents' wells have exploded. Affected residents now buy water from outside sources. The Pennsylvania Department of Environmental Protection (DEP) believes a casing failure is to blame for the drinking water contamination and is holding Cabot Oil responsible. Cabot Oil has agreed to supply clean water to some of the affected residents and has been required to pay compensation to many residents. In September of 2009, Cabot Oil spilled nearly 8,000 gallons of fracturing fluids that seeped into a nearby creek.

Evidence of fracturing fluid has now been found in drinking water sources including the Monongahela River. In response to these cases and others, the natural gas industry has been quick to label these events as unfortunate but highly unlikely implying that these cases are the result of just a few "bad apples." In some cases they claim methane has always existed in these water sources, but simply went unnoticed until now. Without conducting baseline water testing before drilling, the burden of proof required by the courts in many cases cannot be met to prove otherwise.

The *New York Times* publicized recent peer-reviewed research by Duke University showing an association between drinking water contamination and natural gas extraction. The study by Osborn et al. (2011) conducted research at 68 private water wells in Pennsylvania and New York finding that methane concentrations were 17 times higher for wells near active drilling, with some wells having methane levels requiring "immediate action." However, the study found no evidence of fracturing fluid contamination in these wells. The prevalence and commonality of these incidents, coupled with the devastating impacts, seem to suggest the need for caution. Some chemicals, particularly in the produced water, may be harder for residents to detect than methane, especially when the industry refuses to disclose all of the components of the fracturing fluid mixture. Regardless, it is clear that more information on the environmental impacts of natural gas is needed in deciding any need for further regulations.

Recent EPA Action:

Recognizing the need to further understand the true impacts of natural gas extraction, specifically hydraulic fracturing, Congress directed the EPA to

23. It should be noted that *Gasland* did not undergo the scientific scrutiny of a peer-reviewed journal article and because no baseline testing was conducted in *Gasland* or any research thus far, it is difficult to discern the source of contamination and whether it came from gas industry activity. Hopefully, US EPA research will answer these questions in 2012.

study the impact hydraulic fracturing has on drinking water and groundwater. The EPA (2011) identified seven case studies, three of which are in Pennsylvania, to examine the lifecycle of a well and whether hydraulic fracturing affects drinking water. The EPA will also collect information from computer modeling, laboratories, and other data from the industry, states, and communities. Initial results of this study are expected in late 2012. Hence, it is unlikely that there will be any national regulations in the near future, while Ohio hydraulic fracturing in the Marcellus and Utica has already begun. Until Congress or the EPA acts, the regulation of hydraulic fracturing is left to the states.²⁴

Ohio Environmental Protection:

Because the EPA and Congress have essentially relegated any regulatory authority to the states, this increases the importance of the Ohio EPA and the Ohio Division of Mineral Resources Management (ODNR) for environmental regulations. The Ohio EPA (2011) states that ODNR has primary regulatory authority over natural gas drilling, including the treatment and disposal of wastewater in the hydraulic fracturing process. The Ohio EPA also has water quality certification requirements to help preserve wetlands, streams, rivers, and other water sources. The appendix includes a list of the regulatory authority between ODNR and the Ohio EPA.

The Ohio Farm Bureau's Dale Arnold contends that Ohio has better regulatory authority over the oil and gas industry compared to Pennsylvania. Although the Cuyahoga River fire in 1969 in Cleveland, OH was not associated with fracturing, Scott (2009) notes it was a catalyst not only for Ohio environmental regulations, but also the national Clean Water Act in 1972 and the creation of the US EPA (and Ohio EPA). Dale Arnold reckons that even before the Cuyahoga fire, Ohioans had built a "collective consciousness," learning from past oil and gas industry experiences, preparing themselves for future waves.

Ohio's collected experiences and advanced environmental regulations have certainly left the state better prepared to handle the wastewater produced from hydraulic fracturing than Pennsylvania. Much of the wastewater from Pennsylvania comes to Ohio injection wells. Hunt (2011) notes that in June of 2010, Ohio quadrupled out-of-state fees to limit brine coming in from Pennsylvania and other states

while anticipating the increased disposal needs of Ohio's own burgeoning natural gas industry. Despite the increased prices, nearly half of the brine in Ohio injection wells came from Pennsylvania after its officials banned 27 treatment plants from dumping brine into streams. This highlights the importance of Ohio properly addressing the issue of wastewater.

Ohio has made strides in environmental regulations through the drilling permitting process. Permits or "frac tickets" are required for gas companies planning on using hydraulic fracturing to extract natural gas. A frac ticket requires that companies disclose the chemicals used in the fracturing fluid. If a spill or casing failure should occur, Ohio will know many of the possible contaminants for testing. Ohio's permitting also allows residents to more easily prove their water has been contaminated with fracturing fluid.

Because many of the residents that will be most affected by shale gas development are farmers, the Ohio Farm Bureau is advising farmers and residents on the leasing process and is recommending that residents establish independent baseline water and soil quality measures that have been so notably missing from Pennsylvania and elsewhere. In addition, it is now standard practice in Ohio for gas companies to do their own baseline testing on all residents' water within 3,000 yards of the drilling site.

Even with better regulations, accidents may happen. Lustgarten (2009) recounts a 2007 incident of a house explosion in Bainbridge, OH. In a later report, ODNR found that a faulty concrete casing failure from a nearby natural gas well caused methane to be pushed into an aquifer during hydraulic fracturing, which then found its way into the plumbing, building up in the basement of the house.

The Cuyahoga fire itself and other serious environmental incidents have a more profound impact than just on the environment. Congressmen Louis Stokes said in regards to the Cuyahoga fire, "It portrayed a totally different image of Cleveland than the image of a productive, progressive city that was making news of a progressive nature" (as quoted in Scott, 2009). The lessons of the Cuyahoga fire resonate for natural gas development. The negative impacts on the environment can affect communities in lasting ways that cannot be exactly quantified but still require consideration.

24. In 2009, members of Congress introduced the Fracturing Responsibility and Awareness of Chemicals Act, also called the "Frac Act," to undo the natural gas industry's exemption from the Safe Drinking Water Act and require the industry to disclose the chemicals used in the fracturing process. Though reintroduced in March of 2011, it is not expected to pass.

