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Is the Natural Gas Revolution all its Fracked Up to Be for Local Economies?

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Large-scale development of natural gas and oil from shale has been described as a revolution (*New York Times* columnist David Brooks), a bonanza (*The Economist*), and simply a boom (*Forbes*). Regardless of how this historical event is described, all agree that the magnitude of development is huge with large domestic reserves of shale oil and gas set to reduce U.S. oil and gas imports. The U.S. Energy Information Administration (EIA) e stimates that, at current rates of consumption, the United States has enough natural gas from shale alone to supply the entire country for about 90 years (over 2,400 trillion cubic feet) as well as more oil than previously thought (225 billion barrels) (EIA, 2013). For natural gas, the United States is in the early years of a potentially long expansion in production with the EIA estimating that, by 2040, production of natural gas will double relative to the level in the mid-2000s when drilling in shale became common (Figure 1). Yet, concerns about local consequences of extraction of oil and gas from shale formations have caused several states such as New York and Maryland and many local governments around the country to pass a moratoria on hydraulic fracking, the key technology used to develop shale. This collection of articles aims to increase the understanding of several local consequences of unconventional oil and natural gas development.

Articles in this Theme:

A Brief History of Shale Development

The successful extraction of gas or oil from shale rock stems from two principle technologies—high-volume hydraulic fracturing (also known popularly as "fracking") and horizontal drilling. Despite the recent media attention on the technologies, they are not new in principal. A patent application for equipment designed to drill horizontal wellbores was filed in 1919, and the first horizontal wells were successfully drilled in 1929 (U.S. Geological Survey, 1992). Experiments with fracking occurred in the 1930s, with the first commercial application in 1949 (Montgomery and Smith, 2010). The Morgantown Energy Research Center (a precursor to the National Energy Technology Laboratory) researched hydraulic fracturing as early as the mid-1970s (Lockner and Byerlee, 1977).

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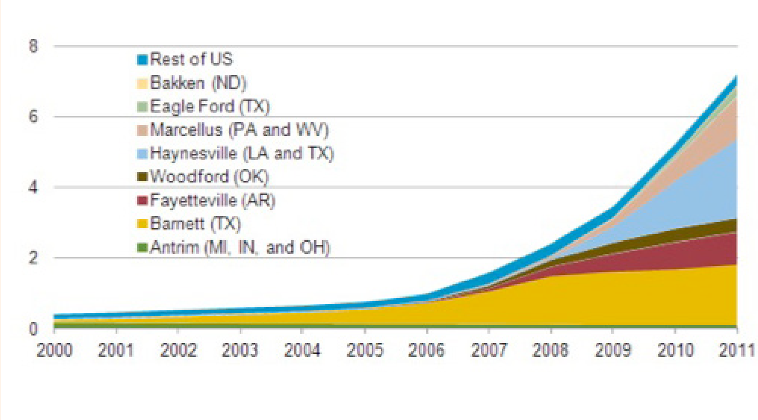
Figure 1: Historical and Projected Production of Natural Gas in the United States



Source: U.S. Energy Information Administration, 2012a

The pioneering work of George Mitchell and others, however, would take the two relatively obscure technologies from conversations in geology and petroleum engineering circles to the American public in the first decade of the 2000s. Mitchell's company, Mitchell Energy and Development, experimented with water, sand, and chemical combinations that, when injected into shale, would release the most gas at the lowest cost. Perhaps more importantly, Mitchell combined horizontal drilling with fracking, which dramatically increased the effectiveness of both technologies.

Mitchell is known by some as the "father of [fracking]" for leading his company to experiment with hydraulic fracturing techniques to extract natural gas from shale rock in the Barnett Shale region in Texas. However, Pierobon (2013) attributes much of the success of Mitchell's company to its team of geologists and seismologists led by Dan Steward during the 1980s and 1990s. According to Pierobon (2013), the modern techniques of hydraulic fracturing developed by Mitchell Energy would not have been possible without the backing of George Mitchell, but it was the team led by Steward that developed a relatively simple mix of sand and water, called a "slick water frac," and developed three-dimensional seismic test data by the company's seismologist Kent Bowker.

By the late 1990s, Mitchell Energy's activities still received little attention from the industry or trade press, with the exception of a short, 5,700-word article in the May 1998 issue of *Oil & Gas Journal* mentioning that natural gas had been successfully extracted from the Barnett shale. Otherwise, the company's activities seemed to escape the industry's radar.

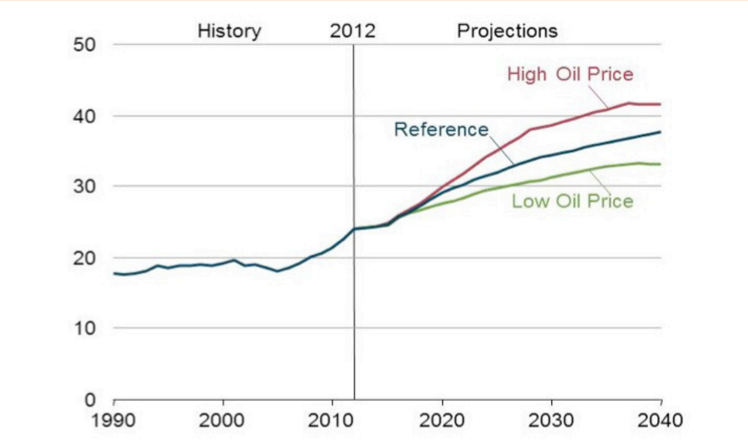
By 2000, Mitchell Energy was seeking additional outside financial support to expand its operations based on its newly developed techniques. One of the potential investment companies included Devon Energy. Mitchell Energy invited representatives from Devon to a secretive, non-disclosure meeting at Mitchell's headquarters and demonstrated its new slick water fracking and three-dimensional seismic imaging techniques. According to Devon Energy's co-founder Larry Nichols, everyone came away from that meeting thinking:

> "Everybody looked at that technology (Mitchell Energy) was developing of hydraulic fracturing and said it doesn't work… It's old, it's tired… there's nothing there. Everyone knows that. Don't waste your time." (Pierobon, 2013)

With talk of Mitchell Energy's efforts growing, however, Devon Energy and Nichols were invited back to Mitchell's headquarters in 2002 and had a different impression. Nichols acknowledged, "We went down there a second time a year-and-half later and discovered it really did work." Shortly thereafter, Devon Energy acquired Mitchell Energy and Development for $3.5 billion, and George Mitchell became Devon's single-largest individual shareholder as part of the deal (Pierobon, 2013).

That meeting between Devon and Mitchell Energy, as it turns out, was a pivotal moment for the natural gas industry. The size of the investment signaled to the rest of the industry that the hydraulic fracturing techniques developed by Mitchell's team were economically viable methods to develop large quantities of the gas trapped in shale. Soon thereafter, additional exploration and production companies began developing natural gas in the Barnett Shale Play and other regions using similar technologies. As shown in Figure 2, shale development was slow after the 2002 meeting, but then expanded exponentially in the mid- to late-2000s.

Figure 2: Estimated Annual U.S. Dry Shale Natural Gas Production, 2000-2011 (trillion cubic feet per year)



Source: U.S. Energy Information Administration, 2012b.

Producing Oil and Gas for 100 Years: Why the Controversy Now?

The current public debate about shale development and its effects may surprise some. The United States has been producing oil and gas for more than a century and has experienced oil and gas production booms before. Why, then, has the current boom spawned so much controversy, prompting moratoria, documentaries, and new activist organizations? The answer has at least three facets.

First, the development of oil and gas from shale formations has reshaped expectations about the supply of fossil fuels for the coming decades at a time when concerns about human-induced climate change are growing. Many see drilling in shale as enabling the United States and others to delay transitioning to a low-carbon, renewable energy economy.

Second, the public interest in shale development reflects, in part, where development is, and will be, occurring. The expected expansion of oil and gas (as indicated by Figure 1 for natural gas) comes from greater drilling not in Alaska's remote North Shore nor miles out in the Gulf of Mexico. Rather, it will come from thousands of wells drilled on private not require the volume of water and sand that current fracking techniques involve. By extension, it did not involve thousands of truckload trips and the noise or dust associated with it. Unlike conventional extraction, hydraulic fracturing produces toxic and radioactive water from a mixture of fracturing fluids and deep saline formation waters. Potential chemical hazards of such include elevated levels of sodium, chloride, calcium, methane, boron, and other higher-chain hydrocarbons (among others) (Osborn et al., 2011).

Why Understanding Local Consequences Matters

Public support for moratoria on fracking, more stringent regulations, or higher taxes on the industry are closely connected to beliefs about local consequences. The potential consequences for people's health, their water and landscape, and the overall quality of life in their communities is what caused over-flow crowds at town hall meetings in New York and elsewhere.

Better information helps policy makers design appropriate policies while a more informed public helps provide the political support for them. Policy debates swayed by unrepresentative, anecdotal evidence will result in real problems being ignored or costly initiatives addressing phantom problems. As mentioned, extraction can involve excessive wear on roads, bridges, and public water systems. Support for measures to raise revenues to address the wear depend on realistic assessments of costs. It took the Pennsylvania legislature until 2012 to begin directly taxing drilling activities through an impact fee on each well drilled. Similarly, prohibition of methods that can be safely used means foregoing the extraction of valuable oil or gas. Foregone extraction means a wealth loss to the resource owner, a foregone source of tax revenue, and depending on the scale, higher energy prices to consumers.

Unfortunately, it is easy for public perception to be swayed by anecdotal evidence. The documentary *Gasland* famously showed a Pennsylvania homeowner lighting on fire the water coming out of his faucet. With its striking visuals and moving personal testimonies, the film brought the water issue to the public's attention, energizing activist movements that engaged many people far removed from places of drilling. Although a picture can tell a thousand words, it cannot answer two important questions: what caused the flammable water in the case in question, and how many cases of the thousands of cases not pictured does it represent?

Yet, there is reason to be optimistic about a growing public understanding of the local consequences of shale development. Prior booms in onshore oil and gas production occurred when health, environmental, and economic data and tools for working with them were very limited. Researchers today, in contrast, have tremendous data at their fingertips, powerful computers, and easy-to-use statistical software to quantify systematic effects of development. In 2014, the county-level oil and gas production data for the lower 48 states was made publicly available. For states like Pennsylvania, databases complete with spatial information are publicly available and allow researchers to know exactly where and when each shale well was drilled. The EIA, in collaboration with the Groundwater Protection Council, is working to create standardized well-level databases for many oil- and gas-producing states. The increased ease of accessing fine-grained data will encourage a proliferation of studies on local impacts to an extent that is incomparable to prior years, the contours of which we outline below.

Local Consequences are Diverse in Nature and Who They Affect

Local consequences can range from low birth-weight babies (Hill, 2013) to economic prosperity (Weber, 2012 and 2014; and Brown, 2014). The distribution of prosperity can be felt unequally among local residents. The case of the Dallas-Fort Worth area is illustrative. The Barnett Shale splits the Dallas-Fort Worth metropolitan region in half and is where high-volume hydraulic fracking and horizontal drilling were first combined and applied at scale. Weber, Burnett, and Xiarchos (2014) document how housing values appreciated more in shale zip codes than in zip codes just outside of the shale. The greater appreciation in part reflects an expansion in the local property tax from an expansion in the value of oil and gas rights, which are taxed as property by local governments and schools in Texas. They show that an improved tax base, in turn, increased revenues to local schools and their per-student expenditures.

The story, however, does not end there. Although housing in zip codes within the shale generally appreciated more than those outside the shale, zip codes with more wells appreciated less than those with fewer wells. The negative relationship between housing appreciation and drilling intensity likely reflects a range of quality of life issues brought on by drilling, including truck traffic, natural gas-related infrastructure on the landscape, lower air quality, noise, and contamination risks to groundwater-dependent homes. Due to the tremendous amount of risk uncertainty, many scientists have advocated for additional testing and research to better understand the mechanism of contamination to groundwater near drilling sites. They call for systematic and independent data collection on groundwater including dissolved-gas concentrations and isotopic compositions prior to drilling operations beginning in a region (Osborn et al., 2011). As such, one can see why local residents have diverse opinions about shale development: the costs and benefits are unequally spread among various groups such as those living near or far from wells, and those with or without subsurface rights.

Our brief description of findings from one study of the Barnett Shale represents the first 100 feet of a mile-deep well with many twists and turns. The articles in this *Choices* theme describe in more detail the salient issues raised by recent and emerging research on local consequences. The first article, by Kelsey, highlights the unique issues facing local governments from shale development, which can generate revenue for local infrastructure, but the frenetic and volatile pace of drilling makes planning for public investments difficult. The second article, by Weinstein, discusses the impacts to employment at both the local and state levels associated with shale development, and highlights how impacts can vary in different contexts. Since much of the current development occurs on farms and ranches, the third article by Hitaj, Boslett, and Weber discusses how development can bring royalty dollars to farmers but also can create more competition for local water resources and employment. The fourth article by Fitzgerald focuses on the distribution of royalty payments to various stakeholders, including private mineral owners. The author finds that energy companies paid more than $30 billion to private mineral owners in 2012 though, in many states, only a small fraction of the payments went to residents living in the county where production occurred. The final article by Olmstead and Muehlenbachs explores the effects of drilling activities on nearby water resources. The authors argue that much of current debate focuses on the impacts to water quality, but much more research is needed to understand the impacts to water quantity as well.

