How shale gas extraction affects drilling localities: Lessons for regional and city policy makers

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Abstract In countries around the world, the public debate over the prospect of high volume hydraulic fracturing for shale gas has revolved around its environmental impacts, while taking as a given that exploitation of this newly available natural gas asset will produce significant economic benefits for local and regional economies. In this paper the authors use multiple methods, including a case study of the Marcellus Shale gas 'play' in the USA, to examine how the economic costs and benefits of high volume hydraulic fracturing have been assessed. They argue that the economic impact models, which have been used to project potential benefits and job creation, provide only a fraction of the information needed to understand the consequences of drilling for the regions in which it occurs. The paper also examines some of the challenges local communities face in responding to the costs posed by shale gas extraction. The authors' analysis indicates that, while shale gas development may increase jobs and tax revenues in the predominantly rural regions where drilling occurs, it can also impose significant short- and long-term costs. To fully assess the economic effects of hydraulic fracturing, local and regional policy makers need to understand the boom-bust cycle that characterises natural gas development. This cycle has implications for local costs and benefits short term, and for the longer-term economic development prospects of localities in drilling regions.

Keywords: *Marcellus Shale, shale gas, high volume hydraulic fracturing, economic impact, economic development, local planning, local regulation*

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INTRODUCTION

High volume hydraulic fracturing for natural gas (HVHF, or as it is frequently called, 'hydro-fracking' or 'fracking') is being attempted in shale deposits around the world, including in the UK, Continental Europe and Canada. In the USA, the discovery of large shale gas deposits in many areas of the country has stimulated natural gas development, producing historically low prices for the commodity. At the national scale, the discovery and exploitation of natural gas assets has been welcomed, particularly in the wake of long-term economic stagnation.

At the local level, the calculation of costs and benefits is more complicated. Like all resource extraction industries, hydraulic fracturing is characterised by a boom-bust cycle. Jobs and spending rise dramatically in localities during the drilling or boom phase of shale development, but drillers leave the region when the commercially viable resource is fully extracted, producing an economic bust. In situations such as that occurring in contemporary USA, where a number of states are engaged in shale gas extraction, drilling rigs may move at short notice from one region to another, causing a series of economic disruptions as drilling starts up, shuts down and starts up again.[1] Regions hosting natural resource development industries have historically been characterised as afflicted by a 'resource curse' because, while the natural resource extraction boom brings jobs and population growth for a few years, it also increases public service costs and 'crowds out' other industries. Boom towns also frequently experience social problems brought about by the influx of a transient population that follows the oil and gas industry rigs from one place to another. After the boom ends, and the drilling crews and their service providers depart, the region may have a smaller population and a poorer economy than before the extraction industry moved in. If the boom-bust cycle is combined with environmental damage, the long-term costs to regions hosting the hydraulic fracturing gas extraction boom may be considerable.

Despite the potential economic and social problems associated with boomtown economies, it is environmental issues that have dominated public discussion of shale gas drilling in the USA. Environmental concerns revolve primarily around a particular technology HVHF — that uses millions of gallons of water along with chemical additives in a drilling process that fractures shale along bores drilled horizontally as well as vertically to extract more gas from formations deep underground. The questions about this technology have focused particularly on its effects on water supply and quality. Many of the environmental risks associated with fracking, however, are a result of the regional industrialisation connected with natural gas development. They occur on the surface rather than underground at the well site, including for example, air pollution from the thousands of trucks required to service the wells and from compressor plants along the pipelines that move the extracted gas to market. These risks are evaluated differently from one community to another and from one country to another. France has banned hydraulic fracturing because of worries about its effects on wineries and tourism; earthquakes connected with test drilling have stalled hydraulic fracturing in Lancashire in the north west of England; the Canadian province of Quebec has instituted a moratorium because of public fears about water contamination; and in the USA, the state of New York established a one-year moratorium on hydraulic fracturing in order to better assess its effects on the environment, including on local community character. AQ1

While there is an active international debate about the environmental consequences of hydraulic fracturing, it has been difficult for localities and regions to assess the predictions about how their economies will be affected by the drilling. Very little research has been conducted on the economic and social costs associated with hydraulic fracturing during the boom phase of development, or on what

Figure 1: Image from the report *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States* prepared for the US Energy Information Administration (EIA), US Department of Energy (April 2011), available at: http://www.eia.gov/analysis/studies/worldshalegas

will happen when the drilling phase ends.

In an attempt to close this gap, the authors review the evidence concerning the short-term (economic impact) and long-term (economic development) consequences of shale gas drilling and production, and examine the methods that have been used to project economic benefits. They demonstrate why an understanding of the boom-bust cycle of natural resource extraction is critical to an accurate calculation of how hydraulic fracturing will affect the local and regional economies where it takes place. They also describe some of the significant costs to communities that are typically associated with natural resource extraction booms. Finally, some of the planning measures that can mitigate the costs associated with natural resource extraction for the affected regions and localities are examined.[2]