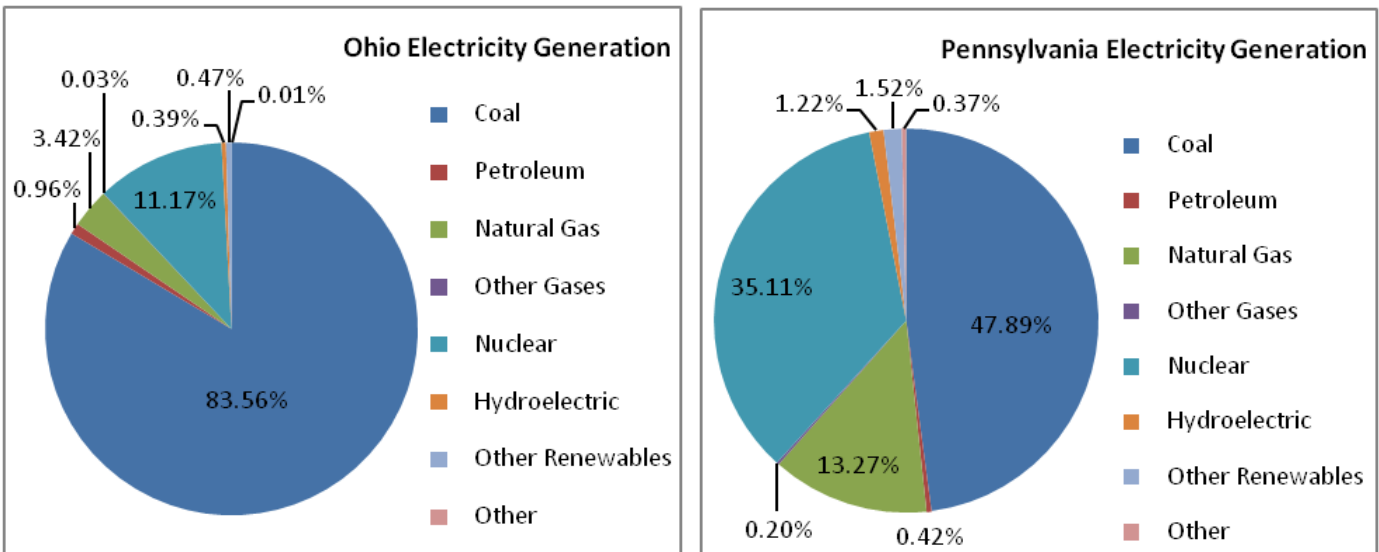
Conclusion

Hydraulic fracturing has made natural gas extraction possible and more productive in shale resources that were previously deemed uneconomical. This has brought a new wave of natural gas extraction to Ohio and other areas. However, recent experiences with hydraulic fracturing have also opened a new debate about the costs and benefits of natural gas extraction. Gary Walzer, Principle Engineer at EMTEC, states that natural gas has the potential to be a substantial source of domestic energy that is cleaner than coal with lower emissions. This has the potential to decrease US reliance on coal. Compared to Pennsylvania, Ohio clearly has a less diversified energy portfolio that relies heavily on carbon emitting coal. Based on electricity generation alone, Ohio is emitting significantly more carbon than Pennsylvania. Natural gas could be a significant first step for Ohio to diversify its energy portfolio and reduce carbon emissions.

Compared to coal, natural gas is not only cleaner but also less expensive to produce electricity. Producing energy in close proximity to where it is needed further lowers energy prices for consumers and industry. Unlike alternative energy, there are market forces pushing for the production of natural gas without the use of inefficient subsidies, though all of the social costs of natural gas (and coal) are not sufficiently priced. Low natural gas prices provide evidence that it is highly efficient for producing electricity. This efficiency is one reason why natural gas is associated with fewer jobs than coal—but

the lower costs make the rest of the economy more competitive.

Does all of this also mean that natural gas will create significant numbers of job for Ohioans? Previous studies on the economic impacts of natural gas appear to have widely overstated the economic impacts. This is not surprising, as these studies are typically industry-funded and industry-funded studies are usually not the best sources of information for economic effects (regardless of the industry). One reason for the overstatement is the energy industry is generally very capital intensive. Alan Krueger, Chief Economist and Assistant Secretary for Economic Policy at the US Department of Treasury stated in 2009, “The oil and gas industry is about 10 times more capital intensive than the US economy as a whole... suggesting these tax subsidies are not effective means for domestic job creation” (US Department of Treasury). The energy industry as a whole also does not account for a significant share of employment. Even if the natural gas industry experiences significant job growth, its employment share is too small to have any significant effect on unemployment rates and on the economy (with the exception of remote rural areas such as in rural Western North Dakota). Previous studies on the economic impacts also fail to account for the displacement effects that the natural gas industry will have on other industries. Finally, from a national perspective greater natural gas production will displace other fossil fuels and their workers as they are no longer needed, in



Source: US EIA

Figure 26: 2009 Electricity Generation Profiles

particular coal.

We use Pennsylvania as a case study to estimate the employment effects of drilling that Ohio can realistically expect. Our analysis shows the employment effects of natural gas are modest given the size of the Ohio and Pennsylvania economy. We show this through (1) an assessment of impact analysis, (2) by comparing drilling counties with similarly matched non-drilling counties in Pennsylvania, (3) statistical regressions on the entire state of Pennsylvania, (4) employment comparisons with North Dakota's Bakkan shale region, and (5) an examination of the employment life cycle effects of natural gas and coal per kilowatt of electricity. Our results are not unexpected as the economic literature has long pointed to the adverse effects of natural resource development through phenomenon such as the "natural resources curse" and Dutch Disease. Likewise, a recent Cornell University study found similar overstatements by the oil industry in terms of job forecasts for the Keystone XL pipeline (Cornell University ILR School Global Labor Institute, 2011). On the other hand, our approaches suggest that natural gas activity will increase per-capita income. We expect this is primarily among landholders receiving royalties/lease payments and through higher wages in the industry. Thus, we expect a short-term infusion of income in affected economies.