For More Information

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Importance of Mineral Rights and Royalty Interests for Rural Residents and Landowners

Timothy Fitzgerald

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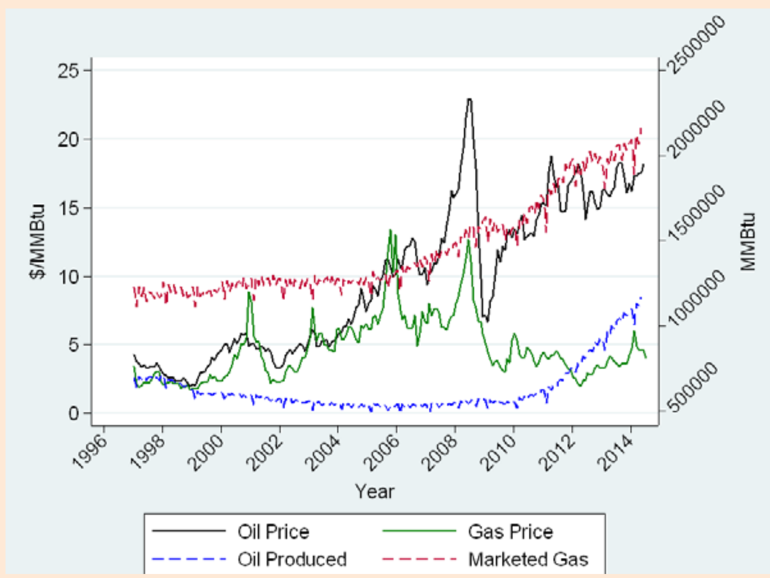
Keywords: Mineral Rights, Oil and Gas, Royalty Interest

The United States is unique in the world insofar as private individuals own a majority of subsurface minerals. While federal and state governments also own minerals, the market for mineral prospects includes many sellers and buyers. Many mineral owners are willing to lease acreage for exploration and experimentation with new extraction technologies (Hefner, 2014). Those individuals capture a share of the proceeds if and when production occurs. Local residents own minerals and stand to gain from production, but the extent to which they do so is not well known. Understanding the legal framework of minerals rights and royalty interests is critical to better understand the magnitude of economic gains from oil and gas royalties.

Figure 1: Onshore Oil and Gas Production in the Continental United States 1997-2014



Source: EIA. Oil converted to Btu at 5.83 MMBtu/bbl.

Recent years have brought a dramatic technological change to the U.S. oil and gas sector, described as the "natural gas revolution," or the "shale gale" to reflect the presence of both natural gas and petroleum in widespread shale deposits (Yergin, 2011; and Deutch, 2011). Technological changes in extraction techniques have made extraction of unconventional resources economic, vastly increasing potentially productive acreage. That change, in turn, has pushed exploration and production into numerous regions that had not seen oil and gas production in recent past and, in other regions, never. Places with marginal resources using conventional technology became very profitable with new technology. As a result, regions such as rural Pennsylvania, much of which overlies the Marcellus shale, have become hotbeds of oil and gas activity.

Table 1. Mineral Ownership in Select States, 2012

	Coverage		Owner		Owner	
	Counties	Leases	In-state	In-county	Federal	State
State	(Count)		(Percent)		(Percent)	
Colorado	25	42,336	61.17	34.52	17.1	1.7
Louisiana	54	100,723	81.7	51.16	1.3	23.2
Montana	8	16,919	47.73	25.16	15.1	6
New Mexico	3	20,177	36.51	18.96	51.1	19.4
North Dakota	13	88,557	36.4	15.13	11.7	23.5
Ohio	32	31,175	95.85	74.03	N/A	N/A
Oklahoma	60	460,952	60.28	24.58	0.7	19
Pennsylvania	26	50,094	90.32	65.66	N/A	N/A
Texas	190	618,905	80.92	28.23	0.2	6.2
Utah	1	1,574	64.1	12.39	48.8	1.5
West Virginia	16	34,258	65.32	41.85	N/A	N/A
Wyoming	10	6,733	41.35	29.35	63.2	6.8
Total	447	1,472,403	74 .96	36.46	11.7	12.1

Source: DrillingInfo.

Notes: In-state and in-county ownership statistics equally weight each county in state. The statistics reported in this table cover all mineral owners and all years. Totals reflect the unweighted averages across all counties included above. Federal and state ownership statistics are revenue shares reported in Fitzgerald and Rucker (2014), which explains methodology underlying the estimates. The totals for these columns are 2012 cumulative oil and natural gas production-weighted averages for states that have data.

The value of the change in U.S. production due to this technological change is impressive. Figure 1 shows U.S. oil and natural gas production and benchmark prices since 1997. Between 2008 and 2013, onshore oil production in the lower 48 states increased by 81%; natural gas production increased by 30% over the same time span, but began to increase before 2008. How much of the value of this change accrues to local residents, and the spatial pattern of royalty capture, are important questions asked by policymakers.

Royalties accruing locally might well have different effects than revenue that accumulates to oil and gas companies, which are often based out of state. Gilje (2012) investigates the consequence of local capture of oil and gas royalties, finding increased deposits in local branch banks lead to an increased number of business establishments dependent on external credit. Counties with more oil and gas production experienced an additional 8.2% in deposit growth during the period 2000-09. A major source of these additional deposits is proceeds from oil and gas royalties and lease bonus payments. The size of royalties themselves is not well known. The value of production varies across counties, and that value is likely to be captured differently. Understanding such variation is useful in making more accurate forecasts of local economic performance.

Predicting support for development and attendant policy issues is a second key implication of understanding dispersal of mineral rents. Widespread ownership and realization of royalties shape a different political landscape than concentration and absenteeism do. Policy issues such as natural gas and crude oil exports, construction of the Keystone XL pipeline from Canada to the Gulf Coast, and regulation of hydraulic fracturing are likely to vary according to the degree to which residents benefit from oil and gas activity. State and local policy issues also arise, such as the collection of tax revenue from out-of-state mineral owners. Tracing ownership and mineral rent distribution is a more direct link to individual economic welfare than previous studies of employment effects (Weber, 2012; and Jacobsen and Parker, 2014).

As testament to the potential wide scope of benefits to royalty owners from oil and gas production, independent oil and gas producer Chesapeake Energy claims 1 million mineral owners have signed leases with their company, or nearly 1 in 300 Americans (Zuckerman, 2013). Those million leases could be concentrated in the hands of far fewer than 1 million mineral owners, however, and the owners may or may not live atop their minerals. So understanding the specific structure of leasing and mineral ownership is elemental to the economic effects of oil and gas development. Kinnaman (2011) cited the failure to consider location where royalties are received and spent as a major shortcoming of studies that forecast the economic impact of natural gas development.

Mineral Rights and Royalty Interests

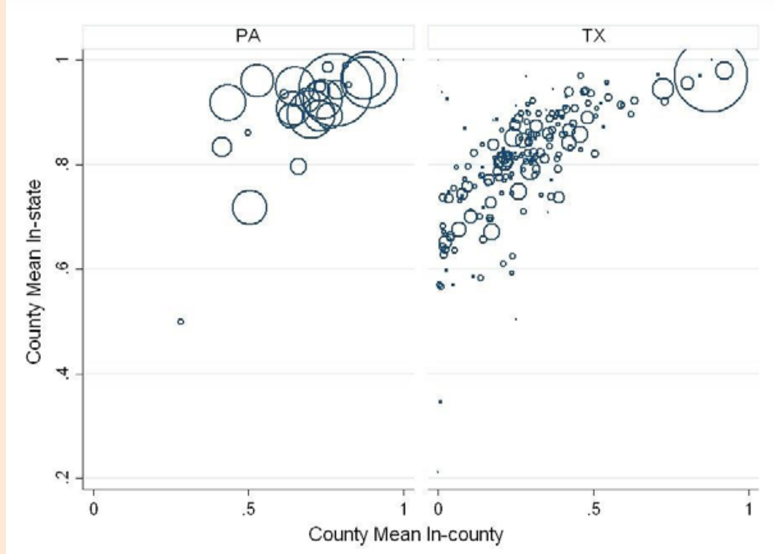
Many different entities own mineral rights in the United States: private individuals and firms, federal and state governments, and in federal trust for tribally owned minerals. The provenance of mineral ownership for these different groups varies and is often directly related to the history of property claims in a particular location. Prior to 1908, the federal government conveyed rights to all minerals through homestead claims, with very little acreage ineligible for claim. After that time, and especially after 1916, mineral rights were never conveyed to private owners and, instead, reserved by the federal government. States and tribes received minerals from federal land grants. As a comparison, in most other countries the government retains ownership of all subsurface minerals. The diffuse ownership in the United States gives many owners an opportunity to benefit from resource wealth.

Property rights are sometimes likened to a bundle of sticks. In that framework, mineral rights are not one stick, but a sub-bundle, because rights to distinct minerals can be held separately. For example, coal and petroleum rights can be separately owned. Mineral rights can also be separated from surface rights. Severance of minerals from surface, commonly called split estate, is a typical arrangement—surprisingly so to some people. The U.S. government reports 57.2 million acres of federal minerals that underlie private surface, though these holdings are concentrated in states in which many land claims were made after 1908. Forty percent of the federal split estate is in Montana and Wyoming; adding Colorado, New Mexico, and North Dakota increases the proportion to nearly three-quarters.

Split estates are related to dissatisfaction with development (Collins and Nkansah, In Press), and one reason for that dissatisfaction is the inability of a surface owner to share in the value of the extracted minerals. This begs an important question—why would it ever make sense to split up the sticks in the bundle? The ability of mineral owners to sever mineral rights from the surface, or rights to one mineral from others, hinges on the degree to which one owner can benefit from both surface and minerals (Huffman, 1982). Specialization provides an important rationale for severance (Barzel, 1997); because agriculture and oil and gas production require different combinations of inputs, it is natural to expect that separate ownership of the surface and mineral rights would generate larger gains than requiring a single owner. The same argument applies to separation of the rights to different minerals. However, the gains from specialization come at the expense of increased transaction costs (Chouinard and Steinhoff, 2008); in the case of federal oil and gas leases, bidders appear to anticipate those higher costs (Fitzgerald, 2010).

A key issue surrounding mineral rights is that ownership of a single acre is often divided among more than one individual. Fractionalization of mineral rights is common and often begins when mineral property is conveyed between generations. An example is a mineral owner bequeathing equal shares to multiple children. By default, mineral rights are conveyed as tenants-in-common rather than as owners of separate acreage, implying each of four children owns a quarter of the whole acreage, rather than all of one quarter of the acreage. This fractionalization compounds with generations and fecundity.

Figure 2: Measures of Local Mineral Ownership, Pennsylvania and Texas



Source: DrillingInfo. Elaboration by the author.

In a vast majority of cases, an oil and gas company interested in exploring for and producing oil or gas does so by leasing rather than buying the acreage. Oil and gas leases are option contracts with several important dimensions. The option has a primary duration and, if that duration elapses before production occurs, the lease expires. A common example is a three-year primary term. Usually the mineral owner is interested in minimizing the delay until production begins.

Monetary compensation from private leases comes in two parts—a royalty share of gross production revenues and an upfront payment called a bonus. If a lease ultimately produces, the royalty revenue usually far surpasses the bonus payment. However, the risk of no production may make bonus preferable to royalty.

In addition to these two payments, the lease language can be negotiated on an individual basis. While almost all leases share a common structure, contractual protections in the form of lease stipulations may be important to some owners. An important example of such a stipulation is a surface use clause. Such clauses legally restrict the extent to which a developer can occupy the surface. Owners of severed minerals likely have less incentive to include surface use clauses, but may be keenly interested in other types of clauses, such as "Pugh" or delay royalty clauses. Oil and gas leases can be customized to the wishes of the mineral owner.