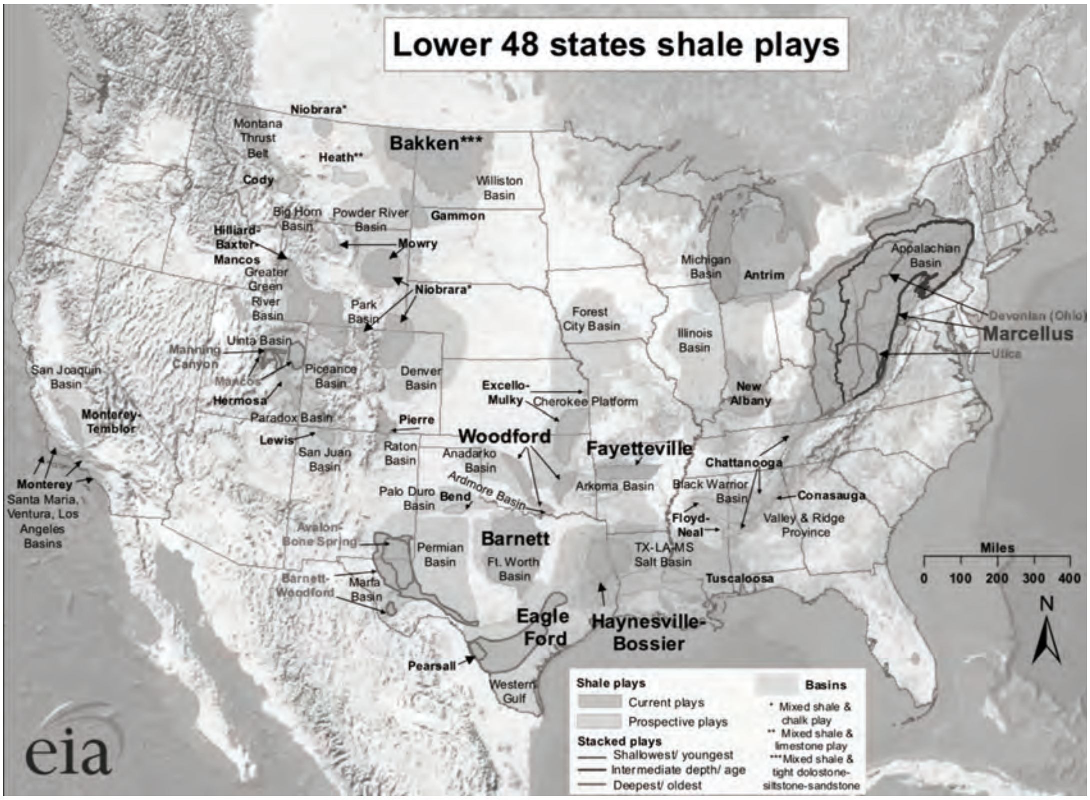
As an empirical anchor, particular attention is paid to a specific region at the centre of shale gas development in the USA — the Marcellus Shale gas play in the northern counties of Pennsylvania and southern counties of New York (Figure 2).

HOW HAVE THE ECONOMIC BENEFITS AND COSTS OF HYDRAULIC FRACTURING BEEN ASSESSED?

Despite concerns about the environmental damage that may result from fracking, US policy makers and the public generally assume that exploitation of this new natural gas asset will produce significant economic benefits for the regions where it occurs, reducing natural gas costs to residents and industries, and providing for long-term economic development. Media coverage of issues surrounding shale gas development has tended to reinforce this assumption.

The idea that dramatic, widespread and long-term economic benefits will accompany shale gas drilling is put forward in a series of input/output model based economic impact reports (EIRs) that have been supported by the oil and gas industry or its associated lobbying organisations.[3]

For policy makers and citizens, the utility of the information provided by these models depends on a clear



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

Figure 2: Map image available from the US Energy Information Administration website at: http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm#field

understanding of the assumptions behind and limitations of input/output (IO) models. In presentations of model results, however, critical information needed to assess the model results is sometimes missing. A model developed by IHS Global Insight, for example, projects that the shale gas industry supported 600,000 jobs in the US economy in 2010 and will support 870,000 in 2015. The model predictions are based on the number of wells to be drilled in the USA.[4] But because no information is provided on the number of wells the industry predicts it will drill, it is impossible to assess or validate the results of the model.

In addition, while IO models project the number of jobs that could be created from a certain level of expenditures on each well, they cannot tell us how many actual jobs will be created, who will get those jobs, or what they will pay. The fact that IO models can only provide job estimates is often ignored, and those estimates are portrayed incorrectly as real job numbers. Ultimately, because of the simplifying assumptions necessary to construct IO models, they cannot be used to analyse wide-ranging structural changes in a regional economy, such as those that occur in conjunction with hydraulic fracturing. These kinds of changes might include increased competition for labour across industries, or decreased ability to retain or attract other industries because of the noise and pollution associated with HVHF.

Kay[5] provides a thorough analysis of the IO model approach to economic impact prediction, emphasising that models can produce very different results depending upon the assumptions on which they are built. The most important assumptions affecting the results from these models are those regarding the pace, scale and geographic distribution of drilling activity.

An example of the care that needs to be exercised in evaluating the results of IO models and their underlying assumptions is the Broome County, New York economic impact study, which was developed very early in the learning curve on Marcellus shale gas drilling. The study authors assumed that hydraulic fracturing would occur uniformly across the County.[6] Analyses of actual drilling patterns in Pennsylvania demonstrate that this scenario (and the assumptions about expenditures that follow from it) is not realistic. Drilling locations are influenced by infrastructure (pipeline and compressor station) access, by topographic and geologic data used to target ease of drilling and high value results, by political considerations including proximity to potentially sensitive locations such as hospitals and schools, and potentially, by zoning regulation.[7] These locations are unlikely to be spread evenly across the terrain of a county. Calculating the amount of drilling that will occur by assuming that wells will be drilled over every acre of the County produced an unrealistic estimate of the amount of expenditures likely to occur in the County. The authors qualify their assumption by presenting a second scenario that cuts the total number of wells to be drilled in the County in half, but this is no more than a guesstimate. The authors do not attempt to determine either the pace or scale of drilling that is likely to occur in the County (based on an analysis of the pattern of drilling in other shale gas plays, for example), or factors likely to affect industry investment in a natural gas market where, in 2011, prices are at historic lows. Rather, they assume full development of the County's natural gas well sites within a short time frame.