As Christopherson and Rightor (2011) point out, it is important to realize these are fairly short-term estimates and may still not account for the cycle of the natural resource boom. The initial boom causes competition for labor in the short-term, bidding up wages. This makes the area less competitive and "crowds out" other sectors, especially those that rely on low cost labor such as agriculture and tourism. As housing prices are bid up, this will also further displace low-income workers. In the long-run, the business climate may suffer as there are fewer businesses that are unrelated to the oil and gas industry, which makes the local economy less diverse and more vulnerable to economic shocks. Our advice to counties experiencing drilling activity is to ensure they properly pay for infrastructure needs upfront, place monies in reserves for after the boom, and build up local

assets such as schools in order to produce lasting benefits from energy development.

Finally, the environmental costs of natural gas need to be realistically addressed by the industry and regulators. Although natural gas can reduce carbon emissions compared to coal and other fossil fuels, there are concerns about its effect on drinking water. Because Ohio has been able to learn from Pennsylvania's experiences with the oil and gas industry, Ohio seems better prepared to deal with the environmental risks. Nevertheless, a realistic assessment of the environmental costs of natural gas should also include the environmental opportunity cost of natural gas. Natural gas mainly displaces coal, which emits even more carbon and also has additional environmental and safety concerns. A Clean Air Task Force report unequivocally states that "coal irreparably damages the environment." Coal poses significant health risks to both miners and nearby residents. Despite the number of years the US has been extracting coal, there are still significant issues with its waste products. Most recently on Oct. 31, 2011 a bluff collapse caused coal ash to be spilled into Lake Michigan (Jones and Behm, 2011). In 2008, the *New York Times* reported that experts called the Tennessee ash flood that dumped over 1.1 billion gallons of coal ash waste "one of the largest environmental disasters of its kind" (Dewan, 2008). We are not understating the environmental costs of natural gas, but rather putting it into perspective in relation to the environmental costs of coal, which is natural gas's main competitor.

Although we should not expect natural gas to be a big job creator, there are significant benefits to producing natural gas that are getting lost in the hype of job creation. Raising expectations that natural gas will not be able to meet is setting Ohio residents up to be disappointed. The true benefits of natural gas need to be highlighted while putting the costs into perspective. Likewise, Ohio needs to plan today about how to make some of the gains from the energy boom permanent. Among many things, this will require innovative policies and funding models to ensure that infrastructure is paid for today and there is adequate funding to maintain that infrastructure in the future.

References

- American Chemistry Council. "Shale Gas and New Petrochemicals Investment: Benefits for the Economy, Jobs, and US Manufacturing." (Mar., 2011).
- Arnold, Dale. Telephone interview. (July 20, 2011)
- Arnold, Dale. Telephone interview. (Oct 25, 2011)
- The Associated Press. "E.P.A. Implicates Fracking in Pollution." The New York Times, (Dec. 8, 2011). http://www.nytimes.com/aponline/2011/12/08/business/AP-US-Fracking-Groundwater-Pollution.html?_r=1&hp
- Barth, Jannette M. and JM Barth & Associates, Inc. "Unanswered Questions about the Economic Impact of Gas Drilling in the Marcellus Shale: Don't Jump to Conclusions." (Mar., 2010)
- Biello, David. "What the Frack? Natural Gas from Subterranean Shale Promises U.S. Energy Independence- With Environmental Costs." *Scientific American*. March 30, 2010 <http://www.scientificamerican.com/article.cfm?id=shale-gas-and-hydraulic-fracturing>
- Clean Air Task Force. "Cradle to Grave: The Environmental Impacts from Coal." (Jun., 2001) http://www.catf.us/resources/publications/files/Cradle_to_Grave.pdf
- Christopherson, Susan and Ned Rightor. "A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale." Working Paper (May, 2011) http://www.greenchoices.cornell.edu/downloads/development/marcellus/Marcellus_SC_NR.pdf
- Considine, Timothy and Robert Watson and Seth Blumsack. "The Pennsylvania Marcellus Natural Gas Industry: Status, Economic Impacts and Future Potential." (Jul., 2011).
- "The Economic Impacts of Pennsylvania Marcellus Shale Natural Gas Play: An Update." (May, 2010)
- Considine, Timothy and Robert Watson, Rebecca Entler, and Jeffrey Sparks. "An Emerging Giant: Prospects and Economic Impacts of Developing the Marcellus Shale Natural Gas Play." (Jul., 2009)
- Cornell University ILR School Global Labor Institute. "Pipe Dreams? Jobs Gained, Jobs Lost by the Construction of Keystone XL." (Sept., 2011). http://www.ilr.cornell.edu/globallaborinstitute/research/upload/GLI_KeystoneXL_Reportpdf.pdf
- Dewan, Shaila. "Tennessee Ash Flood Larger than Initial Estimate." The New York Times (Dec. 26, 2008). <http://www.nytimes.com/2008/12/27/us/27sludge.html>
- Dezember, Ryan and Ben Lefebvre. "Producers, Refiners Sniff Opportunity in Rust Belt Oil Shale." The Wall Street Journal. (Aug. 16, 2011). <http://online.wsj.com/article/0,,SB10001424053111903392904576512671360899338,00.html>
- Gasland. Dir. Josh Fox 2010
- Gearino, Dan. "Energy-industry Study: Oil, Gas Could Add 200,000 New Jobs in Ohio Over 4 Years." The Columbus Dispatch. September, 20, 2011. <http://www.dispatch.com/content/stories/business/2011/09/20/oil-gas-industry-could-boom-in-ohio.html> Accessed Oct 5, 2011
- "Utica-Shale Wells Going Gangbusters." The Columbus Dispatch. Sept. 29, 2011. <http://www.dispatch.com/content/stories/business/2011/09/29/utica-shale-wells-going-gangbusters.html>
- "Kasich Might Push State Fleet to Use Natural Gas. Sept. 23, 2011. "<http://www.dispatch.com/content/stories/business/2011/09/23/kasich-might-push-state-fleet-to-use-natural-gas.html>
- Howarth, Robert W., and Renee Santoro and Anthony Ingraffea. "Methane and the Greenhouse-Gas Footprint of Natural Gas from Shale Formations." *Climatic Change*, Vol. 106, No. 4 (2011), pp. 679-690.
- Hunt, Spencer. "Ohio Taking in Flood of Pennsylvania's Toxic Brine Disposal." The Columbus Dispatch. (Jun. 20, 2011) <http://www.dispatch.com/content/stories/local/2011/06/20/ohio-taking-in-flood-of-pennsylvanias-toxic-brine-for-disposal.html>
- Hughes, David W. (2003) "Policy Uses of Economic Multiplier and Impact Analysis." *Choices* 2nd Quarter. Available at: <http://www.choicesmagazine.org/2003-2/2003-2-06.htm>.
- IHS Global Insight (2009) *The Contributions of the Natural Gas Industry to the U.S. National and State Economies*. Lexington, MA.
- IMPLAN. Explaining the Type SAM multiplier. Downloaded on November 14, 2011 from: http://implan.com/v3/index.php?option=com_docman&task=doc_download&gid=137&Itemid=138
- Irwin, Elena G., Andrew M. Isserman, Maureen Kilkenny, and Mark D. Partridge. (2010) "A Century of Research on Rural Development and Regional Issues." *American Journal of Agricultural Economics* 92 (2): 522-553; doi: 10.1093/ajae/aaq008.