Private oil and gas leases are negotiated between mineral owners and procurement specialists called landmen. Landmen may work for oil and gas companies interested in producing the minerals themselves, or may work as independent contractors who procure leases and bundle them for sale to developers. Regardless of the

Table 2. Variation in Ownership, North Dakota

County	Percent In-County	Percent In-State	Number of Leases
Billings	2.1	36.28	4,859
Burke	11	35.47	7,262
Divide	7.35	28.54	6,745
Dunn	11.31	41.85	9,030
Eddy	0	0	2
Mckenzie	12.06	32.74	18,102
McLean	11.84	39.89	752
Mercer	17.68	43.96	803
Mountrail	16.82	38.28	10,245
Renville	13.16	43.14	2,735
Stark	30.3	43.38	5,756
Ward	33.03	47.38	1547
Williams	30.09	42.33	20,719

Notes: In-state and in-county percentages are calculated on a per-lease basis, without correcting for acreage or fractionated mineral interest. See Table 1 for additional notes.

type of landman with whom the mineral owner negotiates, there are two reasons to expect that an asymmetry of information prevails between the lessor and the lessee. First, because oil and gas leases can have a long duration, negotiation of a lease may be infrequent for any given mineral owner. In contrast, landmen acquire leases regularly and, during busy periods of leasing, one landman may be working on multiple leases simultaneously. This gives the landman an informational edge with respect to the structure of leases as well as current conditions in the leasing market. Second, the technical demands of modern oil and gas production increase the information required to assess the value of mineral acreage. Company landmen are instructed to procure acreage in specific areas, and many independent landmen have technical training that allows assessment of the resource before negotiating. Most mineral owners lack comparable experience, and may be forced to rely on information provided by the landman in the course of negotiation.

After a lease is signed, a delay of months may elapse before additional activity occurs. Leases may be assigned to new owners, who then have to determine where and when to drill wells, obtain necessary permits, and arrive at a prospective well site. The amount of time spent drilling varies depending on the depth and complexity of a well. After the well is drilled, it must be completed, including treatments such as hydraulic fracturing that affect the reservoir characteristics and likely production from the well. Only after completion is the well ready to begin producing commercially and sale of products can begin. Most leased mineral owners eagerly anticipate the first sales because of the expectation of accruing royalties.

Being a Royalty Owner

Because most mineral owners do not develop minerals on their own, one of the most important events in the life of an oil and gas owner is when he or she becomes a royalty owner. After a paying well is brought in on the lease, a division order is signed by the mineral owner to specify the terms on which royalties will be paid. Signing the division order makes the mineral owner a royalty owner.

The first check usually pays six months of royalties, and so is often a large sum. In most cases the royalty owner will subsequently receive monthly checks. Royalties are almost always calculated on gross revenue, so they can fluctuate with production and prices. Because of the geophysics of extraction, production usually falls over time from each well. More wells may be drilled on a property, and that can increase royalty payments. Price risk remains an issue for royalty owners, who may not have access to the full range of hedging strategies due to scale.

Royalty ownership comes with its own special set of problems. One important reality for royalty owners is that the operator has much better information about produced quantities, price received for products sold, and the costs of moving products to the point of sale. A second important reality is that the operator of the well is usually able to deduct reasonable expenses incurred in transporting and processing the produced quantities from the wellhead (where royalties are theoretically due) to the point of sale (where a price can be attached to the units that are sold). These post–production costs, or deductions and allowances, are a regular item on a royalty owner's check stub and often amount to 10% or more of the gross royalty. Here, again, the royalty owner is often at an informational disadvantage. The operator likely considers the benefit of alternative gas-processing contracts, whereas the royalty owner may have limited knowledge of why gas processing is needed.

Royalty owners commonly have disputes with operators. These disputes are often settled amicably, but sometimes result in legal action that receives a judgment. Questions about adherence to lease stipulations, measurement and timing of production, lease expiration, or accounting for post-production costs all crop up periodically. Considerable precedent reduces uncertainty about the outcome of any given dispute, helping to lower costs of resolution.

Mineral Owners

Understanding the disposition of mineral rights and how leases lead to royalties leaves an important question about who are mineral owners. Are local residents the owners of their own minerals, or do absentee ownership and split estate direct most of the rents of mineral development into the pockets of others?

To gain some insight into mineral ownership, Table 1 summarizes a substantial collection of mineral leases complied by DrillingInfo from 12 of 32 producing states. These states include 8 of the top 10 producing states in 2012, and all are in the top 20. Within states, the leases were summarized at the county level to account for geographic variation in leasing terms and underlying geology. The first columns report the number of counties represented in the sample and aggregate number of distinct leases in those counties.

There are considerable differences in mineral ownership across the states. The data allow matching of the reported address of the grantor with the lease location. When the grantor reports an address in the same state as the lease, the lease is recorded as being owned in-state. When the grantor reports an address in the same county as the leased property, the final column records whether the minerals are owned within county.

The contrast across states is depicted in Figure 2, which compares mineral ownership in counties in Texas and Pennsylvania. A large majority of the counties in Pennsylvania for which there are data indicate that most of the minerals are controlled by Pennsylvania residents. In fact, a large majority of counties also have local ownership of minerals, as measured by counties. In contrast, absentee ownership is more common in Texas counties. Like Pennsylvania, some counties are characterized by a very high proportion of local ownership. Greater variation across counties within Texas is evident, with several counties reporting no in-county mineral ownership for the sample of leases examined here. However, for almost all of the reported counties in Texas, the minerals are controlled within the state. This is an important distinction between Texas and other states.

Mineral ownership is not uniform within states. Variation within one state, North Dakota, is reported in Table 2. Across the 12 counties for which there are reliable data, in-state ownership ranges from a high of nearly one-half to less than one-third. The in-county numbers are lower, ranging from one-third to only 2% in Billings County. North Dakota has a high degree of absentee ownership compared to eastern states.

Table 1 also reports the percent of mineral production revenue attributable to federal- and state-owned minerals in selected states (Fitzgerald and Rucker, 2014). A weighted average of the states with data on government mineral ownership, using 2012 production of oil and gas as weights, is included in the total. This suggests that 76.2% of producing oil and gas minerals in the onshore lower 48 are privately owned.

Economic Value of Royalties

Royalties are calculated based on gross revenues. Aggregate quantities produced are widely available. The extent of price dispersion and variability in royalty rates makes estimation of gross royalties more difficult. As a starting point, one large mineral owner secures a uniform royalty rate—the federal government for onshore production. The federal government reported oil and gas royalties of $2.7 billion for fiscal year 2013. Royalties represented 92% of total revenues from onshore oil and gas for 2013, with the balance made up by bonus and rental payments. This underscores the importance of royalties relative to other forms of compensation.

The federal royalty figure also provides a guideline for the aggregate value of royalties. Suppose all other mineral owners captured the same share of production as the federal government. In that case, the aggregate royalties in fiscal year 2013 would be about $23 billion.

able 3. Summary of Oil and Gas Lease Royalty and Ter

	Oil & Gas		Mean	
State	Counties (Count)	Counties (Count)	Royalty (Percent)	Term (Months)
Arkansas	38	27	15.69	53.42
California	3	31	17.46	45.52
Colorado	25	38	14.91	53.00
Kansas	38	91	13.5	38.00
Louisiana	54	63	21.26	38.55
Mississippi	42	43	18.4	47.02
Montana	8	34	15.4	52.69
New Mexico	3	13	20.8	38.49
North Dakota	13	18	17.74	46.07
Ohio	32	61	12.63	47.62
Oklahoma	60	74	18.59	35.88
Pennsylvania	26	36	13.98	58.24
Texas	190	228	19.6	37.46
Utah	1	11	16.57	56.68
West Virginia	16	50	13.56	59.96
Wyoming	19	22	15.33	52.33
Total	559	840	17.65	42.89

Source: DrillingInfo.

Notes: County-level production statistics for private mineral owners for oil or gas produced in the county 2000-2011. State means equally weight each county in state. A total of 2,315,574 distinct leases were included.

Table 4. Gross Value and Capture of Private Oil and Gas Royalties, 2012

State	Gross Value	Federal Value	Gross Royalty	In-State Value
Colorado	9,346	199.8	1,131.5	692.1
Louisiana	14,785	24	2,373.2	1,938.90
Montana	2,678	50.5	325.4	155.3
New Mexico	11,366	726	697.4	254.6
North Dakota	23,313	340.9	2,680.0	975.5
Oklahoma	14,321	12.5	2,137.8	1,288.70
Texas	88,835	22.2	16,297.3	13,187.80
Utah	4,198	256.1	345.7	221.6
Wyoming	11,012	869.9	506.4	209.4
Total	224,860	3,160.3	31,359.3	

Notes: Values are in millions of 2012 dollars. Reported states each have individual calculations for average private royalty rate, proportion of minerals privately owned, and proportion of minerals contolled in state. States with missing values were assigned production-weighted averages and are included in the total. Corresponding aggregate federal royalties are reported as $2.7 billion for FY2013 (September 2012-13).

State governments own and lease substantial mineral acreage. Because different states have retained differing amounts of land, the importance of state ownership varies across the states. In general, western states have retained more land in state ownership and are more likely to have active leasing programs. Exceptions exist, however. For example, Michigan is a relatively modest producing state, but almost one-quarter of gross revenues are generated on state minerals.

Unlike federal minerals, a summary of royalty payments from private oil and gas production is harder to come by. Because private minerals account for about 75% of onshore U.S. production in recent years, we could estimate gross royalties as three-quarters of the usual royalty rate times gross revenue. At least four factors contribute to the variation in private royalty payments. First, there is considerable dispersion in private royalty rates, in contrast to federal or even state-owned minerals. Second, royalty rates vary across regions and over time. Third, royalty owners never actually see the gross royalty, but instead receive a net royalty after transportation and marketing allowances are deducted. Fourth, product prices vary around the country, largely in keeping with transportation and quality basis differentials.

Table 3 presents information about private oil and gas lease terms. Dispersion in royalty rates is prominent both within and between states. Lease terms vary from just over three years in several active states to closer to five years in Utah and West Virginia.

As an illustration of state variation in the value and capture of oil and gas royalties, Table 4 reports calculations for several states using 2012 calendar year production figures. (The gross production revenue values natural gas as dry gas and does not take natural gas liquids into account.) The reported states have precise estimates of the amount of production from federal minerals. Valuing the federal production share at the federal royalty rate of 12.5% gives an estimate of gross royalties due. The estimate of $3.16 billion is higher than the reported net royalty receipts, although the calendar and fiscal years do not match up precisely. One possible inference is that this approximation is too high. A second is that transportation and marketing allowances amount to about 14.5% of gross royalty value for the federal government. There are no previous estimates of the magnitude of post-production costs, but this figure is within the range of anecdotal deductions on private minerals. This estimate is subject to some unobserved variation in when royalties are paid for production in the federal reports, but the gross value estimate presumes royalties are paid concurrent with production.

Using state-specific average royalty rates to generate predictions of gross royalty due to private mineral owners in 2012, we see that Texas is far and away the most important state for generating royalties. In part this is because it is the largest producing state, but also because it has a high proportion of private minerals and relatively high royalty rates. The aggregate 2012 value of private royalties for the major states considered in Table 4 was about $31 billion.

The final column of Table 4 provides an estimate of the share of private royalties that are captured by in-state mineral owners. Of course, mineral owners in a state such as Texas may also be receiving royalties from production in other states, and so this estimate is clearly an underestimate of total royalty income. However, due to substantial out-of-state mineral ownership, a state such as North Dakota sees a large chunk of royalty income disappear across state lines. Local figures are even lower.

Questions for the Future

The effects identified here are fundamentally short term. The long-run financial implications are not well understood. Given the nontrivial revenues accruing to public mineral owners, the long-term fiscal position of state and local governments depends on the ability to use current revenues wisely. For example, many states devote severance tax revenue to a trust fund. Other states, such as Montana, instead dedicate revenues to operational budgets. Disposition of private oil and gas windfalls is subject to a similar tradeoff between investment in long-term productivity and current consumption.

Over the long term, the usage of oil and gas royalty income is a critical question. The reallocation of rents across alternative types of capital is a key question. Most states receiving mineral royalties use the proceeds at least in part to fund education, which is a reallocation from natural to human capital. Rural residents in North Dakota and eastern Montana have experienced decades of population declines. A current population influx has increased the demand for social services, but with the longevity of the Bakken play still in question, infrastructure investments are as difficult for local governments as decisions about investing in the community are for royalty owners.

Questions that rural residents and landowners have about oil and gas development, broadly, and issues of mineral rights and leasing, in particular, are often difficult to answer. And the existing outreach mechanisms, such as the cooperative extension service, have very limited expertise in this area. Oil and gas attorneys can be very useful to landowners considering leases or other contracts. However, the expansion of development into new provinces has outstripped the supply of unconflicted attorneys with expertise in oil and gas issues. While this shortage is likely to correct itself without intervention, the asymmetries of information discussed above are likely to continue in the interim.

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Shale Development and Agriculture

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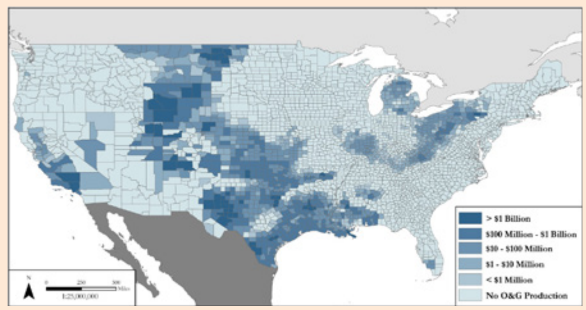
Shale formations rich in oil and gas cover parts of many agriculturally rich states. Since farmers own or operate more than half of the non-urban land in the 48 lower states (U.S. Department of Agriculture, Economic Research Service (USDA, ERS), 2013), the potential for oil and gas drilling to affect the well-being of farmers and the profitability of their farms is high. Most onshore oil and gas production is concentrated in the south-central United States, the western Plains, and the Appalachian Mountain region in the east. The value of this production often dwarfs the local agricultural economy. In 2012, the value of energy production was, on average, 16 times greater than the value of agriculture in energy-producing counties, up from 6 times in 2002 (USDA, National Agricultural Statistics Service (NASS), 2012; USDA, NASS, 2002; and USDA, ERS, 2014).