The projections of job creation and local revenues constructed in IO analyses also depend on assumptions about where expenditures associated with the drilling of each well will be made. Given the geographic organisation of the US oil and gas industry and the concentration of all inputs (manufacturing of equipment, drilling labour, engineering services, etc) in Texas and Oklahoma, it is expected that — while there are local industries that *could* provide inputs to the drillers — a high proportion of expenditures associated with Marcellus shale drilling will be made outside New York or Pennsylvania. Again, an IO model only estimates *potential* regional expenditures. It cannot show that the projected expenditures will actually occur in the drilling region or whether they will rebound to the benefit of the region. Although oil and gas companies indicate that the largest portion of their expenditures in Marcellus Shale regions will take the form of payments to landowners,[8] there is little information to show where landowner leasing bonuses or royalty payments will be spent. If land or mineral rights owners live outside of the drilling region, it is unlikely that they will spend their payments in the localities where drilling is occurring, although they will be subject to taxes in those localities.

Evidence from already developed shale plays indicates that shale gas drilling relies heavily on a workforce that resides in Texas and Oklahoma and moves with the rigs from one shale play to another. Local employment is concentrated in trucking, construction, and retail jobs — many of which are part-time, short-term, and low-wage. Input/output model projections are rarely compared with actual employment data after the industry begins to develop. Using Pennsylvania Department of Labor and Industry data, however, the Keystone Research Center in

Pennsylvania indicates that Marcellus core industries have created approximately 9,300 jobs in that state since the shale development boom began in 2007. These numbers are significantly lower than the 48,000 jobs projected in the industry-supported IO studies.[9]

Finally, the types of IO models typically used to measure the economic impact of HVHF are only snapshots of the regional economy during the entire drilling cycle; they are static rather than dynamic. Because they are constructed around projected expenditures for the drilling of each well, the models do not indicate when expenditures will be made, whether they will be volatile or predictable, and when they will end. They focus their attention on the boom period, when money and population are flowing into the region. In reality, the drilling boom phase of the boom-bust cycle that characterises resource extraction industries may be brief, lasting under ten years. Input/output models cannot forecast what to expect in terms of the time frame for drilling investment, or what will happen when drilling ends.

The limitations of the models that have been used to project the economic impact of shale gas drilling suggest that local policy makers need to read the results of EIRs carefully and with some skepticism. They need to look at the assumptions that underlie calculations of jobs and revenue to see if they realistically portray where, when and how drilling and the expenditures associated with it are likely to occur. While these models provide projections of job creation and tax revenues, they cannot substitute for an analysis of the actual costs and benefits of the production process. For newer shale development regions like the Marcellus Shale, some information 'grounded' in actual experience is available: from case studies of regions that have been through the unpredictable production cycle that characterises natural gas extraction.[10]

In the next section the authors examine why it is necessary to know more about the factors that influence the pace and scale of drilling in order to understand its impact on shale gas drilling regions, both in the short term — the drilling phase, and in the long-term — once drilling has declined as a major stimulus to the regional economy.

THE PACE AND SCALE OF DRILLING AND THE BOOM-BUST CYCLE

The extraction of non-renewable natural resources such as natural gas is characterised by a boom-bust cycle, in which a rapid increase in economic activity is followed by a rapid decrease (Figure 3). The rapid increase occurs when drilling crews and other gas-related businesses move into a region to extract the resource. During this period, population increases and there is a modest increase in jobs outside the extraction industry[11] in construction, retail and services. When drilling ceases, either temporarily or permanently (because the commercially recoverable resource is depleted), there is an economic bust. Population and jobs leave the region.[12] Because of the costs of boom-bust cycles, communities and states anticipating this kind of economic cycle need to understand what will influence the pace and scale of drilling. In the case of HVHF, the pace and scale of drilling will determine the duration of the boom period of the cycle.

There are two ways to understand the pace and scale of drilling in a shale gas play. The first is based on an analysis of total potential natural gas reserves and the capacity of existing or anticipated technologies. For example, according to Engelder, the Marcellus might contain as much as 500 trillion cubic feet (tcf) of

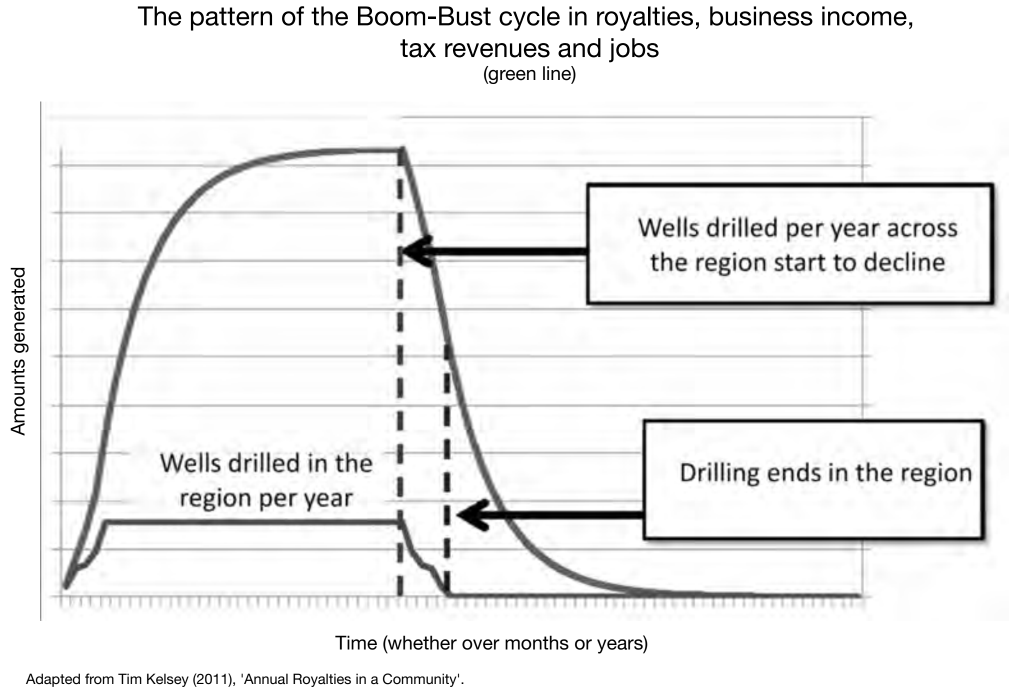


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Figure 3:

