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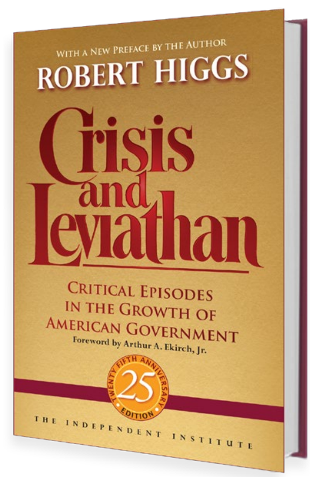

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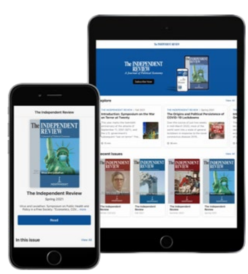

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More Boon Than Bane

How the U.S. Reaped the Rewards and Avoided the Costs of the Shale Boom

ILIA MURTAZASHVILI AND ENNIO E. PIANO

The United States has vast quantities of shale gas, but for decades it was not economically profitable. The economics of shale gas changed in the late 1990s, when drillers working the Barnett Shale in Texas figured out how profitably to extract natural gas from shale. They did so by combining horizontal drilling with hydraulic fracturing, each of which were already standard industry practices. The challenge was that regular water could not be injected at high enough velocities to fracture the shale. One of the keys to the shale revolution was discovering the right chemical mix to make the water slick enough to work in the fracturing process. The combination of these standard techniques and the right chemical mix to treat the water used in the process had consequences similar to a new technology of extraction (Fitzgerald 2013). One of the results of this new process—often called "fracking"—was a dramatic increase in U.S. natural gas production.[1]

The boom was in part a result of the leadership of gas and oil companies. Much credit has been heaped on George Mitchell, whom *The Economist* called the "Father of

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1. A more technical term for this process is *high-volume hydraulic fracturing of shale gas*. We prefer the more popular term *fracking*. Although drillers also frack shale oil, our focus is on fracking shale gas.

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Fracking" ("Father" 2013). Mitchell, alert to the opportunities presented by fracking shale gas, invested millions on a part of the Barnett Shale known as the Wildcatter's Graveyard (Zuckerman 2013). His investment eventually paid off as drillers working for his company, Mitchell Energy, unlocked the secret to economically profitable shale gas extraction.[2] The process exemplifies the importance of Kirznerian entrepreneurial vision as well as Schumpeterian creative and destructive forces of technology-driven economic change: the shale boom was a boon for consumers, but for coal producers it was something of a bane as fracked gas cut into coal companies' producer surplus.

Fracking shale gas sharply increased American natural gas production (Bartik et al. 2016). By one estimate, U.S. oil and gas production increased 69 percent from 2005 to 2014, with nearly two-thirds concentrated on farmland, much of which was a direct result of the shale boom (Hitaj, Weber, and Erickson 2018). However, the shale revolution has been accompanied by substantial debate about its consequences as well as divergent political responses to these new opportunities. For example, despite sharing a shale play—a large accumulation of natural gas in a shale basin—Pennsylvania has seen a massive increase in shale production beginning around 2007–8, whereas New York has yet to see any production because the state adopted a moratorium in 2009 that remains in place today.

The first section of our paper takes up these debates about the consequences of the shale revolution. We review the economics literature on the shale boom, including studies of the effects on prices, employment in the mining and nonmining sectors, and economic externalities, including the consequences for public health and the environment.

Our reading of the literature is that the shale boom produced substantial benefits, among which are lower energy prices, billions in royalty payments to mineral-rights owners, higher employment in the mining sector, and, according to several accounts, positive employment effects in the nonmining sectors. We also address the existing literature on the external costs of shale gas production. Although these costs are significant, and it may be several decades before we can assess the long-run consequences of the shale boom, the benefits appear to substantially exceed the costs. Our provisional conclusion is that the "shale era"—almost twenty years of shale gas development—has been more boon than bane.