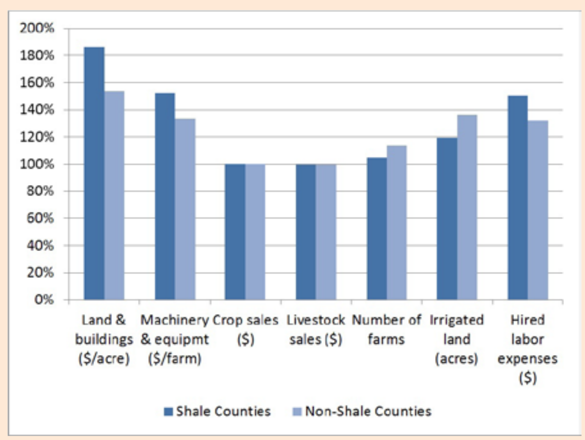
The overall effect of shale development on agriculture is uncertain and depends on local and individual factors. The energy industry makes large payments to farmers who own mineral rights or land needed for pipelines or access roads. However, energy companies also compete for inputs, such as water and labor, which may weaken the profitability of farms, particularly in remote and dry areas. For example, farmers and drilling companies will compete for water in dry parts of Texas and other western states. In rural areas far from population centers, farmers might find it hard to retain hired workers who can make higher wages driving semi-trucks or pouring concrete for well pads. In North Dakota, competition for trains given the use of rail for transporting oil has led to lower local grain prices and mounting concerns over future backlogged shipments of

Figure 1. Value of Energy in 2011



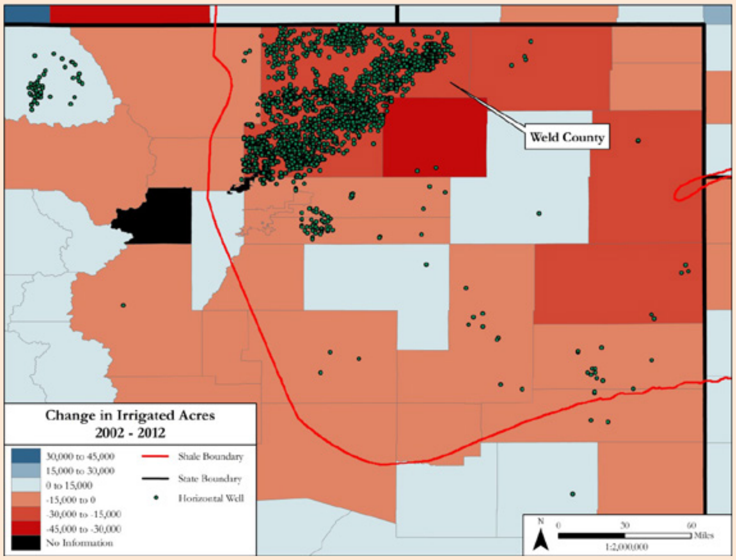
Source: USDA-ERS, 2014.

Figure 2. Change in Agricultural Variables from 2002 to 2012 across Shale and Non-Shale Counties



Source: Based on USDA, NASS, 2002 and 2012 Censuses of Agriculture. Note: Includes counties with shale plays in AR, CO, LA, MO, NM, ND, OK, and TX.

Figure 3. Change in Irrigated Acreage from 2002 to 2012 in Northeastern Colorado



Source: Based on USDA, NASS, 2002 and 2012 Censuses of Agriculture and the Colorado Geological Survey (2014).

grain (Nixon, 2014). Drilling pads and access roads can also reduce the surface area available for crops or pasture.

Shale development from 2002 to 2012 appears to have diverse impacts on agriculture. Farms in shale counties experienced a larger increase in the value of their land and buildings than those outside of shale plays. This suggests that growth in the value of the oil and gas rights has outpaced any decline in the value of land associated with loss of land for agricultural use and potential environmental degradation of the land related to drilling. In addition, within the shale area, the value of machinery and equipment increased compared to non-shale areas. This could be the result of a wealth increase through lease and royalty payments to farmers owning their mineral rights. While crop and livestock production remain unchanged, there is some evidence of farm consolidation in shale areas. Competition for water may explain why shale areas had a smaller increase in irrigated acres, while competition for labor could account for the relatively larger increase in hired labor expenses in shale areas relative to non-shale areas.

The descriptive comparisons, of course, mask exactly why and how shale development may be affecting agriculture.

Water Quantity and Quality

Much of the concern with the recent wave of oil and gas development regards its potential impacts on water quantity and quality. Shale development uses large quantities of water because of its reliance on hydraulic fracturing to create fissures in rocks to release the oil and gas trapped within. A typical horizontal shale gas well requires 2 to 4 million gallons of water during the fracturing process (U.S. Department of Energy, 2009). Although water use associated with shale development is small at the state level, it may cause large increases in water demand in specific areas (Nicot and Scanlon, 2012). This is especially a concern for water-scarce areas in Texas and other western states where many shale wells have been drilled (Freyman, 2014).

The use of water in hydraulic fracturing has also led to concerns about water quality. In Pennsylvania, Osborn et al. (2011) found evidence that drilling can affect groundwater through methane migration or faulty well casings. It can also affect surface water quality through spills at drilling sites or if drilling wastewater is not properly processed by treatment plants before it is discharged into rivers and streams (Kargbo, Wilhelm, and Campbell, 2010; and Olmstead et al., 2013).

Water quality and quantity concerns associated with shale development may affect farming and ranching in several ways. Farmers may face higher water prices due to competition with energy companies. In certain areas of the country, such as Texas and Colorado, farmers and ranchers may sell their water rights to energy producers thereby diverting water use from agriculture (Gold and Campoy, 2011; and Healy, 2012). Greater demand for water in general could cause farmers to transition from water-intensive crops such as cotton and rice to crops requiring less irrigation or none at all. In particularly dry areas dependent on irrigation, farmers may stop growing crops altogether and switch to ranching. In Weld County, Colo., for example, large-scale drilling accompanied a large decline in irrigation (Figure 3).

Concerns associated with water quality may also affect the decisions of farmers. The Food Safety and Modernization Act of 2010 requires pre-testing of all water used for irrigation. Any decrease in water quality caused by nearby shale development could reduce the water available for irrigation or force farmers to find alternative sources of water that meet the Act's quality standards. In addition, many farms are also valued for their use as a rural residence, not for production. The potential human health implications described in Finkel and Law (2011) could make such farms less desirable as residences, thereby lowering their value and the well-being of their residents.

Livestock farms are also sensitive to changes in water quality. A recent study by Bamberger and Oswald (2012) suggests that livestock are highly susceptible to water quality impacts from shale gas development. Water contamination effects on livestock health may encourage some livestock farmers to transition to growing crops or to relocate their farms. In addition, organic farmers in areas with shale development areas may face consumers' fears regarding the quality of their products. This concern has led the Pennsylvania Association for Sustainable Agriculture to call for a moratorium on shale development until the state has fully evaluated its impacts on water quality, food safety, and farmer well-being. Some organic food companies have expressed concern that they could lose their organic accreditation due to nearby unconventional gas development (Miller, 2012).

Competition for Inputs: Labor, Land, Infrastructure, Supplies

Aside from water, shale development can affect the price of other agricultural inputs such as labor, land, and infrastructure. Weber (2012) finds that shale gas development added about 1,780 jobs and $69 million in wages in counties in Colorado, Texas, and Wyoming that experienced a boom in natural gas production. While the workers directly involved in drilling, completing, and operating a well are highly specialized, demand for labor in supporting services, such as driving and construction, could force farms to pay higher wages to retain their similarly skilled workers. There is evidence that greater shale development caused the average wage per job in a county to increase, though the effect varies by region (Brown, 2014; and Weber, 2014). In the Bakken Shale region of North Dakota, in particular, finding seasonal workers has become difficult and most farmers are resorting to labor from foreign countries who work under H-2A visas (Deede, 2014). Temporary workers around drilling areas typically rent housing, which has caused rental prices to escalate. In Bradford County of Pennsylvania, houses that previously rented for $500/month could rent for $4,500/month due to the increased demand from the industry (Drohan et al., 2012).

Shale development requires land for drilling sites, gas processing facilities, pipelines, access roads, and water impoundments. Drilling itself occupies relatively little land. Five acres from which multiple wells are drilled can provide the capability to extract gas from about 500 to 1,000 acres (U.S. Department of Energy, National Energy Technology Laboratory (NETL), 2013). Other infrastructure, however, such as access roads and water impoundment areas, also requires land. Companies must clear the right of way over any pipelines they wish to install (Williams, 2012). Many agricultural activities can occur on top of pipeline rights of way, though the disturbing of the soil can lower crop yields. Drohan et al. (2012) find that if all the wells permitted in the Marcellus Shale area in Pennsylvania by June 2011 were developed, it would convert at least 1,600 to 2,600 acres of agricultural land and 1,300 to 2,200 acres of forest land into industrial land.

When farmers do not own the mineral rights to their land, they are unable to direct where wells are placed on their property. Gibson (2013) finds that oil companies in North Dakota drilling in the Bakken often do not respond to even modest requests for change, such as moving a well pad to the other side of a fence to allow for calving. In one North Dakota example documented by Gibson, a farmer could not profitably farm around a 7-acre well pad that was built in the middle of a 20-acre field. Although he received compensation for the loss of use created by the well pad area, it did not cover his losses.

Farms are also affected by an increase in the price of inputs that are used in shale gas development. For example, mulch and straw are used for erosion and sedimentation control on gas sites, but also for animal bedding (Drohan et al., 2012). On the other hand, lower natural gas prices can bring down the cost of nitrogen-based fertilizers since natural gas accounts for about 70% to 90% of the estimated cost of producing them (Pirog and Ratner, 2012). However, the high demand for fertilizers in recent years has translated mainly into increased profits for fertilizer producers compared to cost savings for fertilizer consumers (Pirog and Ratner, 2012).

Greater demand for transportation infrastructure from the oil and gas industry can affect farmers in several ways. Produced oil and gas can be transported by rail, increasing competition for rail resources that farmers rely on for marketing their crops. Olson (2014) estimates that rail shipment delays have caused a loss of $66.6 million in North Dakota's farm-level revenue for crops that were sold from January through April 2014. In addition, increased truck traffic damages roads, particularly dirt roads, which farmers rely on to move their machinery and agricultural products. Abramzon et al. (2014) find that a new well in Pennsylvania required on average about 600 to 1,100 one-way loaded heavy truck trips. They estimate that heavy truck traffic on Pennsylvania's state-maintained roadways from shale gas development in 2011 created roughly $13,000 to $23,000 worth of damages per well. Other costs from truck traffic include declining health of livestock due to air pollution. In

North Dakota, Bakken-related truck traffic on red-rock gravel roads creates dust. Gibson (2013) found that cattle sometimes reject the dust-laden feed, refuse to lay in the dusty hay, and even die from dust pneumonia. In the long run, farmers could benefit from the subsequent repair of a damaged road or the conversion of dirt roads to asphalt. Similarly, farmers gain from railroad and highway expansions driven by the demand from the oil and gas industry.

Farmer Wealth

In 2011, energy lease and royalty payments to farmers amounted to $2.3 billion, almost half the value of payments provided by the USDA's direct payment commodity program, which was on average the largest federal farm income support program in the 2000s (Weber, Brown, and Pender, 2013). This increased wealth, in turn, may have various effects on farmer decisions. Payments may provide farmers with the money to expand and upgrade their operations, thereby improving their farms' long-term financial viability. Alternatively, the payments may allow marginally profitable farmers to retire early or switch to less labor intensive activities, for example, from dairy to beef cattle. The combination of early retirement among farmers and greater investment for others may cause the consolidation of production and land ownership.

Subsurface rights in most of the continental United States are privately owned. Before drilling for oil and gas, companies must lease the rights from the owner through a lease contract, which specify a payment to the owner for signing the lease (often called a bonus payment) and a percentage of the value of production to be paid to the owner (the royalty). The lease will also state a time after which the lease expires if production has not occurred. Upon expiration, the farmer may sign a new lease, earning a new bonus payment. Bonus payments may range from a few dollars to $9,000 an acre (Andrews, 2009; and Pronko, 2013). The standard royalty rate is 12.5%, though this rate can be much higher if there is a strong likelihood of marketable production (Fitzgerald and Rucker, 2013).