natural gas, and in a 2008 report with Lash, he estimated that perhaps 10 per cent of that gas (50 tcf) might be recoverable.[13] The following year, he estimated that recoverable reserves could be as high as 489 tcf.[14] More recent estimates of recoverable gas fall in the 200–300 tcf range. From a geologist's perspective, extraction of these total recoverable reserves could take decades.

Another perspective on the pace and scale of drilling looks at what are the likely firm strategies in response to their profit opportunities in particular shale plays and among potential extraction sites. For example, given a limited number of drilling rigs, they will be deployed in those places (within a gas play or across gas plays) where profits are most likely. The question for an energy company is not whether a well is viable in terms of potentially recoverable gas, but whether it is commercially viable — that is, will it make money for the operator (the owner of the mineral rights) and the drilling companies. An understanding of the choices made by operators and their subcontractors in a shale play requires an analysis of the costs and delivery rates of drilling operations, margins of commercial profitability, and corporate financial and competitive relationships.

Production in shale plays is unpredictable and only a small number of wells may be able to produce commercial volumes of gas over time without re-fracking, which is very costly. Evidence from the Barnett and Haynesville shale plays in the USA, for example, indicates that high initial production rates may drop off rapidly, making it difficult for operating companies to cover their finding and development costs. Industry investment advisors are cautious about the long-term productivity of the US natural gas plays. Their advice to investors is simple: 'Shale production is characterised by a steep decline curve early in its productive life.

The more oil and/or gas that you can make up front the better the economics.'[15]

And, according to geologist and investment adviser Arthur Berman, who has analysed production trends across US shale plays:

> … most wells do not maintain the hyperbolic decline projection indicated from their first months or years of production. Production rates commonly exhibit abrupt, catastrophic departures from hyperbolic decline as early as 12–18 months into the production cycle but, more commonly, in the fourth or fifth years for the control group. Pressure is drawn down and hydraulically produced fractures close… Workovers and additional fracture stimulations may boost rates back to previous levels, but rarely restore a well to its initial decline trajectory. More often, a steep hyperbolic or exponential terminal decline follows attempts to remedy a well's deteriorating performance. [16]

The possibility that only some wells will exhibit the hyperbolic production curves that are used to describe trends *across* wells in a shale play adds to the uncertainty for investors, operators and for the communities where drilling occurs.[17] Because shale plays may not produce the long-term commercial results indicated by the hyperbolic curves used by the industry to describe production (and encourage investment), they add to the financial risks already attendant to shale gas drilling.[18]

The risks and uncertainties facing investors and drilling communities have been exacerbated by the debt-driven character of development in shale plays. Operators have sought to buy up leases and hold them during a period when money and leases can be had cheaply, but this has put them into debt. The short-term prospects for reducing that debt are uncertain because of depressed US natural gas prices. A typical boom occurs during a period when energy prices are high. The current shale gas drilling boom in the USA, occurring during a period of low US natural gas prices, appears to be driven as much by the low cost of borrowing capital and global investment as by anticipated profits from the natural gas itself (if sold in the USA at current prices).

Despite the financial risks associated with natural gas drilling anywhere in the USA, the Marcellus Shale is considered to have among the best economics of the large US shale gas plays because of the potential richness of its reserves, but also because of low transport costs to the major domestic natural gas markets, inexpensively-acquired leases, and the absence of severance taxes. It also has significant drawbacks because of its proximity to populated areas, and the prospect of regulatory controls over water withdrawal and wastewater disposal as well as on the drilling process.

For those living in the Marcellus Shale region, gas operating company assessments of the commercial viability of wells and how to best exploit the resource have important consequences. Evidence from the Barnett Shale (in Texas) suggests that individual Marcellus wells may have short commercial production lives. Because the Marcellus play is large and geologically complex, however, the play as a whole is likely to have natural gas drilling and production over an extended period of time. Individual counties and municipalities within the region are likely to experience accelerated boom and bust cycles, while the region as a whole is industrialised to support continued drilling, storage, and transportation of natural gas. Counties where drilling-related revenues were never realised or now have ended may still be impacted by this *regional* industrialisation, such as truck traffic, gas storage facilities or pipelines. These more widely distributed impacts need to be taken into account when anticipating what effects natural gas drilling will have on communities, their revenues, and the regional labour market, as well as on the environment.

In anticipating some of the costs, it is possible to learn from the experience of already developed shale gas plays in the USA.

WHAT DO WE KNOW ABOUT WHAT OCCURS IN LOCAL COMMUNITIES AND REGIONS WHERE SHALE GAS DRILLING OCCURS?

Natural resource extraction industries typically play a small role in national economies. They are capital rather than labour intensive industries and their employment impact is tiny compared to industries such as retail or health services.[19] On the other hand, these industries have major impacts on the regions where production takes place. Shale gas drilling brings a short-term economic boom to the regions that experience it. As drilling companies move into a community, local expenditures rise on everything from car parts to pizza and beer. New jobs are created in construction, hotels and retail. Landowners receive mineral leasing and royalty payments and have extra spending money in their pockets. This increased economic activity is very welcome, especially in light of the 'great recession'.