In the second section, the paper argues that it is necessary to consider fracking from a political economy perspective to understand the key features of the shale boom, including why the benefits appear to exceed the costs. Several schools of thought provide insight into the performance of political-economic systems, including institutional economics, Austrian economics, the Bloomington School of institutional analysis, and public choice (Boettke and Leeson 2015). Recent work suggests that these

2. Such alertness to new economic opportunities is a defining feature of the Austrian perspective on entrepreneurship, which emphasizes that it is the knowledge of specific individuals that often drives the process of innovation in the economy (Kirzner 1997; Leeson and Boettke 2009).

schools of thought, despite many differences, remain complementary (Boettke and Lopez 2002; Leeson and Subrick 2006).

The U.S. shale boom illustrates the complementarity of these political economy perspectives. Austrian economics, with its understanding of entrepreneurial leadership and vision as well as of creative destruction as a result of technological change, provides insight into the origin and consequences of fracking technology. Economic institutions, especially the robust system of private-property rights to minerals, provided powerful incentives for owners to contract with gas companies. Another defining feature of the U.S. institutional context is polycentrism, which we argue encouraged regulatory experimentation in an environment characterized by uncertainty about how to best regulate shale gas. We conclude with some considerations about the role of politics in the shale boom.

The Consequences of the Shale Boom

It is useful to divide the consequences of the shale boom into fracking growth and fracking externalities. Fracking growth includes the effects of shale gas development on prices, royalty payments, and employment in the mining and nonmining sectors. Fracking externalities include the social costs of shale gas development that are not typically included in the analysis of fracking growth. Together, the extent of fracking growth and the extent of fracking externalities determine whether shale gas development is a boon or bane.

Fracking Growth

One of the effects of the shale gas revolution has been a substantial reduction in the price of energy. Catherine Hausman and Ryan Kellogg (2015) found that the U.S. shale boom reduced prices for natural gas and that the cost reductions were passed through to consumers. For the period 2007 to 2013, consumer surplus increased by about $74 billion a year because of declining prices, although producer surplus fell: once wells are drilled, they have low marginal operating costs and are rarely idled, which in this period resulted in revenue to producers declining by about $30 billion a year. These declines were partially offset by spudding—the drilling of new wells, or spuds, to extract gas—which increased producer surplus by about $4 billion a year over this period. As a consequence, the total welfare gain during this period was $48 billion annually, which is sizable given retail spending on natural gas was around $160 billion in 2013. For the economy as a whole, the change was about one-third of one percent of gross domestic product, or about $150 per capita. The study does not consider explicitly the losses of surpluses from other energy producers due to the reduced price of fracked gas and oil that would subtract from these benefits, although Hausman and Kellogg consider the environmental costs of shale gas development (which we consider later in our discussion of externalities).

The benefits of the shale boom also include royalty payments. In shale-producing counties in the United States, between one-third and two-thirds of the mineral rights are privately owned (Collins and Nkansah 2015). Gas companies must lease these mineral rights prior to fracking. A standard oil-and-gas lease specifies three terms: the length of the contract, the bonus, and royalties. Owners usually receive bonuses independent of well production, whereas the royalty depends on the latter.[3]

The available evidence suggests that these royalty payments generate large benefits to local and regional economies. According to James Feyrer, Erin Mansur, and Bruce Sacerdote (2017), each million dollars of new oil and gas extracted produced $80,000 in wage income, $132,000 in royalty payments and business incomes, and 0.85 jobs to the local economy. Within the region, these economic impacts are around three times larger. From 2005 to 2012, shale gas development in the United States resulted in 640,000 jobs, which they estimate reduced the rate of unemployment by about 0.42 percent during the Great Recession. Jason Brown, Timothy Fitzgerald, and Jeremy G. Weber (2016) found that in 2014 the six major U.S. shale plays generated a total of $39 billion in royalties. Despite these substantial benefits, the leasing process is not necessarily efficient. Katie Jo Black, Shawn McCoy, and Jeremy G. Weber (2018) found that the main source of royalty payments is a quantity effect from more leases signed with shale gas production rather than better lease deals for owners as the price of shale increases, and Ashley Vissing (2015) finds that the leasing process may be biased against women and minorities. One of the reasons for these inefficiencies is asymmetric information that benefits the landmen[4] and ultimately confers advantages on gas companies.[5] Yet even with these inefficiencies and distributional concerns, there appear to be large economic benefits for the owners of mineral rights.