Because royalty payments are based on the value of production, they will vary substantially over time as the productivity of wells and energy prices change. A typical shale gas well can produce between 1 and 5 million cubic feet per day during the first month, but production can decline by nearly 70% by the end of the first year (King, 2014). After the initial rapid decline in production, wells can continue to produce gas at a slowly declining rate. There are differences in the methodology and parameters used in life-cycle analyses of well productivity (Branosky, Stevens, and Forbes, 2012), leading to production forecasts that vary from 20 (King, 2014) to 70 years (Fuquay, 2013). For a well that produces 2 million cubic feet of gas per day in the first month and an assumed natural gas price of $4 per thousand cubic feet, annual royalties would start at $200,000, drop to $80,000 in the first and second years, and decline to $23,000 in the sixth year (King, 2014). Since 2008, the wellhead price of natural gas has varied from $3 to $11 per million cubic feet.

Farmers, however, may not always own the rights to the oil and gas beneath the land that they own. In places where oil and gas rights have at one time held meaningful value, they were often severed from the surface rights in what is known as splitting the estate. Where oil and gas rights have value, a landowner may split the estate by selling a property but retaining the rights. Most of the areas with shale oil and gas resources have some history of drilling, making it less likely that the surface owners own the rights to the oil and gas below. Recently, Weber and Hitaj (2014) found small effects of shale gas development on farm real estate values in Texas' Barnett Shale. In contrast, shale development had a large positive effect on farm real estate in northeastern Pennsylvania, which does not have a history of drilling. The contrasting results likely reflect the prevalence of split estates.

Community Well-Being

Aside from affecting the profitability of farms, shale development can influence the well-being of farm households if the livability of their surrounding communities changes. The extraction, processing, and transportation of oil and gas have led to substantial decreases in air quality in some areas (Litovitz et al., 2013; and Rich, Grover, and Sattler, 2014), which have been implicated as the potential cause of nearby infant health issues (Hill, 2012). Noise and light pollution occur near shale wells and processing facilities (Clark et al., 2013). Differences in regulations across states can affect the magnitude of these negative impacts (Richardson et al., 2013). In New York and Pennsylvania, residents have expressed concern about the effects of a large influx of workers, and there is evidence that criminal activity can increase in counties experiencing drilling (Stedman et al., 2012; and James and Smith, 2014). Both prostitution and drug use have risen in the Bakken Shale (Boyce, 2014), while the fracking boom in Texas has been connected with a rise in fatal traffic accidents (Olsen, 2014).

Shale development can also create community tensions by increasing inequality (Schafft et al., 2014). Kelsey, Metcalf, and Salcedo (2012) found that lease and royalty income is heavily skewed to a small portion of residents in the Marcellus Shale. In some counties, only 11.3% of lease and royalty income accrues to the bottom 90% of landowners residing in the county.

Despite its various community costs, shale development has improved state and municipal finances through driller fees, severance taxes on gas production, or well fees. In 2011 and 2012, for example, Pennsylvania raised over $400 million in revenue through a per-well impact fee, some of which is allocated to local governments that host drilling operations (McNulty, 2013) to help off-set some of the aforementioned negatives that can occur with rapid business expansions in areas not prepared for the boom. Moreover, in some states, local governments can tax the value of oil and gas rights as property. Looking at the Barnett Shale in Texas, Weber, Burnett, and Xiarchos (2014) found that expansion in the local property tax base through appreciation of oil and gas rights led to greater school spending and higher housing values in shale areas.

Much Uncertainty Remains

Shale development has a range of diverse consequences for agriculture. They can be positive or negative and vary at the regional, local, and even farm levels. Farms in the Marcellus Shale are unlikely to face water quantity issues, compared to areas in North Dakota or Colorado, where water is scarce. Even there, the impact can vary across farms and over time. Farmers in areas without prior oil or gas drilling experience, such as northeastern Pennsylvania, are more likely to own their mineral rights and receive royalty income, which they can then invest in the farm.

The long-term effects of development, both economic and environmental, are still unclear since large-scale drilling began only in the early 2000s in Texas and later elsewhere. By financing investment, expansion, or retirement, the wealth created through lease and royalty payments may have long-term consequences for the agricultural landscape even after well production stops. Likewise, spills or other environmental mishaps could degrade some parcels of land for decades. In balance, shale development comes with challenges and opportunities for farmers and their rural communities with uncertain, long-term effects.

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Unconventional Oil and Gas Development: Challenges and Opportunities for Local Governments

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Much of the public attention to unconventional oil and gas development has focused on the potential environmental and health impacts, such as water degradation and air quality. Yet the social and economic impacts of such development, including the full range of activities necessary to produce oil and gas from a specific location, such as leasing; seismic testing; construction of access roads, wellpad, and pipelines; drilling; water acquisition and disposal; and well completion can also be substantial (Brasier et al., 2011; Farren et al., 2013; Ferrar et al., 2013; Finkel et al., 2013; Jacquet, 2014; Raimi and Newell, 2014; Schafft, Borlu, and Glenna, 2013; and Williamson and Kolb, 2011).

Such impacts can create challenges for local governments which bear substantial responsibility for public infrastructure, human services, public safety, and other services that may be affected by unconventional oil and gas development. The nature of such development exacerbates these challenges, which include sudden, major impacts on infrastructure and services; local control; and perhaps, most significantly, the need to plan proactively and appropriately to the development process.

Infrastructure and Service Impacts

The onset of unconventional gas and oil development in a community can create sudden major changes in the demand for services, depending on the scale of development and the population size of the communities affected. Work crews for unconventional energy development are highly specialized, typically focusing on only a small proportion of the tasks required to complete a well, so they frequently shift between locations within and between drilling regions to conduct their individual specialty. One workforce study in Pennsylvania estimated that it takes more than 420 workers, spread across 150 different occupations, to drill and complete a well; yet the total time required by all of these workers for an individual well only totals 13.1 to 13.3 full-time equivalent people (Brundage et al., 2011). In addition, the highly specialized nature of the workforce means many local residents in regions without substantial existing unconventional oil and gas activity initially do not have the skills necessary to compete for certain jobs. As a result, non-residents temporarily move into the community, in some cases driving up rents and creating housing affordability and infrastructure challenges (Williamson and Kolb, 2011).

The influx of new workers, particularly in rural areas with relatively low populations, can strain housing, at least temporarily (Farren et al., 2013; and Williamson and Kolb, 2011). In some western states, this has forced local governments to upgrade public sewer and water infrastructure (Raimi and Newell, 2014). Perhaps the most common service impact on local governments is road maintenance and repair (Jacobson and Kelsey, 2012; and Raimi and Newell, 2014), precipitated by substantial increases in truck and other vehicle traffic. Other potential impacts include increased or changing demands for police and emergency services (Jacobson and Kelsey, 2012; and Raimi and Newell, 2014), and even increased problems for some local governments to retain their workforce (Raimi and Newell, 2014). Complicating governmental responses to such changing service demands is the extent to which the demands will be temporary (e.g. lasting only as long as the boom) or long term. Often this isn't clear to local officials, yet it makes a significant difference in whether the services will be required for the future, much less how local governments should plan to pay for such investments. There are cases of local governments, such as Rifle, Colo., whose residents are stuck paying off infrastructure expenses long after the need for them while the energy companies and workers have moved on.

Documenting service and cost impacts on local governments can be difficult because local governments accommodate some increased service demands by shifting existing staff and other resources to cover the changes rather than increasing spending. For example, local officials in Susquehanna and Washington counties in Pennsylvania used such an approach to manage service impacts from Marcellus shale development (Jacobson and Kelsey, 2012). Measuring such impacts is much more difficult than looking at municipal or county budget changes, yet are no less real if other services have to be cut or reduced due to local government resources shifting to address impacts of unconventional oil and gas development.

Local Control and Coordination

The regionally dispersed nature of the drilling activity similarly creates control and coordination challenges for local governments. Much of the popular attention on drilling has focused on the well pads, including the drilling and hydraulic fracturing activity that occurs there. Yet unconventional oil and gas development activity is much broader than what occurs on the pads because it requires significant supporting infrastructure such as water withdrawal and impoundment sites; pipe and other material storage; sand unloading and storage facilities; gravel quarries for aggregate; equipment storage and maintenance facilities; and worker housing, some of which often are located an hour or more drive from the well pad they are supporting. Activity on any one well pad may only last several months, while activity at supporting locations can continue for years, as long as wells are being developed in the area. All this means that unconventional oil and gas development needs to be thought of as a regional activity, simultaneously spanning many communities (development typically extends across counties), rather than something that can be monitored or regulated solely by any one local jurisdiction.

Whether and how local governments can respond to the influx of development depends critically on the legal framework in their state, including the extent to which state laws allow mining and related activity to be regulated at the local level. Both New York and Pennsylvania have recently had major court decisions regarding the ability of local governments to zone or otherwise regulate unconventional gas development, clarifying the extent to which local governments are preempted from controlling such activity. In New York, an appellate court ruled that municipalities had that right under existing state law to ban shale development (Norse Energy v. Town of Dryden), while in Pennsylvania, the Pennsylvania Supreme Court threw out provisions of a recently passed state law that attempted to take away local governments' ability to zone or regulate such activity (Robinson Township v. Commonwealth). Even in locations where state law preempts local regulation of drilling activity, local governments typically do retain substantial control over other impacts arising from the supporting infrastructure, such as on housing, traffic, and public safety.

Officials in these states may find that local control of unconventional oil and gas development is a double-edged sword. From a community development perspective, local control is beneficial because it gives residents a voice in what occurs within their community. On the other hand, local control raises significant questions about the capacity of local governments to understand, monitor, and proactively engage in regulating unconventional oil and gas activity, which will be discussed in the next section. It also potentially makes implementation of regional responses more difficult. More fundamentally, local control may further exacerbate levels of conflict within some communities due to the development activity (Jacquet, 2014; and Kelsey and Ward, 2011).

With the large amount of lease and royalty dollars that can go to mineral rights owners, zoning decisions affecting where drilling can occur literally can be decisions about "who will be a millionaire." Similarly, there is the strong possibility that such decisions will lead to "takings" lawsuits from residents aggrieved that they are unable to lease or fully use their mineral rights. It is unclear how courts would rule on such "takings" claims, yet even if local governments are successful in defending against such claims, they likely will bear significant legal costs. If they are unsuccessful, the compensation and penalties they would owe easily could be in the millions. Either outcome could financially strain small, local governments with shallow pockets.

Local Capacity

One of the largest potential challenges is simply ensuring that local governments have the capacity to manage the issues arising with unconventional oil and gas development regardless of the local control options they have available. Much of this development is occurring in very rural areas, which typically are governed by governments with limited staff and resources, and offer a narrow range of services. Such staffing leaves little capacity to deal with sudden new demands on local government, and they can be overwhelmed by unconventional oil and gas development. In addition, the activity can be very fast with little advanced warning so that local governments and others can plan and adjust. Companies' plans may change unexpectedly, making local planning even more difficult (Jacobson and Kelsey, 2011).

Local government capacity can differ substantially, greatly affecting their abilities to respond to the issues arising with the unconventional development. For example, one of the Pennsylvania counties most affected by Marcellus shale development has a one-person planning office; in contrast, a larger neighboring county being similarly affected by Marcellus activity has almost 30 staff in its planning office. The larger county has been more effective in proactively planning and monitoring what is occurring, revising ordinances and plans, and dedicating staff to specific challenges such as transportation and housing.

The potential for sudden waxing and waning of drilling activity can make it difficult for local governments to decide whether or when to hire additional staff because it can be unclear how long additional staffing will be required much less whether new taxes and other revenues will be sufficient to pay for such positions. Even when they decide to hire, it can be difficult to find qualified candidates within the community itself due to the specialized skills required and difficult to attract non-local applicants due to disruptions in the local housing market.

The result is that much of the local government response to this activity is done with existing staff resources, who typically already have enough "normal" responsibilities to keep them occupied (Jacobson and Kelsey, 2011). Staff can get shifted to handle issues arising from the development, letting their previous responsibilities go unfulfilled. For example, some Pennsylvania local officials in highly active drilling areas reported that they spent one quarter of their time dealing with natural gas-related issues, while another township's two policemen spent almost all of their time dealing with gas-related traffic (Jacobson and Kelsey, 2011). Much of such shifting is to address pressing short-run issues, such as emergency road repairs, responding to citizens' questions and concerns, and inspecting infrastructure and building sites. It can be difficult in such a crisis mode to focus on long-run issues and to carefully consider the long-term implications of short-run decisions.