In the USA, high volume hydraulic fracturing for shale gas has been taking place since the early 2000s, primarily in the western states. In the Marcellus Shale states of eastern USA hydraulic fracturing is even more recent. Even over this short period of time, however, experience is providing critical lessons. Each state has a distinctive set of issues because of differences in ownership (public vs. private land), climate, terrain, proximity of the play to population centres, and the availability of skilled labour. Yet despite these differences, the experience of shale gas regions can be used to identify common issues that are likely to arise with shale gas extraction. Among the most consistent local policy and planning issues across shale gas regions are those that derive from the boom-bust cycle of shale gas development, and the unpredictability of drilling and production activity across time and space.

Unfortunately, a full description of impacts on local communities is difficult to assemble because — with the exception of data on crime statistics — data must be assembled county-by-county, or agency-by-agency locally. There is an analysis of social and economic impacts common to counties in the Western States, where the local impacts of rapid development of shale gas drilling have been documented,[20] and anecdotal evidence from counties in the northern tier of Pennsylvania. Although not definitive, the accumulating body of evidence provides a picture of what localities can expect with natural gas extraction and what they should plan for. In the next section, the authors examine some of the most prominent of those impacts — on population, employment, and public services.

LOCAL SOCIAL AND ECONOMIC IMPACTS OF SHALE GAS DEVELOPMENT

At the heart of the social and economic challenges facing communities where natural gas development occurs is the rapid increase in a transient population using the region as a production site. Perhaps unexpectedly, this rapid increase in activity is not associated with a commensurate increase in population resident in the counties where the drilling occurs. The authors' analysis of population change in core natural gas drilling counties during the first decade of the

2000s indicates that the resident population in these largely rural counties has grown marginally if at all. There are various reasons that population growth does not occur in these core counties, but the most frequently cited are the absence of services, the higher cost of living, and the lower quality of life in an industrialised environment. For these reasons, the economic and social impacts of natural gas development are likely to be felt not only locally but regionally, affecting cities and counties in areas adjacent to the drilling localities themselves.

Another reason for the absence of new residents in drilling counties is the character of the workforce engaged in drilling and the transient demand for the services provided to drillers and drilling companies. As described by Jacquet,[21] the drilling phase of shale gas development usually depends on an out-of-state workforce. Although resident workers may be employed during the drilling phase as truck haulers or in service and construction jobs, even these jobs may be filled by workers who move into the drilling area while maintaining a permanent residence in another state. This in-migration of transient workers has been exacerbated by the great recession in the USA and the paucity of job opportunities elsewhere in the nation. In the case of the drilling workforce itself, this means a sudden influx of young men — some with families, many without. Some will be experienced gas field veterans, others will be those drawn from other places to the boom and the prospect of work.

In Sublette County Wyoming, for example:

> As the number of gas wells drilled *per year* (authors' emphasis) exploded from 100 in (the year) 2000 to more than 500 in 2007, the population of Sublette County swelled by 24%. During that same period, Wyoming's population grew by just 4%, indicating that workers and their families were flocking to the area to meet the new labor demands. The largest increase in population came from teens and young adults, aged 15 to 24, followed by adults aged 25 to 44.[22]

This short-term population influx also creates significant demands on public services.

According to Jacquet,[23] traffic on major roads increased, as did the number of traffic accidents, the number of emergency room visits, and the demand for emergency response services. In addition, local schools experienced increased demand as new workers entering the region enrolled their children. And, as demand for all manner of good and services increases and local businesses seek to exploit the boom, prices go up — not just for temporary residents, but for long-time local residents as well. Jacquet found that local prices in Sublette County increased by twice the national rate over a six-year period.

Williston North Dakota is an isolated prairie town where another shale gas boom is occurring, and it has been inundated by people from all over the USA looking for work. While they frequently find work, they have nowhere to live. The homelessness rate in the city has risen to at least 19 per cent, with many people living for long periods in temporary quarters.[24] Unfortunately, the boom-bust cycle of gas development discourages investment in the housing needed for this workforce. Local interviews indicate: 'Developers have been slow to build more apartments, largely because they got stung by the region's last oil boom that went bust in the 1980s.'[25]

The price inflation characteristic of shale boom areas especially affects rental housing. Evidence from across shale plays indicates that rents rise dramatically in drilling areas. Local long-term renters who cannot afford their apartments any longer are displaced, and may seek housing assistance from local government. Hotels and motels fill up with transient gas drilling workers.

This increased demand for hotel rooms may benefit hotel and motel owners and local restaurants, but it hurts other local businesses, as hotels may have few rooms available for a more traditional clientele: business travellers, recreation seekers, and tourists.

In the long run, given the population declines suffered by many communities in the Marcellus region, this influx of new people may be welcome. Some newcomers may like the area and decide to stay. According to a recent US Associated Press story,[26] the small state of Wyoming has seen population increases and an unemployment decline over the past decade, especially in communities near gas drilling areas. But for local governments, this population influx comes with added costs, both in the short run and in the long run.

The consistent theme is that local governments — counties, cities, townships, villages — are subjected to a wide range of demands for new services or increased levels of service, and that the administrative capacity, staffing levels, equipment, and outside expertise needed to meet those demands are beyond anything that has been budgeted.