The economics literature also considers the extent to which shale production has resulted in a "resource curse." Economists seek to understand how resource dependence, which is usually measured by resource production or revenues as a share of total output, affects long-run rates of economic growth, employment in the resource and nonresource sectors, and poverty rates.[6] The potentially harmful relationship

3. The state legislatures typically require a minimum royalty payment to protect the interests of mineral-rights owners. This minimum rate usually is 12.5 percent, although some states allow the gas companies to deduct postproduction costs from those payments, which may result in the mineral-rights owner receiving a smaller percentage than expected.

4. In the context of the fracking industry, landmen are intermediaries between mineral-rights owners and oil and gas companies.

5. To the extent that the leases distribute rents without affecting their size, these issues may not necessarily be inefficient. Such distributional issues are not necessarily economically relevant, although in some instances distributional conflict can result in costly delays in contracting for property rights (Libecap 2009).

6. The international resource-curse literature considers a much broader set of consequences of the resource extraction, including political conflict, violence, and corruption (Collier and Hoeffler 2005; Ross 2015). The literature emphasizes the role of institutions, public policies, and resource characteristics, such as the ease of appropriation, to explain the extent of a resource curse (Ross 2015; Parker and Vadheim 2017; Vahabi 2018). Those factors are less relevant in considering a fracking resource curse in the United States, which benefits from political stability.

between resource dependence and these outcomes is what economists mean by the "resource curse." The effect on the nonextractive sector is often called the "Dutch Disease."

A robust literature considers the extent of a resource curse in the U.S. economy. Using data from the Americans states, Elissaios Papyrakis and Reyer Gerlagh (2007) find that natural resource wealth reduces economic growth by decreasing investment, schooling, openness to immigration, and research-and-development expenditures. Ellis Goldberg, Erik Wibbels, and Eric Mvukiyehe (2008), using seven decades of data and case studies from Louisiana and Texas, conclude that resource abundance is associated with slower economic growth and less-competitive politics. Alex James and David Aadland (2011) use county-level data to show that resource-dependent economies exhibit lower economic growth. Yet a related study based on evidence from two decades of data from coal-mining communities in Appalachia concluded that coal mining is associated with lower poverty, which suggests a possible reversal of the resource-curse effect (Partridge, Betz, and Lobao 2013). Karen Clay and Margarita Portnykh (2018) consider both the long-run and short-run effects of agricultural and mineral endowments on state economies from 1936 until 2015, finding that resource endowments had no impact on long-run growth of per capita income but that coal and agricultural land endowments resulted in slower population growth.

Several studies consider the extent of a resource curse with conventional oil and gas extraction. Grant D. Jacobsen and Dominic P. Parker (2016) look at several decades of data on oil and gas booms and busts in the western United States, finding evidence of a positive local-employment effect but an increase in income and unemployment compensation in the aftermath of the bust. Hunt Allcott and Daniel Keniston (2017) explore the possibility of a Dutch Disease associated with conventional oil and gas extraction, finding little evidence of adverse effects based on over five decades of data on conventional oil and gas production.

The resource-curse literature typically considers long-run, or growth-related, effects of resource intensity on regional or national economies. Given the long-run orientation of the resource-curse literature, it is likely too soon to conclude if there is a resource curse connected to the shale boom. However, several studies consider whether there are the makings of a resource curse by examining the available evidence on output and employment at the national and state levels since the shale boom commenced. Thiemo Fetzer (2014) finds that employment effects in the nonmining sector are positive. Using a decade of data from the shale gas boom in Colorado, Texas, and Wyoming, Jeremy G. Weber (2014) also concludes that the shale boom increased output and employment, including in the nonmining sector. Peter Maniloff and Ralph Mastromonaco (2017) explore the possibility of a Dutch Disease with shale production, whereby a resource boom can reduce economic growth in the nonextractive tradable sector when the resource boom ends suddenly or when it is coupled with sector-specific investment or learning by doing in the tradable sector. They note that much of the resource-curse literature in the United States focuses on price-driven resource busts, but because the shale boom was technologically driven, busts are less likely. They find around half-a-million local jobs attributable to the shale boom in the United States, with effects concentrated in extractive industries, the local nontradable and service sectors, and areas with the largest increases in drilling activities.