Planning for the Long Run

Of most importance is the critical need for local governments and communities experiencing such development to think long term rather than just focusing on the day-to-day crises which may arise during the onset of unconventional oil and gas development. The volatility of oil and gas prices can create sudden surges or declines in development activity, resulting in rapid influxes or outflows of workers in a community or increasing the difficulty in planning and providing public services. Even without this price volatility, the drilling phase of development requires much more labor than does the production phase (the Pennsylvania workforce study mentioned earlier, for example, found that a Marcellus shale well annually only requires 0.2 to 0.4 full-time equivalent jobs once it begins producing, considerably less than the 13.1 to 13.3 required during the drilling phase itself). Many of the jobs created from such a boom are in the extraction, retail, and construction sectors (Brown, 2014; and Marchand, 2012) which last only as long as the development activity occurs. Thus, the major employment impacts of unconventional oil and gas development largely occur during the drilling and development phases, which mean the end of drilling can result in a major economic shock to a host community.

Recent experience suggests that the short-term economic gains can be substantial; for example, state income tax returns from residents of Bradford County (Pennsylvania's top Marcellus drilling county) reported an overall 19.1% increase in personal income between 2007 and 2010 (inflation adjusted) with little change in the number of such tax returns filed (Hardy and Kelsey, 2013). The average change in personal income at the county level in Pennsylvania during this same time period was a 2.7% decline. Local governments similarly can experience short-run economic benefits, depending on the local tax structure. In their multiple state study looking at the short-term impacts, Raimi and Newell found that most local governments have experienced net fiscal benefits from the recent unconventional oil and gas activity, though the impacts have been negative for some governments in western North Dakota and eastern Montana.

For communities with struggling economies, such short-term economic activity can be hard to ignore. The risk is that such gains will occur only over a short period of time, and that the local economy may not be better off once the drilling slows or stops. When viewed as a temporary influx of dollars into the community, unconventional oil and gas development activity can create the potential for communities to grow and diversity their economies, making them better off in the long run than if the oil and gas activity had never occurred. An example of such a long run view is the myriad of Pennsylvania farmers using leasing and royalty dollars to pay off loans, buy new farm equipment, and repair buildings.

The long run implications of the volatility and eventual decline of economic benefits are less clear. The academic literature on the long term economic impacts of natural resource development offers mixed conclusions, with some studies suggesting that local economies do not benefit from such activity in the long term (James and Aadland, 2011; and Papyrakis and Gerlagh, 2007), while other recent work, such as Allcott and Keniston (2013) and Brown (2014), challenge this. It is clear, however, that local governments can fall into a "lottery trap," spending short-run gains without planning for a future downturn. Jokes about "doing better next time" are rife in areas that have experienced past boom and bust cycles.

The attitude of local officials toward the fiscal benefits from this development is critical. Because these tax and impact fee dollars result from extraction of a non-renewable resource, they will be unsustainable over the long term. Decisions about how to spend such revenues have critical, long-run implications for the communities. Incorporating these windfalls into annual operating budgets on items unrelated to the development activity, either by increasing spending or by providing tax cuts, puts the governments at risk of becoming too dependent on the extraction activity, exposing them to potentially difficult decisions once the drilling (and flow of dollars) slows or ends. Instead, if the funds are viewed as capital to invest in long-run community improvements of benefit after the drilling activity ends, such as strengthening or revitalizing infrastructure required after the drilling ends, improving parks or recreational facilities, or upgrading equipment or facilities, the dollars can help local governments make critical community investments for the long run that were not possible prior to the drilling activity.

Perhaps most importantly, the regional nature of unconventional oil and gas activity and the need to manage it at such a regional level has the potential of strengthening local governments' connections and working relationships with each other. Though difficult to do, improving such relationships can be of benefit in the future as new issues arise.

Activity based on non-renewable resources such as that with unconventional oil and gas development is unsustainable, and will end. Local governments and citizens need to manage the issues of the present while planning for the future to ensure that the decisions they make will leave the community at least as well off, if not better off, in the long run.

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Hydraulic Fracturing and Water Resources

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JEL Classifications: Q25, Q35, Q50
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The potential for impacts on water resources is often recognized as an important issue when shale gas development is discussed. Potential and significant impacts on groundwater and surface water resources might arise by wellbores traversing drinking-water aquifers, the use of significant water inputs, and the generation of large wastewater streams. Water withdrawals for energy development could reduce instream flows in rivers and streams, or reduce groundwater levels, diminishing ecosystem services—such as species habitat, recreation, and pollution assimilation—and reducing water available for other diverted uses. Water pollution from shale gas development could reduce or degrade the quality of available resources for uncompensated downstream users who divert water from shared rivers and streams, or users of a common aquifer. Accidental releases are one avenue for these impacts. Liquid waste treatment and disposal is another. Recent research is beginning to shed more light to better inform public concerns.

What Does the Scientific Literature Say?

Water Quality Concerns

The potential for contamination of groundwater from hydraulic fracturing has received significant attention in the popular media. Case studies of isolated incidents of groundwater contamination do suggest links with shale gas activity. For example, in Pavilion, Wyo., studies by two federal agencies found contamination in groundwater wells from shale gas activities, though it is not clear whether the source was a leak from the well casing or seepage from surface fluid storage ponds (U.S. Environmental Protection Agency, 2011; and Wright et al., 2012). In Alberta, Canada, an energy developer inadvertently fractured a well above the targeted gas-bearing formation, contaminating groundwater in the process (Energy Resources Conservation Board, 2012).

Regions with plentiful methane in the sub-surface often have high methane levels in groundwater, thus it can be difficult to attribute groundwater quality impairment to energy development. There is evidence consistent with migration of methane from Marcellus Shale gas wells in Pennsylvania to overlying groundwater wells (Osborn et al., 2011; and Darrah et al., 2014). In the latter study, results are consistent with casing and cementing failures as the source of contamination. The occurrence of this phenomenon is likely to vary significantly; a study in Arkansas' Fayetteville Shale did not detect evidence in groundwater of stray gas contamination or contamination by brine (Warner et al., 2013b).

Much of the public attention regarding groundwater contamination focuses on the process of hydraulic fracturing itself. However, the potential for the movement of brines and fracking fluids from deep shale formations to overlying aquifers through natural or induced fractures is debated in the scientific literature (Vengosh et al., 2014). The migration of fracking fluids and other contaminants, if it is even possible, would likely unfold over a long time frame, making impacts from current, unconventional gas development undetectable in the short run.

Though much of the public discussion has centered on potential risks to groundwater aquifers, risks to surface water rivers and streams may be greater in scope and magnitude (Krupnick, Gordon, and Olmstead, 2013).

And emerging evidence suggests that surface water quality impacts from shale gas development may be significant. The most significant measured impacts thus far have to do with the release of partially treated wastewater to rivers and streams. In the Marcellus Shale, 10% to 70% of fracking fluid inputs may return as flowback, along with formation brine, sometimes called produced water, which contains naturally occurring contaminants such as heavy metals and radioactive material (Vidic, 2013). Most flowback in the Marcellus is now recycled for new well completions, with the remaining liquid waste either trucked to industrial wastewater treatment facilities or transported to deep injection wells in Ohio, West Virginia, and New York (Jiang, Hendrickson, and VanBriesen, 2014). In western shale plays, there is little recycling of water inputs and essentially no shipments to wastewater treatment facilities—deep injection is a widely-available, cost-effective disposal option. In many shale plays, the regional wastewater treatment and disposal burden has expanded significantly due to energy development. For example, in Pennsylvania, shale gas wastewater flows represent a 570% increase over baseline oil and gas wastewater flows in 2004 (Lutz, Lewis, and Doyle, 2013). This increase is important whether shale gas wastewater is shipped to wastewater treatment plants or injected deep underground; the injection of very large quantities of new fracking waste into deep injection wells has caused faults to slip, resulting in seismic activity in states such as Arkansas, Ohio, and Oklahoma (Ellsworth, 2013).

Regulators have focused on shipments of flowback and produced water from Marcellus Shale gas wells to municipal and industrial wastewater treatment plants as a public and environmental health concern. In 2011, Pennsylvania banned shipments to municipal sewage treatment plants, though industrial "centralized waste treatment" (CWT) facilities continue to treat shale gas waste (Pennsylvania General Code, 2010; and Zhang et al., 2014). Impacts on rivers and streams from the incomplete treatment of the salty wastewater have been demonstrated (Olmstead et al., 2013; and Wilson and VanBriesen, 2013). The increased concentration of dissolved solids may affect economically important species such as brook trout (Weltman-Fahs and Taylor, 2014) as well as the quality of downstream drinking water (Wilson and VanBriesen, 2013). Radioactive material from treated shale gas waste is also accumulating in stream sediments after partial removal by CWTs, suggesting potential long-run impacts on human and ecosystem health (Warner et al., 2013a; and Zhang et al., 2014).

The water pollution problems from partially treated flowback and produced water being released to rivers and streams are serious, but they are regional in nature. As discussed above, most U.S. regions with significant shale gas resources also have plentiful deep injection well capacity for liquid waste disposal. The Marcellus Shale region is an exception to this rule, though the limited deep injection capacity in this region may be a problem in other global shale plays. Two additional surface water quality risks are not region-specific and may cause damages more broadly.

First, the recent rapid increase in shale gas development has caused an infrastructure boom, including well pads, pipelines, and roads. The associated land clearing, construction, and installation of impervious surfaces may increase stormwater runoff, erosion, and sedimentation of local rivers and streams, particularly because oil and gas construction sites have been exempt from the Clean Water Act's stormwater control regulations for construction sites since 2005. Empirical evidence of increases in total suspended solids (TSS) downstream of shale gas well pads in Pennsylvania has been demonstrated (Olmstead et al., 2013).

Second, the specter of widespread accidental releases contaminating surface water has been a focus of public concern. The only empirical study to examine this possibility shows no statistical evidence of systematic pollution associated with gas wells in Pennsylvania through 2011 (Olmstead et al., 2013). However, individual spills can and do occur. For example, a 2007 accidental release of fracking fluids to a creek in Kentucky had toxic impacts on fish, including two federally protected species, lasting several months (Papoulias and Velasco, 2013).

Water Quantity Concerns

Water inputs to hydraulic fracturing vary with geology, the amount of recoverable gas, number and length of horizontal wellbores, and other factors. Approximately 2 to 4 million gallons are required for wells in the Marcellus Shale (Veil, 2010), and somewhat more – about 5 million gallons per well – in the Barnett Shale in Texas and Oklahoma (Nicot et al., 2014).

Empirical evidence for hydraulic fracturing impacts directly related to freshwater extraction is thin. In the Marcellus Shale region, surface water is generally plentiful, and withdrawals for shale gas development represent a very small fraction of total withdrawals (Mitchell, Small, and Casman, 2013). Withdrawals for hydraulic fracturing in Texas—which includes part or all of the Barnett, Fayetteville, Haynesville, and Eagle Ford shales—amount to less than 1% of statewide water withdrawals (Nicot and Scanlon, 2012). In addition, while shale gas production is somewhat more water-intensive than conventional gas, it is less water-intensive than the production of most other fossil fuels such as coal, and conventional and unconventional oil (Kuwayama, Krupnick, and Olmstead, 2014).

However, the risks associated with surface water consumption can be expected to vary both spatially and over time. Globally, 38% of shale resources are in areas that are arid (Reig, Luo, and Proctor, 2014), where water's marginal value in alternative uses could be high. In Texas' sparsely populated Eagle Ford Shale, water use for fracking may increase to 89% of total use in area counties during peak production (Nicot and Scanlon, 2012). Water rights structures and the regulation of water withdrawals will mitigate the impacts to varying degrees. Even within a river basin, small streams may be relatively more sensitive to changes in water quality and availability than larger river segments; these smaller water bodies support about 40% of surface water withdrawals in the Marcellus Shale (Mitchell, Small, and Casman, 2013). In addition, water withdrawals during low-flow periods, such as summers and droughts, may have more significant ecosystem impacts (Entrekin et al., 2011).

While the amount of groundwater used for fracking in the humid eastern United States is negligible, fracking in arid and semi-arid regions uses significant groundwater inputs. For example, groundwater use in Texas' Barnett Shale represented about 50% of total withdrawals for fracking in 2006, though Barnett operators have since increased the use of surface water, and this percentage has dropped (Nicot et al., 2014). Even in semi-arid states, however, groundwater withdrawals for fracking represent a small fraction of total statewide withdrawals (Murray, 2013; and Nicot and Scanlon, 2012). The extent to which the resulting groundwater depletion represents a negative effect depends on geologic as well as economic and institutional factors. The rates of recharge in some aquifers are so low that many would be considered non-renewable resources over our lifetimes, and the speed at which they are depleted should take into consideration the future foregone uses such as for municipal drinking water supplies. Compared to the case of groundwater pollution resulting from hydraulic fracturing, far less attention has been given to groundwater use, including its impacts on agricultural production.

What Does the Economics Literature Say?