Infrastructure impacts

One critical area of impact is on local roads and bridges. As Randall points out:

> Dust, noise, and road damage from industry truck travel are tops on the list of citizen complaints in areas where gas is extracted via shale gas drilling. A typical Marcellus well requires 5.6 million gallons of water during the drilling process, in almost all cases delivered by truck. Liquid additives are shipped to the well site in federal DOT-approved plastic containers on flatbed trucks; hydrochloric acid and water are delivered — and flowback is hauled away — in tanker trucks. Millions of gallons of liquid used in the short (weeks-long) initial drilling period account for half of the estimated 890 to 1340 truckloads required per well site. Because of its weight, the impact of water hauled to one site (364 trips) is the equivalent of nearly 3.5 million car trips. Few roads at the town level in New York State have been built to withstand this volume of heavy of truck traffic.[27]

Pennsylvania state officials report scrambling to re-route trucks in the wake of rural roads sometimes rendered impassable for local motorists or emergency responders, while sources in the Barnett Shale region of Texas cite early deterioration of city streets that increases the burden on taxpayers. That is because, even though access roads to the well sites are built and maintained by the operators, many of the journeys made by all those trucks are on public roads. Most roads, especially the rural roads that predominate in the Marcellus region (and especially under Winter and Spring freeze-thaw conditions), are not designed to withstand the volume or weight of this level of truck traffic.

In Pennsylvania, local governments can utilise State Department of Transportation protocols to post weight limits and require permits and bonding of overweight truck operators, an incentive for the operators to either do the excess maintenance themselves or pay for damage to the roads. However, operators are inclined to post bonds only in municipalities or counties where they have well sites, while the trucks travel much longer routes through other towns and counties. Their roads are left vulnerable.

Recommendations from those in

already developed shale plays centre on the planning, posting, and enforcement of truck routes that minimize the intrusiveness and damage caused by high-volume truck traffic, and on local Road Use Agreements (RUAs) or state-level fees that support accelerated road maintenance while gas drilling or production activity is underway.

These need to be supported by comprehensive traffic impact studies, well-documented baseline data backed by video and photographs of pre-development road conditions, and specialized legal advice — processes that require additional staff and, for most communities, funds for consulting engineers and lawyers as well.

Whatever regulation and technical assistance the province or state may provide, many of the costs of drilling fall on local governments. And, these costs are likely to fall on some localities where drilling makes no appreciable contribution to the economy either through job creation or tax revenues. Contemporary shale gas drilling is likely to have both intense local impacts for the drilling period, and longer-term regional consequences as well because of the widespread industrialisation that accompanies contemporary hydraulic fracturing.

Regional industrialisation impacts

Well pads are not the only feature in the industrial landscape brought about by shale gas development. Water extraction sites must be developed to fill trucks transporting water to the well pads. After extraction, the gas has to move from the well sites to the main transmission lines via a network of pipelines and compressor stations. Toxic flowback and produced water from the wells has to be transported to treatment facilities, which must be built to handle its particular array of toxic waste.

These elements of the industrial landscape will be located where geologic or logistical factors dictate, but not necessarily in the jurisdictions where drilling is currently taking place or production (and therefore tax revenue) is being generated. For local governments, the same questions as for well sites or pipeline infrastructure apply to these facilities: Who — the state, the province, or the localities — is to regulate them, and monitor and enforce standards; what staffing and resources will that require; and how shall the funds to support those efforts be provided?

These facilities typically include:

- 'Man camps' (essentially caravan sites) for short-term out-of-state workers
- Depots for equipment
- Staging areas
- Gravel quarries
- Water extraction sites
- Wastewater treatment plants capable of handling toxic material
- Injection wells
- Disposal areas (landfills)
- Gas storage facilities.

Connecting all these facilities and services are rail spurs and thousands of heavy trucks.

These industrial facilities create a wide range of potential environmental hazards and stressors, all of which have implications for the regional economy and adjacent industries, such as tourism and agriculture. For example, apart from the dangers inherent in a widespread network of pipes full of methane or in high-pressure equipment generally, noise is a major concern related to compressor stations: they produce noise levels in the 85 to 95 decibel range. These levels are at or above the US Occupational Safety and Health Administration (OSHA) threshold of safety for an 8-hour day, and compressors work a 24-hour day. These environmental stressors can have an effect on nearby citizens, adjacent property values, and on other industries in the vicinity, particularly agriculture and tourism.

In the USA, regulation of this extensive industrial infrastructure is likely to occur at a level of government above that of the locality. Localities may have a role in the permitting of pipeline routes along city/county rights-of-way. Local government may also require filings and notice to abutters, and demand incident reporting and filing of as-built drawings for emergency planning. For compressor stations, local regulation may be able to establish setbacks, maximum noise levels, fencing and landscaping requirements, and enhanced standards for units adjacent to residential areas.

If not reused, flowback fluids from the hydro-fracking process or the produced water from producing wells must be removed from the well sites by trucks and transported to treatment facilities or injection wells. These facilities, too, may be subject to permit or construction standards that are set or implemented at the local level. All of these local or regional activities require expertise, administration, monitoring, and enforcement capacity, and all entail planning and public administration costs.

One example of the impact industrial facilities may have on a region is provided by the proposed gas storage facility in the Finger Lakes region of New York State, a major area for tourism because of its scenic beauty, small towns and vineyards. This facility is being planned by Inergy Midstream, LLC for the former US Salt plant just north of Watkins Glen, New York, with underground storage for 1.45 billion cubic feet of natural gas. The new owners propose to add an up-to-88.2 million gallon liquid propane storage facility, also underground, plus a 14-acre, 92 million gallon brine pond on the surface.