- Jackson, Robert B. and Brooks Rainey Pearson, Stephen G. Osborn, Nathaniel R. Warner, and Avner Vengosh. "2011 Research and Policy Recommendations for Hydraulic Fracturing and Shale-Gas Extraction." Center on Global Change, Duke University, Durham, NC. <http://www.nicholas.duke.edu/cgc/HydraulicFracturingWhitepaper2011.pdf>
- James, Alex and David Aadland. "The Curse of Natural Resources: An Empirical Investigation of U.S. Counties." *Resource and Energy Economics*, Vol. 33, No. 2 (May, 2011), pp. 440-453.
- Jones, Meg and Don Behm. "Bluff Collapse at Power Plant Sends Dirt, Coal Ash into Lake." *Milwaukee Journal Sentinel*. (Oct. 31, 2011) <http://www.jsonline.com/news/milwaukee/authorities-investigate-bluff-collapse-at-we-energies-plant-132929538.html>
- Kargbo, David M. and Ron G. Wilhelm and David J. Campbell. "Natural Gas Plays in the Marcellus Shale: Challenges and Potential Opportunities." *Environmental Science & Technology*, Vol. 44 (2010), pp. 5679-5684.
- Kelsey, Timothy W. and Martin Shields, James Ladlee, and Melissa Ward. "Economic Impacts of Marcellus Shale in Pennsylvania: Employment and Income in 2009." Marcellus Shale Education & Training Center. (Aug., 2011) <http://www.marcellus.psu.edu/resources/PDFs/Economic%20Impact%20of%20Marcellus%20Shale%202009.pdf>
- Kilkenny, Maureen and Mark D. Partridge. (2009). "Export Sectors and Rural Development." *American Journal of Agricultural Economics* (91): 910-929.
- Kleinhenz and Associates. "Ohio's Natural Gas and Crude Oil Exploration and Production Industry and the Emerging Utica Gas Formation." (Sept., 2011)
- Leech, Andrew. "Who Needs Pipelines, the Oil Bucket Brigade is Ready." *Globe and Mail Blog*. (Dec. 12, 2011) <http://www.theglobeandmail.com/report-on-business/economy/economy-lab/the-economists/who-needs-pipelines-the-oil-bucket-brigade-is-ready/article2268015/>
- Lustgarten, Abraham. "Buried Secrets: Is Natural Gas Drilling Endangering U.S. Water Supplies?" *ProPublica*. (Nov. 13, 2008) <http://www.propublica.org/article/buried-secrets-is-natural-gas-drilling-endangering-us-water-supplies-1113>
- "Officials in Three States Pin Water Woes on Gas Drilling." *ProPublica* (Apr. 26, 2009) <http://www.propublica.org/article/officials-in-three-states-pin-water-woes-on-gas-drilling-426>
 - "Frack Fluid Spill in Dimock Contaminates Stream, Killing Fish." *ProPublica* (Sept. 21, 2009) <http://www.propublica.org/article/frack-fluid-spill-in-dimock-contaminates-stream-killing-fish-921>
- NationalAtlas.gov. <http://www.nationalatlas.gov/mapmaker?AppCmd=CUSTOM&LayerList=LakesRivers&visCats=CAT-hydro.CAT-hydro>
- Oakland, William H. and Frederick T. Sparrow and H. Louis Stettler III. "Ghetto Multipliers: A Case Study of Hough." *Journal of Regional Science*, Vol. 11, No. 3 (Dec., 1971), pp. 337-345.
- Ohio Environmental Protection Agency. "Drilling for Natural Gas in the Marcellus and Utica Shales: Environmental Regulatory Basics." (Jul., 2011) <http://www.epa.ohio.gov/portals/0/general%20pdfs/generalshale711.pdf>
- Ohio Department of Natural Resources. "Marcellus Shale Well Activity Since 2006." (Aug. 25, 2011) http://www.dnr.state.oh.us/Portals/10/Energy/Marcellus/MarcellusWellsActivity_08252011_Version2.pdf
- "Utica Shale Well Activity Since 2006." (Aug. 25, 2011) http://www.dnr.state.oh.us/portals/10/Energy/Utica/UticaWellsActivity_08252011.pdf
- Osborn, Stephen G. and Avner Vengosh, Nathaniel R. Warner, and Robert B. Jackson. "Methane Contamination of Drinking Water Accompanying Gas-Well Drilling and Hydraulic Fracturing." *PNAS*, Vol. 108, No. 20 (May, 2011), pp. 8172-8176. <http://www.nicholas.duke.edu/cgc/pnas2011.pdf>
- Papayrakis, Elissaios and Reyer Gerlagh. "Resource Abundance and Economic Growth in the U.S." *European Economic Review*, Vol. 51, No.4 (May, 2007), pp. 1011-1039.
- Partridge, Mark D. and Dan S. Rickman. "The Dispersion of U.S. State Unemployment Rates: The Role of Market and Nonmarket Factors." *Regional Studies*, Vol. 31 (1997a), pp. 593-606.
- "U.S. State Unemployment Differentials in the 1990s: The Role of Equilibrium Factors Versus Differential Employment Growth." *Growth and Change*, Vol. 28 (1997b), pp. 360-379.
- Pennsylvania Department of Environmental Protection. "Wells Drilled by County Summary 2000-2011." (Oct., 2011) <http://www.dep.state.pa.us/dep/deputate/minres/oilgas/2000-2011Well%20DrilledbyCountySummary.htm>
- ProPublica. "What is Hydraulic Fracturing." <http://www.propublica.org/special/hydraulic-fracturing-national>