Thomas DeLeire, Paul Eliason, and Chris Timmins (2014) consider the impact on jobs in manufacturing and total employment for each new well spudded. They find that there is a negative effect on manufacturing, with a loss of about 5.5 manufacturing jobs with each new well spudded. There is also a mean total employment effect of adding 4.2 additional and persisting jobs per well spudded. However, they also find that in some counties in Pennsylvania the local economy is becoming more natural gas dependent—the conventional definition of the resource curse—with fracking accounting for more than 10 percent of total job growth. These counties may enjoy benefits from employment growth, but the downside is their local economies' increasing vulnerability to fluctuations in global natural gas prices.

Another important line of inquiry considers the impact of resource booms on human capital investment. Stratford Douglas and Anne Walker (2017) consider coal mining in more than four hundred Appalachian counties as a natural experiment, finding that resource dependence reduces both long-run and short-run growth of income. Around 15 percent of the resource curse with respect to coal mining is explained by what they call the "education channel"—the reduction in incentives to invest in education. Dan Rickman, Hongbo Wang, and John Winters (2017) consider this channel with shale gas and oil extraction in Montana, North Dakota, and West Virginia, finding that attainment of high school and college degrees is lower because of the shale boom. West Virginia has experienced mostly a shale gas boom, and so these authors' results suggest that there may be a cost in terms of education in states experiencing a shale boom.

There are still some gaps in the literature. The literature on booms and busts in the United States during the nineteenth century has shown that a bust in the local economy may have broader benefits to a region (Clay and Jones 2008). Another conclusion from economic history is that earlier booms generate knowledge that makes the next boom more productive, such as by providing new and better information about how to extract resources (Clay and Wright 2010). The economics literature has yet to explicitly compare the earlier shale booms with the later ones as economic historians have compared mining booms during the nineteenth century.

The economic studies of fracking growth suggest that there are substantial benefits from shale gas development, including lower prices, higher employment, and royalty payments. There appear to be inefficiencies in the contracting process, but those challenges affect mainly the distribution of producer surplus, not total benefits from shale gas development. Some of these gains may be offset by increasing dependence on shale in some counties that have experienced the shale boom as well as from lower levels of human capital investment.

Fracking Externalities

The studies just mentioned do not explicitly consider economic externalities associated with shale gas development. For conventional oil and gas, one of the main regulatory challenges with extraction is producer–producer externalities. Gary D. Libecap (1989, 2007) shows that the emergence of private-property rights is perhaps the most important explanation why common-pool resources, including oil and gas reservoirs, are used in socially beneficial ways.[7] The relative ease of extracting conventional oil and gas means that drillers have incentives to compete with others (Libecap and Wiggins 1985; Wiggins and Libecap 1985). The institutional and regulatory solution is to establish property rights over the reservoir, such as through unitization agreements, which establish a collective property right in which all drillers with access to a reservoir are residual claimants but also establish (and monitor) extraction quotas. Drillers maximize the value of the reservoir when they agree on unitization, thereby internalizing the externalities associated with incomplete property rights (Libecap and Smith 1999, 2002).

The geology of shale gas reduces the risk of a pumping race. In fact, geology made extracting shale gas economically unprofitable until George Mitchell's engineers figured out how to do it. Rather, as Robert Holahan and Gwen Arnold (2013) explain, the challenge with shale gas is external effects imposed by producers on third parties. To be sure, these external effects are also present in conventional oil and gas extraction, but the specific challenges differ, as does the geographic reach of the external effects in that shale gas often affects many communities across several contiguous counties.

A robust literature considers the external costs that affect third parties. Much of the literature focuses on the consequences of shale gas development on water. Radisav Vidic and his colleagues (2013) could not find evidence of a causal relationship between hydraulic fracturing and groundwater contamination. One reason may be that fracturing typically occurs more than a thousand feet below the water table, and the wells are reinforced with several feet of concrete and steel. However, there is evidence that fracking contributes to contamination of surface water near wells, including through air pollution, although existing studies have not yet quantified the costs of such contamination (Olmstead et al. 2013; Vengosh et al. 2014).