The site for this major facility is near the intersection of two gas transmission pipelines and, as a salt mine, is an appropriate natural gas storage site. But Watkins Glen is in Schuyler County, which is not part of the 'fairway' — the purported 'sweet spot' for Marcellus drilling in New York, so it is not likely to obtain local tax revenue from well production. Whatever the plant may contribute in the way of local taxes, Watkins Glen currently depends on revenue from Finger Lakes tourism, attendance at its famous road race, the local wine industry and agriculture. Consequently, the potential hazards to air or water from such a facility, or the prospect of a fire or explosion, are particularly troubling to local policy makers. On the other side of the equation, this capital-intensive plant operation is expected to produce only ten jobs after its construction.

Officials in regions already experiencing shale gas drilling encourage planning and the development of fewer, centralised locations for all these industrial functions, in order to minimise the impacts on local communities. Because hydraulic fracturing entails a regional industrial infrastructure, this planning will necessarily require inter-county cooperation and state assistance.

Finally, the regulation of whatever facilities are constructed will be a responsibility shared between the state and local governments, in ways as yet unclear. Localities will have to allocate resources to negotiating with the state — and many departments of state government are involved — for agreements that protect their interests and those of their citizens.

HOW ARE LOCALITIES RESPONDING TO THE CHALLENGES POSED BY SHALE GAS DRILLING?

Different communities respond differently to the prospect of natural resource extraction in their region, as do their policy makers. One factor in these differing responses lies with citizens' familiarity or unfamiliarity with the industry. Another appears to be a difference between a 'dominion' and a 'stewardship'orientation toward the natural world. In a survey of 6,000 households in the drilling regions of New York and Pennsylvania, respondents who perceive lower risks from hydraulic fracturing think of the natural environment in terms of its utility, while those who perceive higher risks see humans as part of — and responsible for — the ecosystem. The survey indicates that most residents value the quality of life in their largely rural communities and they are concerned about the lack of jobs, but they weigh those concerns differently. Although there is a large middle group of respondents who are not clear about what will happen to their communities, there are sizable groups that are polarised in their expectations about the impacts of shale gas development, and that trust different sources of information on what is occurring. This bodes a fractious political environment for local officials, and suggests the need for careful planning: 58 per cent of those surveyed think that the negative impacts associated with hydraulic fracturing can be prevented, but only 22 per cent indicate that those negative impacts can be repaired once they occur.[28]

In the USA shale gas plays that have been in operation for some time, local government officials have the benefit of looking back on their experience and on what they think are the most important measures that communities can undertake when faced with the challenges posed by natural gas drilling. Their recommendations emphasise efforts to educate the general public and landowners in particular, and to make the process of natural gas development as transparent as possible.

According to these experienced local officials, administrative costs for all manner of planning, permitting, monitoring, and enforcement activities rise, as does the cost for computer systems to support them. So do demands on the police, courts, jails, services to displaced renters, and other social services. To these are added demands on the school system, on the public health department, and on the healthcare system generally. Fire and emergency services must be prepared for the kind of fire, accident, or spill incident that drilling operations can produce, requiring new equipment and training, though many communities have volunteer or 'call' operations that may not ever be prepared, or willing, to take on a major hazardous materials incident.

A Clinton County Pennsylvania review of the early impacts on their departments turned up one additional factor in the costs to government: losing their employees to private sector jobs in the gas play. That adds the cost of recruiting and training new staff, and the need to increase salaries to attract or retain them.

All this suggests to local governments three crucial elements of preparation:

1. **The need for baseline data.** Without the baseline data on roads, water treatment, rents, traffic, use of government equipment, etc, local governments cannot hold the well operators or their subcontractors accountable for the increased cost to local services that their activities generate, nor can they make a good case for relief from the state.
2. **The need for a dedicated revenue stream from gas production.**
3. **The need to budget for future costs.** Just as the unfolding of demands on localities from the effects of shale gas development may not correspond to the flow of tax revenue from gas production or lease/royalty payments to

landowners, so the effects of shale gas exploration may last far longer than the boom in drilling activity in any given locality. Lowering property taxes during the revenue boom may only lead to raising them even more when the full effects on local government operations are realised. Better to utilise the variety of budgeting instruments — fiscal impact fees, trust funds, capital reserve funds and a healthy fund balance — designed to stabilise the tax rate by setting aside monies to defray future costs.

WHAT DO WE KNOW ABOUT THE LONG-TERM ECONOMIC EFFECTS OF HVHF SHALE GAS DEVELOPMENT ON LOCAL AND REGIONAL ECONOMIES?

In this paper, the authors distinguish between the short-term impacts of HVHF natural gas drilling — on jobs, revenues, and costs to communities — and the long-term consequences for economic development. Economic development (as distinct from economic *impact*) is defined here in terms of indicators that show whether a county or region's population has an improved standard of living, job opportunities, and the kind of diverse economy that can weather downturns in any particular industrial sector.

It is evident that natural gas drilling will create work in shale gas regions during the drilling phase. The population flowing into the region will create demand for retail businesses and in hospitality industries, such as hotels and restaurants. Construction activity will also increase. Analyses of what kinds of jobs are likely to be produced during the drilling boom underscore that these three sectors are most likely to create jobs outside of the drilling industry itself. However, as Barth notes,[29] there are reasons to be cautious about the natural gas drilling industry as a route to long-term economic development, especially in rural counties. This caution arises from studies that show that rural regions whose economies are dependent on natural resource extraction frequently have poor long-term development outcomes. In some cases, they may end up worse off after a boom-bust cycle than they were before it started. While this may seem surprising given the economic activity that floods into a region during the drilling phase, there are some readily understandable reasons for poor long-term prospects.