- Rioux, J.J. and J.A. Schofield. "Economic Impact of a Military Base on its Surrounding Economy: The Case of CFB Esquimalt, Victoria, British Columbia." *Canadian Journal of Regional Science*, Vol. 13, No. 1 (1990), pp. 47-61.
- Ruggles, Steven and J. Trent Alexander, Katie Genadek, Ronald Goeken, Matthew B. Schroeder, and Matthew Sobek. *Integrated Public Use Microdata Series: Version 5.0* [Machine-readable database]. Minneapolis: University of Minnesota, 2010.
- Sapien, Joaquin. "With Natural Gas Drilling Boom, Pennsylvania Faces an Onslaught of Wastewater." *Pro-Publica* (Oct. 4, 2009). <http://www.propublica.org/article/wastewater-from-gas-drilling-boom-may-threaten-monongahela-river>
- Scott, Michael. "Cuyahoga River Fire 40 Years Ago Ignited an Ongoing Cleanup Campaign." *The Plain Dealer*. June 22, 2009. http://www.cleveland.com/science/index.ssf/2009/06/cuyahoga_river_fire_40_years_a.html
- Soraghan, Mike. "Study Finds Methane Contamination Rises Near Shale Gas Wells." *The New York Times*. (May 9, 2011) <http://www.nytimes.com/gwire/2011/05/09/09greenwire-study-finds-methane-contamination-rises-near-s-87464.html?pagewanted=all>
- Southgate, Douglas. Personal Interview (July 14, 2011).
- Southgate, Douglas and Jeffrey Daniels. "Shale Development in Ohio: Utica and Marcellus, Liquid Hydrocarbons and Gas." (Oct., 2011).
- Stabler, Jack C. and M. Rose Olfert. "Community Level Multipliers for Rural Development Initiatives." *Growth and Change*, Vol. 25, No. 4 (Oct., 1994), pp. 467-486.
-*Saskatchewan's Communities in the 21st Century: from Places to Regions*. Regina, SK: Canadian Plains Research Centre, University of Regina. (2002)
- US Department of the Treasury. "Statement of Alan B. Krueger Assistant Secretary for Economic Policy and Chief Economist, US Department of Treasury Subcommittee on Energy, Natural Resources, and Infrastructure." (Sept., 2009) <http://www.treasury.gov/press-center/press-releases/Pages/tg284.aspx>
- US Energy Information Administration. "Annual Energy Outlook 2011." http://www.eia.gov/neaic/speeches/newell_12162010.pdf
- "The Geology of Natural Gas Resources." Feb 14, 2011. <http://www.eia.gov/todayinenergy/detail.cfm?id=110>
 - "What is Shale Gas and Why is it Important?" August 4, 2011. http://www.eia.gov/energy_in_brief/about_shale_gas.cfm
 - "Natural Gas Year-In-Review 2009." July, 2010. http://eia.doe.gov/b1d.biz/pub/oil_gas/natural_gas/feature_articles/2010/ngvir2009/ngvir2009.html
 - "Short-Term Energy Outlook." (Sept., 2011) http://205.254.135.24/steo/steo_full.pdf
 - "U.S. Natural Gas Imports Fall for Third Year in a Row." <http://www.eia.gov/todayinenergy/detail.cfm?id=770>
 - "Natural Gas Consumption by End Use." http://205.254.135.24/dnav/ng/ng_cons_sum_dcu_nus_a.htm
- US Environmental Protection Agency. "Hydraulic Fracturing." Accessed 5 Oct 2011. <http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/index.cfm>
- "Hydraulic Fracturing Research Study." (Jun., 2010) <http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf>
- Vardon, Joe. "Kasich Talks of Renewable Energy's Value but Hints at Tweaking State Rule." *The Columbus Dispatch*. Sept. 22, 2011. <http://www.dispatch.com/content/stories/business/2011/09/22/realism-on-renewable-energy.html>
- Walzer, Gary. Phone Interview (July 20, 2011).
- Weinstein, Amanda L. and Mark D. Partridge and J. Clay Francis. "Green Policies, Climate Change, and New Jobs: Separating Fact from Fiction." *Swank Program in Rural-Urban Policy Summary and Report* (Jun., 2010).
- Wilson, Holton J. "Impact Analysis and Multiplier Specification." *Growth and Change*, Vol. 8, No. 3 (Jul., 1977), pp. 42-46.

Appendix 1: County Comparison Mining (blue) vs. Non-Mining (green)

See notes to figures 15-18 for more details. Southern drilling counties include Washington, Greene, and Fayette. Southern non-drilling counties include Franklin, Perry, and Cumberland. Northeastern drilling counties include Tioga, Bradford, and Susquehanna. Northeastern non-drilling counties include Union, Columbia, and Carbon.