There is a growing literature in economics examining various impacts from hydraulic fracturing, including impacts on employment, health, and electricity prices (see Mason, Muehlenbachs, and Olmstead, forthcoming, for a review). Of this literature, only a small handful of papers focuses on water resources and fracking. A survey of Pennsylvania residents in four counties on the Susquehanna River found that they would be willing to pay an average of $10.46 per month—in aggregate, about $9.3 million per year—for eliminating all risks to area waterways through the "implementation of public safety measures around gas wells (such as the installation of containment ditches)" (Bernstein, Kinnaman, and Wu, 2013). In a different survey (Siikamaki and Krupnick, 2014) of a random sample of households in Pennsylvania and Texas, Texas households may be willing to pay about $24 per year to eliminate pollution related to shale gas development in 1% of the state's surface water bodies. Pennsylvania residents' willingness to pay for reducing such surface water impacts was about $10 per year (Siikamaki and Krupnick, 2014).Siikamaki and Krupnick (2014) have also estimated households' willingness to pay, in Pennsylvania and Texas, for reducing the risk of groundwater contamination. On average, households in both states are willing to pay about $33 per year to reduce by 1,000 the number of groundwater wells with potential pollution problems related to shale gas development.

A study of the Pennsylvania real estate market suggests that groundwater contamination risk from fracking—real or perceived—has been capitalized in housing prices. Using transaction records of all properties sold in 36 counties in Pennsylvania between January 1995 and April 2012, Muehlenbachs, Spiller, and Timmins (2014) compare the difference in impacts from drilling across properties that have access to publicly supplied, piped water and properties that depend on their own private, drinking water well. They focused on properties that were sold more than once and calculated the change before and after drilling a well. The researchers then compared how this change differed by drinking water source. Groundwater-dependent homes within a mile of a shale gas well lost about 3.4% of their market value after the well was drilled. These negative impacts become more pronounced the closer the house was to the well, reaching -16.7% within .6 miles (1km). Properties with access to piped water from public water sources, conversely, experienced small net gains (6.6%) on average at a distance of a mile, likely because royalty payments made to homeowners for the mineral rights offset other costs of proximity (such as the loss of a preferred visual landscape, potential pollution, or traffic congestion). However, those benefits tend to disappear for homes within a .6-mile-distance of a well, likely because the negative effects of proximity outweigh any benefits from lease payments. With these numbers they identify the component of the negative impact specifically attributable to groundwater contamination risk and find that this can vary between 10% to 22% of the house value, depending on the distance to the top of the well. This implies very large local economic impacts from groundwater contamination risk, or the perceptions thereof.

Towards a Full Cost-Benefit Analysis

The majority of the scientific literature to date has focused on water quality impacts, with less research on the water quantity impacts. There is evidence that incomplete treatment of wastewater at treatment plants has impaired downstream water quality in rivers and streams. There is also some evidence linking groundwater contamination to shale gas activity, and significant public concern about these impacts, with surveys indicating that people are willing to pay to avoid risk. Furthermore, the potential risk of groundwater contamination—real or perceived—from hydraulic fracturing has already had real effects on the housing market. Many of the risks discussed have not yet been monetized, which would be a necessary next step to perform a cost-benefit analysis.

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Unconventional Oil and Gas Development's Impact on State and Local Economies

Amanda L. Weinstein

JEL Codes: O13, Q32, Q33, R11, R58
Keywords: Economic Impact, Hydraulic Fracturing, Resource Booms

Economists have long regarded innovation as key to economic growth and crucial to raising the wellbeing of society. The innovative combination of horizontal drilling and micro seismic technology with hydraulic fracturing, commonly referred to as "fracking," has impacted the economies of communities across the United States. Hydraulic fracturing has opened up previously uneconomical shale resources for oil and gas extraction. Oil and gas production from shale has been steadily growing. Now, after decades of remaining heavily dependent on foreign energy sources, the United States suddenly and unexpectedly appears to be on the verge of becoming the largest oil and gas producer in the world.

Such sweeping change in the energy market has and will continue to benefit energy users from households to firms throughout the United States. While the benefits of low energy prices are shared across the United States, much of the economic benefits, particularly in employment and earnings, are concentrated on the regions that happen to find themselves located atop sizeable shale resources. These communities, which are often small and rural, are growing at exceptional rates.

Hydraulic fracturing has created new boom towns across the United States, but for towns such as Williston, N.D., this is not their first boom. When the energy boom of the 1970s went bust in the 1980s, many of Williston's new residents and businesses moved on to opportunities elsewhere. There are concerns about what will happen to these towns when this current boom ends. As with previous booms, volatile energy prices or unsustainable resources may make the boom go bust. It is, therefore, critically important for communities to have an accurate estimate of the recoverable resources available through hydraulic fracturing and the expected economic gains in employment and earnings. Communities can then weigh the benefits against the costs to prepare for what lies ahead. The first regions to see hydraulic fracturing drilling rigs on the ground provide valuable lessons learned about what to expect in the first years of shale development. Because this shale boom is still in its early stages, we will have to take a look further back for any lessons learned in the long run.

Looking to Early Innovation Adopters

Arguably the best way for these communities to gauge the probable economic impact is to look to communities that have already started hydraulic fracturing. In the Northeast region of the United States, Pennsylvania was the first. It is centered over the Marcellus shale play, the largest source of recoverable natural gas in the United States. Pennsylvania provides its neighboring states with an excellent case study on the economic impacts as shale development progresses.

In the first six years of increased activity (from 2004 to 2010), Pennsylvania gained approximately 10,000 oil and gas jobs (Figure 1). However, the impact of drilling reaches beyond that of just the jobs within the oil and gas industry, the direct effect. Shale development also has an indirect effect on industries supplying inputs to them as well as an induced effect from workers spending their earnings, for example, on restaurants, bars, and hotels. All of these additional items are called the multiplier effect. Previous

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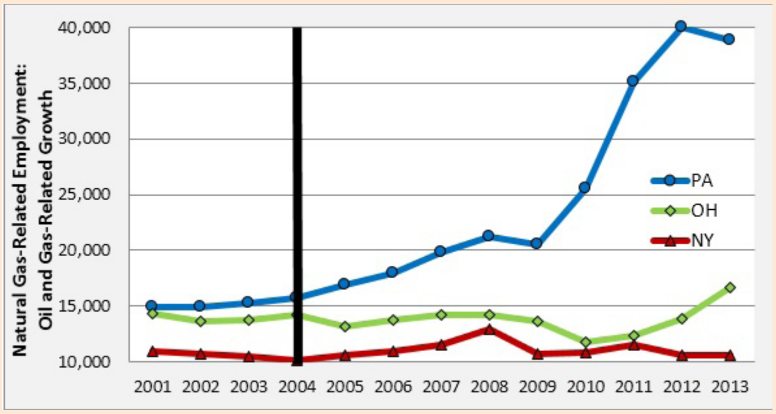
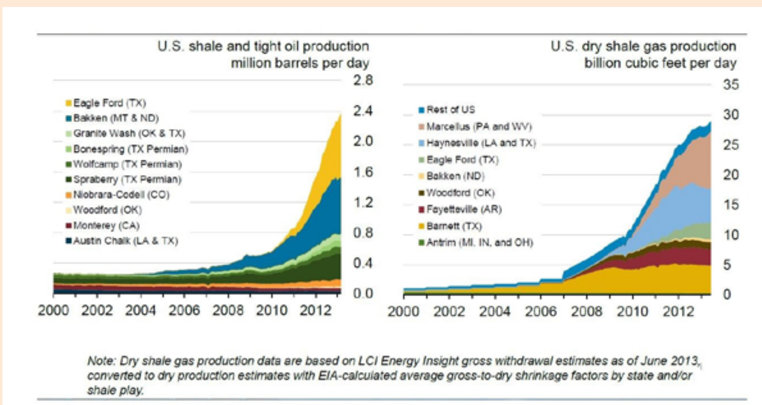
Figure 1: Historical and Projected Production of Natural Gas in the United States



Source: U.S. Energy Information Administration, 2012a

Figure 2: Historical and Projected Production of Natural Gas in the United States



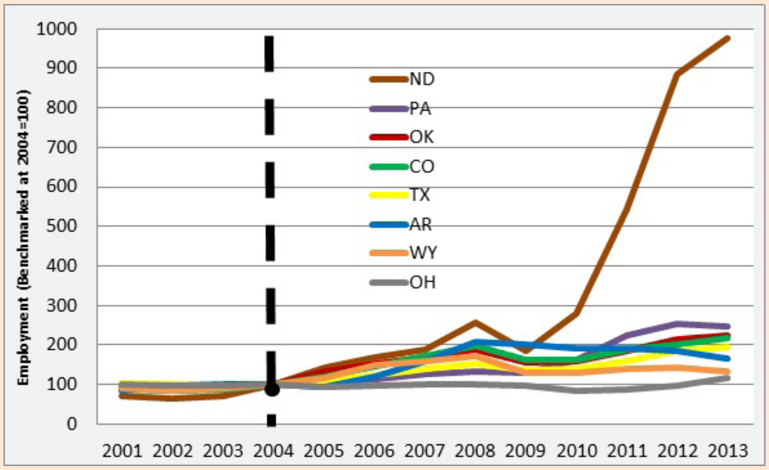
Source: U.S. Energy Information Administration, 2012a

literature generally finds that mining activities have a local multiplier effect of about 2 (or less), meaning that for every oil and gas job created in a locality there will be 1 additional job created in other industries in the area (Kraybill and Dorfman, 1992; and Black, McKinnish, and Sanders, 2005). Thus, using a multiplier effect of 2, Pennsylvania added a total of 20,000 jobs in the first six years of shale development (Weinstein and Partridge, 2011). However, it should be noted that more recent work on the impact of oil and gas employment growth suggests that a multiplier may be closer to 1.7 (Brown, 2014) or 1.3 (Weinstein, 2014). If the multiplier is less than 2, the total impact may be smaller than initial estimates. It also implies that the composition of the workforce is shifting more heavily towards mining industries.

Pennsylvania's neighbors, whom also sit atop the Marcellus and Utica shale plays, should expect oil and gas employment growth similar to Pennsylvania. Just a few years after Pennsylvania began drilling, Ohio followed suit. So far, Ohio's employment effect seems to be on par with Pennsylvania's. In three years since 2010, Ohio has gained approximately 5,000 direct oil and gas jobs, implying about 10,000 total jobs were created as a result of drilling activity after accounting for the multiplier effect (Figure 1). New York, on the other hand, instituted a moratorium on fracking in 2008 and recently voted to continue the moratorium until May 2015. Figure 1 depicts the diverging paths of these 3 states as a result of their different experiences with unconventional oil and gas development.

Pennsylvania's natural gas employment has continued to rise since 2010, adding 13,000 additional oil and gas jobs, bringing the total estimated employment impact of drilling to about 46,000 jobs from 2004 to 2013. The growth in oil and gas employment in just a few short years is impressive, though many, including the oil and gas industry, expected the impact would be significantly larger. Various studies predicted the economic impact would be an order of larger magnitude. One industry-funded report estimated that 140,000 jobs were associated with shale development in Pennsylvania in 2010 (Considine, Watson, and Blumsack, 2011). Another predicted that Ohio could expect closer to 200,000 jobs as opposed to 20,000 (Kleinhenz and Associates, 2011). There are a number of reasons why these studies estimated improbably large effects—from employing unrealistic assumptions in their models to double counting effects—and not accounting for some of the negative effects shale development can have on a community (Weinstein and Partridge, 2011; and Weinstein and Partridge, forthcoming). However, it should not be surprising to find modest employment impacts from shale development. First, the energy industry tends to be rather capital intensive with the output (oil or natural gas) requiring more capital than labor inputs in its production. Second, the energy industry accounts for just a small share of the economy. For example, even

Figure 3: Historical and Projected Production of Natural Gas in the United States



Source: U.S. Energy Information Administration, 2012a

after adding approximately 24,000 oil and gas workers in Pennsylvania, the oil and gas industry accounted for just 0.7% of a workforce of about 6 million in 2013. Even with tremendous growth rates, such a small industry would be hard pressed to have much of an impact on a large, statewide economy.

Pennsylvania is not the only state that has ramped up production of either natural gas or oil from shale by using hydraulic fracturing. Figure 2 shows the dramatic increase in oil and gas production from shale in the United States broken out by the various shale plays scattered across the country.

Figure 3 shows the growth of oil and gas employment in the various states most impacted by the recent developments in extraction from shale. For each state, the total number of oil and gas jobs is benchmarked at 100 for the year 2004—approximately when the boom began. The impact of shale development on Pennsylvania and the other states represented in Figure 2, though still notable, is dwarfed in comparison to North Dakota (Figure 3). North Dakota sits atop the Bakken shale play, the second largest source of recoverable oil from shale in the United States. Its oil and gas sector is now at about 24,000 jobs, up from 2,400 in 2004.

North Dakota's economy is significantly smaller than that in Pennsylvania. Thus, the oil and gas sector will likely have a larger impact on North Dakota than Pennsylvania. However, oil and gas jobs still make up less than 6% of employment and North Dakota's unemployment rate has dropped only slightly from 3.5% in 2004 to 2.9% in 2013 (Weinstein and Partridge, forthcoming; U.S. Bureau of Labor Statistics, 2014b). Expecting such a small industry to make a significant impact on even a small state economy is a bit unrealistic. The oil and gas industry is more likely to affect smaller economies, especially rural and remote areas, where drilling activity is often concentrated. That is where the large impacts will be.