First, the crews who come into a region place demands on a limited housing stock and housing prices rise, driving low income renters to leave the area, and creating a potential labor shortage for other businesses. This type of displacement can be seen in Northern Pennsylvania, where low-income families are being displaced by drillers in the local rental markets around the drilling sites.[30]

While competition for labour creates some short-term winners among locals, such as truck drivers, it also raises costs for other businesses in the region as labour costs for those occupations rise. For example, dairy farmers in the Marcellus region of northern Pennsylvania and the southern tier of New York, who are already in a marginal economic situation, are being further squeezed because of rising costs for transporting their milk to the dairies. These businesses may go under during the drilling phase, leaving the region with fewer businesses outside of gas drilling, and thus a less diverse and more volatile economy.

Economists refer to the situation in which short-term but high-wage resource extraction leads to a poor business climate for other businesses as 'crowding out'. While crowding out particularly affects businesses that require a reliable low cost labour supply (agriculture, tourism, or retirement communities, for example), even higher wage businesses such as manufacturers may be deterred from investing in a resource extraction economy. Higher housing costs, labour competition and social issues make the resource dependent region less attractive to other employers than alternative locations.

Resource extraction regions are also infamous for having serious governance challenges. Volatile revenue leads to poor government planning and a lack of accountability, even as demands on government rise and may continue to persist long after the tax revenue from the drilling phase has dried up. When the local boom ends, the human and physical infrastructure built to support a boomtown population is left for a much smaller population to support. As Feser and Sweeney describe in their study of such communities' experience with out-migration and population loss:

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> During the boom period, the county's physical infrastructure was planned and installed to accommodate an expanding population. The nature of infrastructure such as roads, sewer and water facilities, and schools is that once it is built, it generates ongoing maintenance costs (as well as debt service costs) even if consumption of the facilities declines … the departure of mine workers and higher income, mobile professionals left the burden of paying for such costs to the remaining smaller, lower-income, population.[31]

In general, US counties that have hosted drilling activities show evidence of population loss after the drilling ends. For example, counties in New York and Pennsylvania with significant natural gas drilling (1994–2009) are characterised by greater population loss when compared with similar rural counties in their respective states.

Finally, although there are some local winners in a resource extraction economy, in the long term their numbers appear to be outweighed by the local losers. After the initial construction and drilling phases, there are very few well-paying, stable jobs available in the production phase or in the industrial facilities servicing the regional industry (such as gas storage sites). As a result, income inequality tends to increase in natural resource extraction counties.

Evidence suggesting caution in projecting long term economic development from natural gas drilling comes from a study of 26 counties in western US states that have based their economic development on the extraction of fossil fuels (natural gas, oil, and coal).[32] This study shows that these counties (those that have at least 7 per cent of their total jobs in resource extraction industries) have not performed as well as similar counties without extraction industries. Both their average annual growth in personal income and their employment growth (1990–2005) were lower than their peer counties without extraction industries. These energy-dependent county economies exhibited a set of similar characteristics. They had:

- Less economic diversity
- Lower levels of educational attainment
- More income inequality between households
- Less ability to attract investment.

Also, a majority of the energy industry focused counties (16 of the 26) lost population during this period. Though the reasons for this loss are not fully documented, anecdotal information suggests that they may include the higher cost of living in these counties and the displacement of residents who do not want to live in an industrialised landscape — for example, retirees.

In part, the difference between the extraction-focused counties and other counties has emerged because new service-based industries, especially tourism, have been growing in rural western US counties and are creating more jobs than extraction industries. The extraction counties do not attract as many tourism dollars as counties without extraction industries. The picture is uneven, however. While energy extraction counties underperformed in terms of the growth of real personal income, employment, and population, they outperformed their peer counties in terms of growth in earnings per job and per capita income. But for these measures — average earnings per job and per capita income — there was only a modest positive difference (0.6 per cent per year from 1990 to 2005).[33]

In general, the research that has been done on resource extraction in rural areas offers no guarantee that counties where fossil fuel reserves are developed will have a significant long-term advantage over counties where they are not.

WHAT IS MOST IMPORTANT IN EVALUATING THE ECONOMIC CONSEQUENCES OF SHALE GAS DRILLING?

If one wants to understand how natural gas drilling will affect communities, the economic impact models typically used to project potential job creation give only a fraction of the information that is needed. Economic impact models do not address major questions about the cumulative costs to communities that come with drilling, and about how the pace and scale of drilling will affect royalty payments and the tax revenues to pay those costs. There are also potential negative consequences for other industries located in the drilling region, including agriculture and tourism. A realistic assessment of how natural gas drilling will affect the regional economy must have a framework that has been missing from IO models, one that looks at long-term consequences and cumulative impacts.

In the case of high volume hydraulic fracturing for shale gas, the evidence from across shale plays[34] and from broader studies of natural resource dependent economies indicates that one should be cautious about expecting positive long-term outcomes (beyond 5–10 years). Natural resource extraction has a poor record of leading to strong, diversified regional economies.

In thinking about and responding to the environmental and economic challenges posed by shale gas drilling, elected officials and other policy-makers need to start with the realisation that natural gas is a non-renewable resource. Good stewardship from an environmental perspective requires assessing the long-term costs and benefits of HVHF technologies and their implications for the natural and human environment in which gas extraction occurs. Although the economic consequences of HVHF gas drilling have been counter-posed to environmental concerns, positive economic outcomes cannot be taken for granted. Thus, elected and appointed officials also need to take responsibility for careful management of the local and regional economies affected by HVHF gas drilling and their longer-term sustainability. This means anticipating what may occur in the short term during a boom, and in the longer term when drilling ends. Both of these periods will present difficult issues. It is only by anticipating what may occur, planning for change, and communicating a concrete vision for the future that policy makers can make the kinds of choices that will stand the test of time. There will be no second chances.

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[P1]Authors please insert callout for Figure 1 within the text.
[P2]Authors please provide a caption for this figure.
[P3]Author: we assume that this is the same as ref 12.