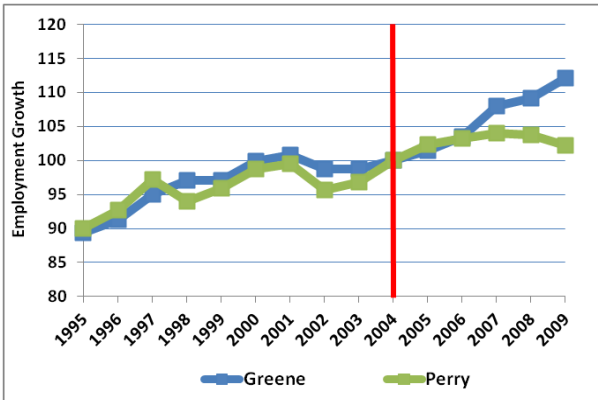


Figure 27: Employment Growth Comparison Greene vs. Perry

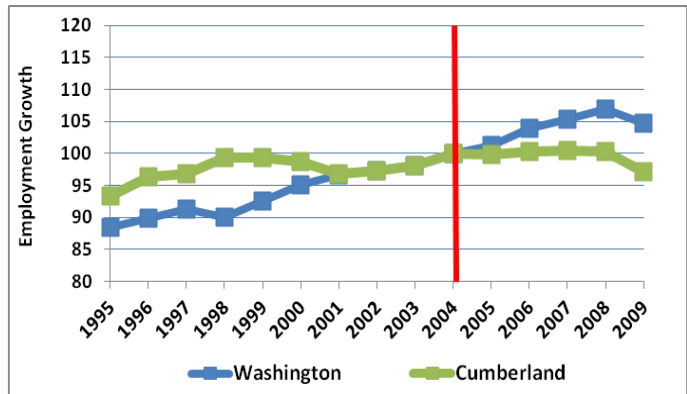


Figure 28: Employment Growth Comparison Washington vs. Cumberland

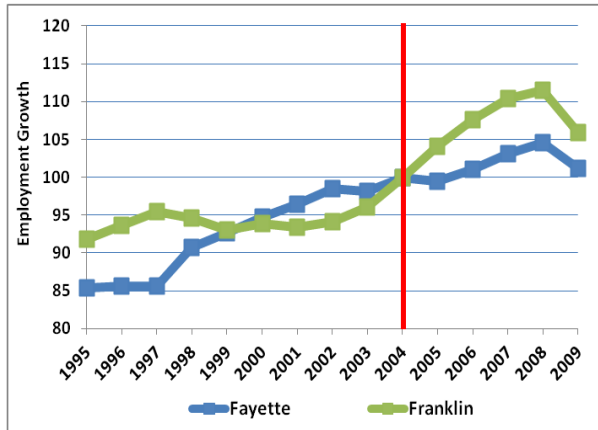


Figure 29: Employment Growth Comparison Fayette vs. Franklin

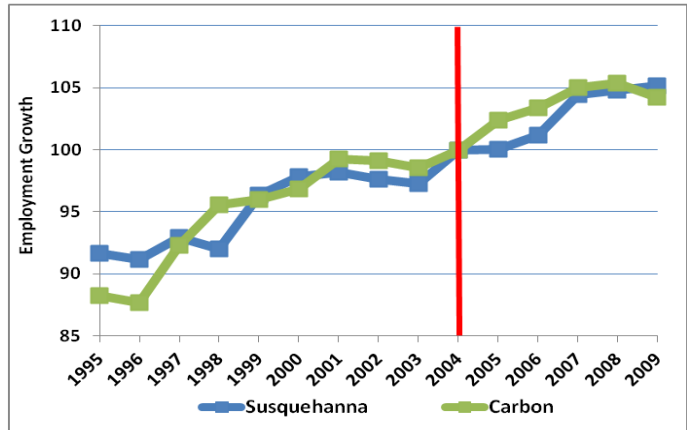


Figure 30: Employment Growth Comparison Susquehanna vs. Carbon

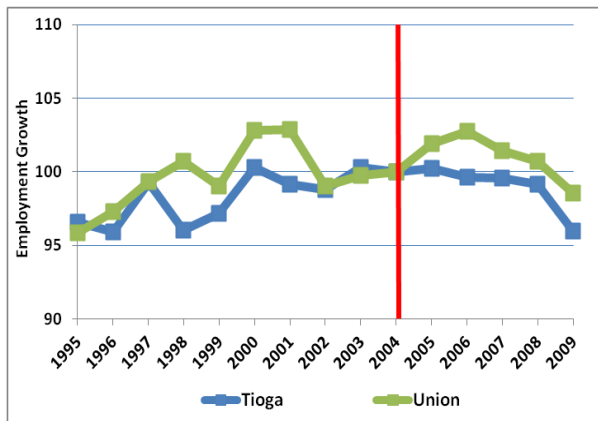


Figure 31: Employment Growth Comparison Tioga vs. Union

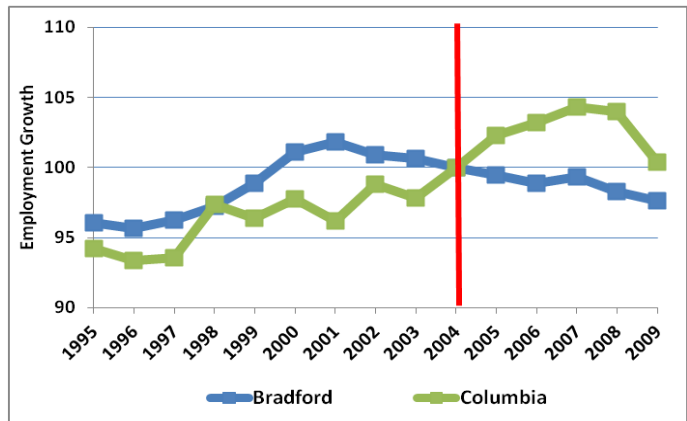


Figure 32: Employment Growth Comparison Bradford vs. Columbia

Appendix 1: County Comparison Mining (blue) vs. Non-Mining (green)