Small Town Shale

North Dakota's drilling activity is most concentrated around Williston in Williams County. The share of oil and gas employment in Williams County was over 39% in 2013, significantly higher than the state's share of oil and gas employment (U.S. Bureau of Labor Statistics, 2014a). With a larger share of the economy, the oil and gas sector will likely have more of an impact at the county level. The unemployment rate of North Dakota dropped slightly during shale development, but the unemployment rate in Williams County dropped more significantly from 2.7% in 2004 to 0.9% in 2013 (U.S. Bureau of Labor Statistics, 2014b). With unemployment rates this low, Williston-area businesses reported having trouble finding enough people to work in restaurants, hotels, and other establishments even after raising their wages substantially (Johnson, 2012). The average weekly wage in Williams County tripled from 2001 to 2013 (U.S. Bureau of Labor Statistics, 2014a).

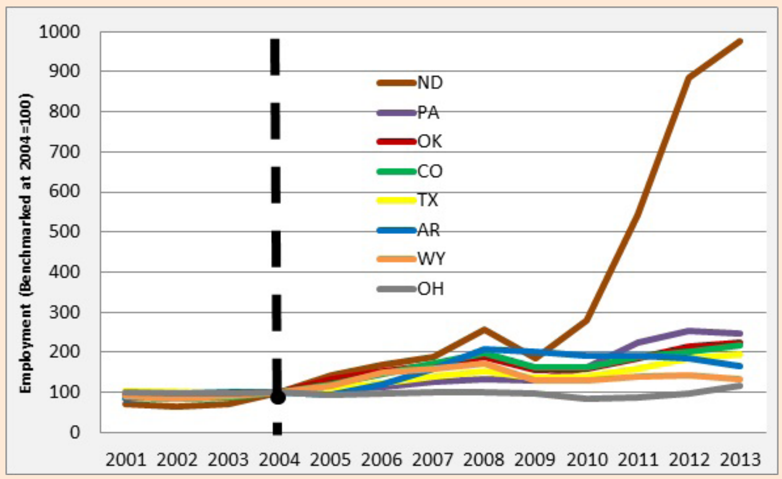
Many of these employees, along with oil and gas workers, come from out of state to fill these jobs in order to meet labor demands and the skill requirements of more specialized jobs associated with the oil and gas industry. The influx of workers has provided counties with a level of economic growth that most policymakers envy. However, the magnitude and abrupt nature of the economic growth in these small towns also means that these economic benefits come with growing pains such as strains on local services and the housing market (Oldham, 2012). There are reports of dilapidated roads, overcrowded schools, and workers sleeping in "man camps" made from shipping containers in Williston. Although higher home values are a boon to homeowners, residents who are renters will be negatively impacted by higher housing prices. However, Farren et al. (2013) found that, in Pennsylvania, shale development raised the fair market rent only in those counties experiencing the highest levels of drilling activity. In general, shale development had a somewhat minimal impact on the housing market in Pennsylvania. The contrasting housing market experience of counties in Pennsylvania and North Dakota is due to the fact that Williston is more rural and remote. Drilling counties in Pennsylvania can rely on nearby cities and more populous counties to supply extra housing. More rural and remote counties will likely be less prepared to deal with the strain on local services and the housing market.

County policymakers will need to be prepared for all of the costs and benefits that shale development may bring. Luckily, they can look to the regions that started this new wave of unconventional oil and gas development to better estimate their own expected costs and benefits in the short run. To get a fair and accurate estimate of the employment and earnings impact, we need to find a way to measure the immeasurable. We need to compare what happened in these drilling counties to what would have happened had there been no drilling activity at all, a counterfactual. A counterfactual should be a non-drilling county that is nearly identical to a drilling county in every way except there was no shale development. For example, before Ohio began drilling, it was a good counterfactual to compare with Pennsylvania (Figure 1). Without shale development, Pennsylvania's oil and gas employment would have remained flat or even decreased similar to Ohio.

To examine the impact on drilling counties in Pennsylvania, Weinstein and Partridge (2011) compared counties with the most intensive drilling activity in the Northeast and Southwest regions of Pennsylvania (Washington, Greene, Fayette, Tioga, Bradford, and Susquehanna) to similar non-drilling counties (Perry, Franklin, Cumberland, Union, Columbia, and Carbon). Figures 4 and 5 show the employment and earnings growth of drilling and non-drilling counties in Pennsylvania (benchmarked at 100 for the year 2004). Drilling and non-drilling counties appear to be on the same growth path before drilling activity begins, which suggest the chosen non-drilling counties are good counterfactuals. After drilling activities began, the growth paths of drilling and non-drilling counties diverged. Drilling counties in Pennsylvania have higher employment and earnings growth from shale development.

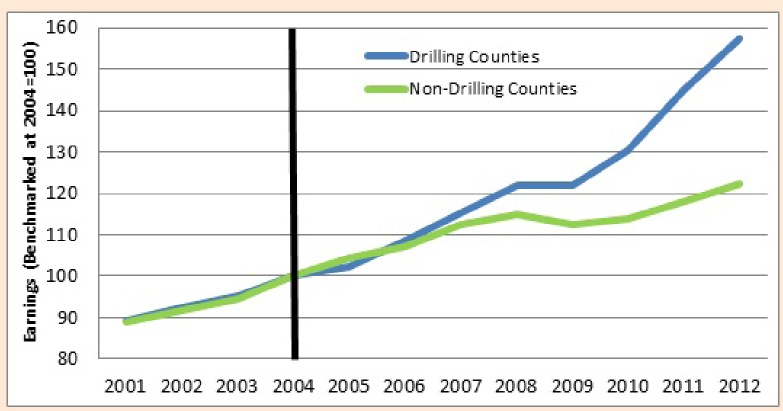
To get a more comprehensive look at the impact of shale development, Weinstein (2014) looks at counties across the United States finding that shale development is associated with a 1.3% annual increase in employment and a 2.7% annual increase in earnings. The impact on earnings is likely more significant due to a number of factors including higher wages in the area and income generated from leasing and royalty payments to landowners. Although the examination is short run, Weinstein does find that the economic impact of shale development seems to wane over time. To better predict what the long-run impact on their communities may be, policymakers will have to take a look further back to the fates of previous boom towns.

Figure 4: Historical and Projected Production of Natural Gas in the United States



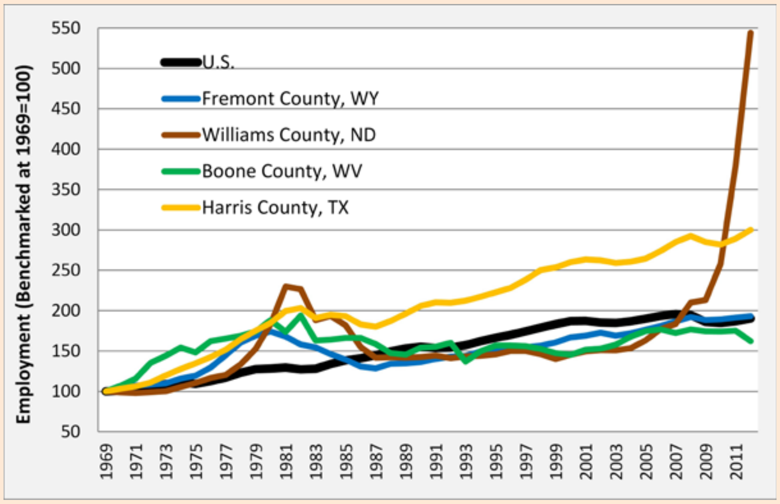
Source: U.S. Energy Information Administration, 2012a

Figure 5: Historical and Projected Production of Natural Gas in the United States



Source: U.S. Energy Information Administration, 2012a

Figure 6: Historical and Projected Production of Natural Gas in the United States



Source: U.S. Energy Information Administration, 2012a

Looking to the Past

This is not the first energy boom the United States has experienced and will not likely be the last. Figure 6 shows employment growth in the United States from 1969 to 2012. It depicts a few examples of previous booms in various counties across the United States, namely the energy boom of the 1970s.

Some residents of Williston (the county seat of Williams County, N.D.) have been around long enough to have experienced the previous energy boom, and subsequent bust, and are now wary of the current shale boom. The boom of Williston's past is evident in Figure 6. Williston's previous boom was among the most prominent during the 1970s with its economic growth far higher than the national average. Figure 6 also shows that Williston's boom in the 1970s was followed by a bust in the 1980s when energy prices dropped. After the bust, Williston's employment lagged the United States until the recent shale boom began lifting it back above the U.S. growth path. There are concerns that Williston will once again return to the sluggish employment growth that lags behind the United States but only after another bust hits. If a bust hits as before, there may be little to keep workers in Williston which could turn it into a ghost town.

Williams County is not the only county that received a jolt to its economy during the energy boom of the 1970s. Many of these communities experienced the same type of pattern: a large employment boom far outpacing the United States followed by a bust and fairly consistent sluggish growth thereafter. Jeffrey City in Fremont County, W.Y., has just such a growth path. Jeffrey City developed around the discovery of uranium and became a true company town with Western Energy actually managing the town itself and replacing any form of local government. Most people who moved to Jeffrey City did so to work for Western Energy. As energy prices rose along with expectations of increased nuclear power, the price of uranium rose from $8 to $40 per pound in just three years. As prices boomed so did Jeffrey City; the population rose from 750 in 1970 to almost 4,000 in 1980. Just as Jeffrey City was about to peak, the Three Mile Island accident changed national opinion on nuclear energy. Within just two years, 95% of the workforce left town. The volatility of energy prices and the reliance on one industry left Jeffrey City a ghost town (Amundson, 1995). All busts are not as severe as Jeffrey City, but it shows that the growing pains of the boom are typically minor compared to the strains associated with a bust.

Black, McKinnish, and Sanders (2005) examined how counties in West Virginia, Kentucky, Ohio, and Pennsylvania fared during the coal boom of the 1970s and subsequent bust in the 1980s. In terms of employment effects, they find that the bust had a stronger negative effect than the boom's positive effect. Less than two jobs were created for every 10 coal jobs created (a multiplier of 1.2) during the boom, but 3.5 jobs were lost for every 10 coal jobs lost during the bust. Additionally, highly skilled workers are more likely to leave in a negative demand shock like an energy bust while low-skilled workers are more likely to stay and become unemployed (Mauro and Spilimbergo, 1999). In these coal regions, local residents became more mobile during the coal bust because of the skills they acquired during (and, in part, because of) the coal boom. This compositional change in the local labor market as a result of a bust can decrease the skill levels in these areas. Counties in this region that are heavily dependent on coal, such as Boone County, W.V., will be especially impacted by such a negative demand shock. Coal mining accounts for over 30% of the workforce in Boone County (U.S. Bureau of Labor Statistics, 2014a) and Boone County's employment growth has been below the national average since the bust.

These are just a few examples among many of the boom towns that have gone bust in the United States, but does a boom town necessarily have to go bust? Maybe not. Harris County, Texas, which includes Houston, seems to have boomed along with other energy economies in the

1970s, but did not have a severe bust followed by sluggish growth. Its employment growth remained above the United States even after the downturn it experienced. Houston's experience likely differed because its economy is far more diverse than the other boom towns. The share of mining employment in Harris County is just over 4%, far less than that of Boone County, W.V., or Williams County, N.D. One industry simply can't bring the entire economy of Houston down. Additionally, the booms that do hit Houston are much more moderate. Dramatic and unprecedented booms like the one Williston, N.D., now finds itself in (Figure 6) may just mean it has farther to fall.

The Long Run Impact

The fate of our economy should not rest in the hands of one industry nor should one industry be expected to have a large impact, especially when that industry holds a rather small share of the economy. It also seems unfair to saddle an industry with such unrealistic goals and shortsighted of communities to ignore the potential long run impact. It should come as no surprise that the true economic impact of shale drilling is smaller than many initial estimates first suggested. Nevertheless, when an industry does hold a large share of the local economy as in Williston, N.D., and other small mining towns, the fate of the economy may rest in the hands of that one industry. In this case, the impact may be large enough to turn a small town into a boom town or a ghost town.

Unconventional oil and gas development has undoubtedly increased the employment and earnings in communities with shale resources. However, sustained, stable economic growth should be the goal of these communities or any community. We look to innovations and innovators to grow our economies and raise the standards of living in society, but these innovations and the resulting economic growth can be accompanied by growing pains, especially if growth happens too quickly. When boom towns arise, we justifiably fear the bust. The volatility of the boom-and-bust cycle can be difficult for a community to overcome. If shale boom communities can find a way to use the economic benefits of the boom to moderate the industry's impact, they may have less reason to fear a bust. Communities may be able to avoid or lessen the impact of a bust by using their newfound fortunes to prepare for the long run—by diversifying their economies, raising the skill level of their workforce, maintaining or improving their local services, and mitigating any other negative effects associated with drilling.

For More Information

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