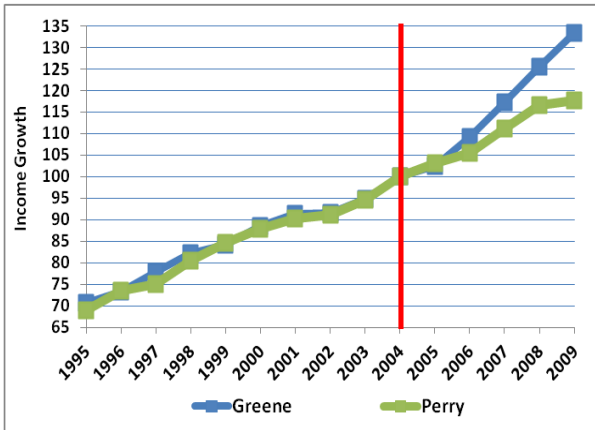


Figure 33: Per Capita Income Growth Comparison Greene vs. Perry

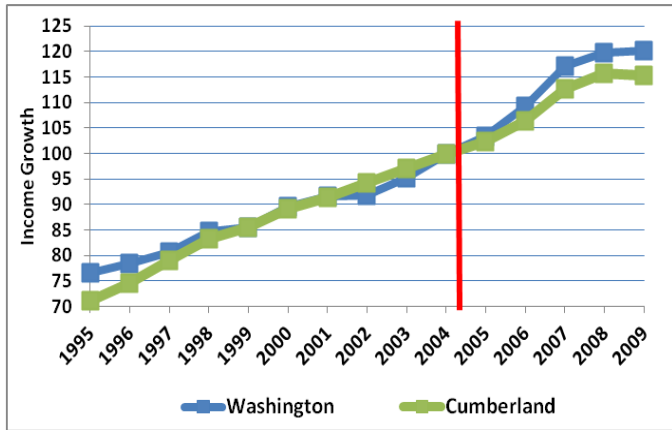


Figure 34: Per Capita Income Growth Comparison Washington vs. Cumberland

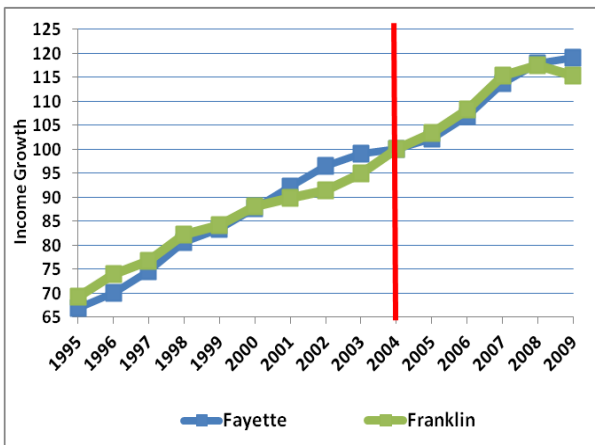


Figure 35: Per Capita Income Growth Comparison Fayette vs. Franklin

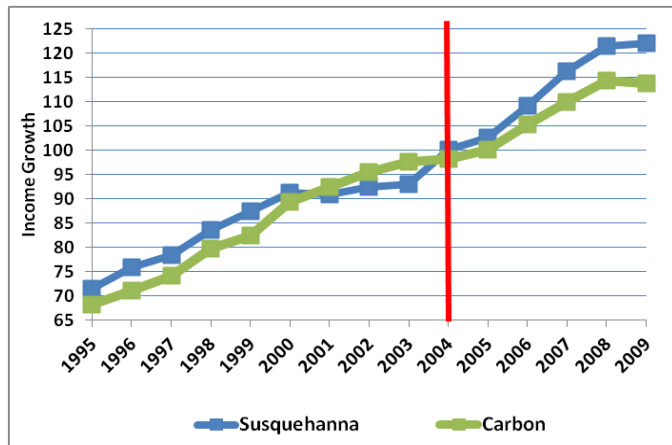


Figure 36: Per Capita Income Growth Comparison Susquehanna vs. Carbon

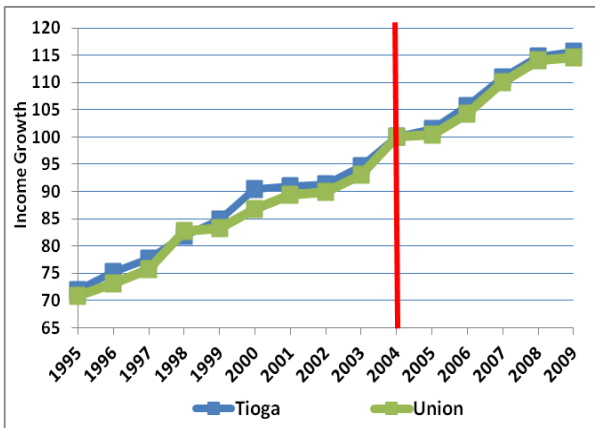


Figure 37: Per Capita Income Growth Comparison Tioga vs. Union

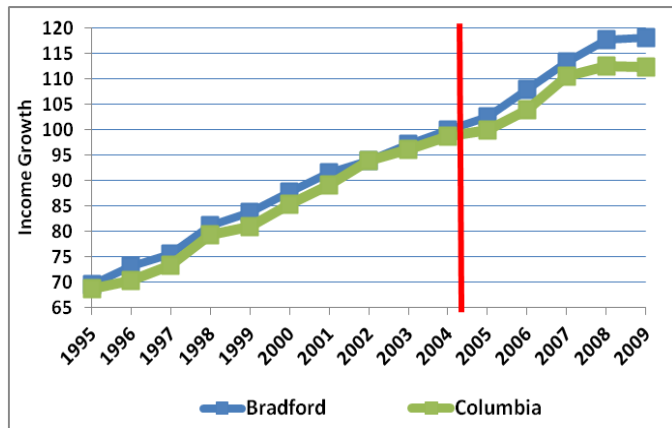


Figure 38: Per Capita Income Growth Comparison Bradford vs. Columbia

Appendix 2: Statistical Methodology

In 2005, drilling began in Pennsylvania in a number of counties with natural gas potential due to the location of resources in the Marcellus shale. The choice of county to develop shale gas was based on the random occurrence of natural resources and not prior economic conditions. However, there may be other inherent county differences between drilling and non-drilling counties. For example, counties with drilling tend to be rural. Likewise, counties tend to have many factors that influence their economic growth such as the quality of its government, distance to urban centers, and educational and demographic attributes of the population. These factors are either constant or change very slowly. We treat these as county fixed effects on county growth.

We want to measure the economic impacts of drilling. Equation 2 shows the impact of the number of wells on the percent employment growth (Y_{it}) for county i in period 1 (2005-2009). However, the empirical estimation of this impact would not be able to account for county fixed effects (C_i). This could bias the estimates of the impact of drilling by omitting relevant variables that differentiate drilling counties from non-drilling counties. Thus, equation 3 estimates the impact of drilling since 2005 on the difference in employment growth between period 1 and period 0 (2001-2005). The county fixed effect is differenced out and thus there should not be omitted variable bias.

Table 5 shows the results of this estimation using the total number of well drilled since 2005. We also include additional controls to better account for differences in the way larger or wealthier counties may have reacted to shale development, or more importantly, how wealthier or more urban counties were differentially affected by effects of the housing bubble/bust and the Great Recession. Using the total number of wells parameter estimate, Table 5 shows that drilling has a small and statistically insignificant impact on percent employment growth.

$$Y_{i0} = \beta_0 + \beta_1(\text{Number of Wells})_{i0} + C_i + \varepsilon_{i0} \quad (1)$$

$$Y_{i1} = \beta_0 + \beta_1(\text{Number of Wells})_{i1} + C_i + \varepsilon_{i1} \quad (2)$$

$$Y_{i1} - Y_{i0} = \beta_0 + \beta_1(\Delta \text{ Number of Wells}) + \varepsilon_i \quad (3)$$

A similar method is used to empirically estimate the impact of drilling on per capita income with results presented Table 6. In this case, drilling has a statistically significant impact on percent per capita income growth.

2005-09 Percent Employment Growth Minus 2001-05 Percent Employment Growth	Parameter Estimate	t-value
	Difference in Employment Change	
Total Wells 05-09	1.769E-05	1.14
2001 Log Population	0.023	2.64
2001 Log Per Capita Income	-0.096	-1.55
N	67	
R2	0.118	
Adjusted-R2	0.076	

Table 5: Impact of drilling on employment

2005-2009 Percent Income Growth Minus 2001-05 Percent Income Growth	Parameter Estimate	t-value
	Difference in Income Change	
Total Wells 05-09	2.515E-05	2.11
2001 Log Population	0.084	2.53
2001 Log Employment	-0.086	-2.76
N	67	
R2	0.205	
Adjusted-R2	0.167	

Table 6: Impact of drilling on income

Another method to develop a counterfactual to compare how drilling counties would have done if there was no drilling is to use a difference in difference approach. The difference in differences approach treats drilling as a treatment in a natural experiment. The difference in differences estimates the causal effect of the difference between the treatment and control group before and after treatment (drilling). This is shown below in equation 4 where $i=0$ represents non-drilling counties and $i=1$ represents drilling counties; $t=0$ is still the first time period (2001-2005) and $t=1$ is the second time period (2005-2009).

$$[E(Y_{11}) - E(Y_{01})] - [E(Y_{10}) - E(Y_{00})] \quad (4)$$

To measure the impact of drilling on the employment growth of county i in time period t (Y_{it}), a control group needs to be established (non-drilling counties). This is further expanded in equation (5). The main effect of

Appendix 2: Statistical Methodology

the treatment group, β_1 controls for the difference between the treatment and control in period 0. The main effect of the second period, β_2 controls for the difference between the effects of the second period compared to the first period. The parameter of interest, β_3 estimates equation 4: the impact of the number of wells had on counties since drilling began in 2005. Through asymptotics, it can be shown that the probability limit of the estimate of β_3 is equivalent to equation 4.

$$Y_{it} = \beta_0 + \beta_1(\text{Number of Wells}_{it}) + \beta_2t + \beta_3(t*\text{Number of Wells}_{it}) + \varepsilon_i \quad (5)$$

Table 7 shows the empirical estimation of equation 4 for employment growth. The results are similar to those in Table 5 with the impact of drilling on employment being small and statistically insignificant. Table 8 reports the estimates of equation 5 for per capita income growth. Similar to Table 6, it shows that drilling appears to have had a positive statistically significant impact on per capita income growth.

Percent Employment Growth	Parameter Estimate	t-value
Time Period*Total Wells	1.763E-05	0.91
Time Period	-0.05	-4.12
Total Wells	-3.240E-06	-0.23
Log Population	-0.005	-0.85
Log Per Capita Income	0.066	1.69
N	134	
R2	0.125	
Adjusted-R2	0.091	

Table 7: Impact of drilling on employment

Percent Income Growth	Parameter Estimate	t-value
Time Period*Total Wells	3.119E-05	2.52
Time Period	0.0253	3.51
Total Wells	-3.310E-06	-0.37
Log Population	0.009	0.55
Log Employment	-0.007	-0.43
N	134	
R2	0.205	
Adjusted-R2	0.167	

Table 8: Impact of drilling on income

Appendix 3: Ohio Environmental Regulatory Authority

Summary of ODNR and Ohio EPA regulatory authority over oil/gas drilling and production activities

	Ohio Department of Natural Resources	Ohio Environmental Protection Agency
Drilling in the shale deposits	<ul style="list-style-type: none"> ✓ Issues permits for drilling oil/gas wells in Ohio. ✓ Sets requirements for proper location, design and construction of wells. ✓ Inspects and oversees drilling activity. ✓ Requires controls and procedures to prevent discharges and releases. ✓ Requires that wells no longer used for production are properly plugged. ✓ Requires registration for facility owners with the capacity to withdraw water at a quantity greater than 100,000 gallons per day. 	<ul style="list-style-type: none"> ✓ Requires drillers obtain authorization for construction activity where there is an impact to a wetland, stream, river or other water of the state. ✓ Requires drillers obtain an air permit to install and operate (PTIO) for units or activities that have emissions of air pollutants.
Wastewater and drill cutting management at drill sites	<ul style="list-style-type: none"> ✓ Sets design requirements for on-site pits/lagoons used to store drill cuttings and brine/flowback water. ✓ Requires proper closure of on-site pits/lagoons after drilling is completed. ✓ Sets standards for managing drill cuttings and sediments left on-site. 	<ul style="list-style-type: none"> ✓ Requires proper management of solid wastes shipped off-site for disposal.
Brine/flowback water disposal	<ul style="list-style-type: none"> ✓ Regulates the disposal of brine and oversees operation of Class II wells used to inject oil/gas-related waste fluids. ✓ Reviews specifications and issues permits for Class II wells. ✓ Sets design/construction requirements for Class II underground injection wells. ✓ Responds to questions/concerns from citizens regard safety of drinking water from private wells from oil/ natural gas drilling. 	
Brine/flowback water hauling	<ul style="list-style-type: none"> ✓ Registers transporters hauling brine and oil/gas drilling-related wastewater in Ohio. 	
Pumping water to the drill site from a public water supply system		<ul style="list-style-type: none"> ✓ Requires proper containment devices at the point of connection to protect the public water system.

Source: EPA (2011)