Another potential challenge is contamination of drinking water when water used in fracking is recycled for reuse by communities. Elaine Hill and Lala Ma (2017) have found that shale gas development within one kilometer of a community water system increased gas-related contaminants in drinking water. Hill and Ma conclude that because they studied water that had already been treated, standard community-based treatment is not sufficient. However, the costs of contamination are likely to be small, in part because avoiding it is not especially costly, but also in part because much of the

7. In U.S. economic history, private property is also an important explanation for investment in infrastructure to provide for public health (Troesken 2015).

population may not rely on groundwater. Pennsylvanians in counties with shale gas development spent $19 million on bottled water in 2010 due to perceived risks to drinking water. But because only around 14 percent of Pennsylvanians are served by groundwater community water systems, Hill and Ma concluded that "the associated external costs of these well pad developments in Pennsylvania are likely to be small due to the size of the affected population" (2017, 525). More importantly, their study is based on data obtained before the state prohibited standard treatment plants to recycle water used in the fracturing process in 2012. The regulatory response illustrates that the states often respond proactively to external effects of shale gas development.

Although the best available evidence could not detect a link between fracking and groundwater contamination, the perception that there is such a link could still reduce housing values. Lucija Muehlenbachs, Elisheba Spiller, and Christopher Timmins (2015) use groundwater dependence of homes near wells to identify the causal effect of shale gas development on home values, a potentially important cost for homes that depend on groundwater. Using evidence from Pennsylvania, these authors find an annual loss for groundwater-dependent homes within one and a half kilometers of a well to be $30,167, while piped-water-dependent homes exhibit small positive impacts ($4,802). The piped-water findings appear to be driven by expectations of royalty payments from ownership.

Although close proximity to wells may reduce home values, the overall effect on housing values in zip codes with fracking may nevertheless be positive. Jeremy G. Weber, J. Burnett, and Irene Xiarchos (2016) find, based on data from the shale boom in Texas, that housing values increased five to six percentage points in shale-producing zip codes from 1997 to 2013. This improvement reflected improved local public finances: the value of natural gas rights expanded the local tax base by $82,000 per student, increasing school revenues and expenditures. What may be driving the decrease in home values in Pennsylvania is that the local tax base is not expanding as much in Pennsylvania as it is in Texas, which would offset the declining value from groundwater dependence. There also appears to be much to gain from fracking in New York as far as housing values are concerned. Andrew Boslett, Todd Guilfoos, and Corey Lang (2016) show that mineral-rights ownership is important, as those in New York who stood to gain from leasing their property lost about 23 percent of their home value because of the moratorium.

Another important question is how proximity to shale wells affects health. One line of research considers the impact of shale gas development on birth weight. The economics literature recognizes the social costs from low birth weight (LBW) (Almond and Currie 2011). One reason why the studies of infant health are attractive is that researchers have quality data on where mothers are during pregnancy, which increases confidence in the link between health outcomes and economic activities.

Janet M. Currie, Michael Greenstone, and Katherine Meckel (2017) found a 25 percent increase in LBW (birth weight less than 2,500 grams) for mothers living within one kilometer of a well, although these negative effects are lessened within one to three kilometers of a fracking site, with no health impact outside the three-kilometer band. Currie, Greenstone, and Meckel estimate that one percent of births, or about 29,000 births from July 2012 until June 2013, occurred in the United States within one kilometer of an active shale-producing well. The study may even underestimate the positive health consequences because women living near shale wells may have benefitted from shale production, such as by owning mineral rights. This increase in income could have offset adverse health effects (Aizer and Currie 2014).

Currie, Greenstone, and Meckel (2017) emphasize that LBW is a risk factor for numerous negative outcomes, including infant mortality, attention deficit hyperactivity disorder, asthma, lower test scores, lower schooling attainment, lower earnings, and higher rates of social welfare program participation. However, estimating the social costs of LBW is challenging. Douglas Almond, Kenneth Chay, and David Lee (2005) consider whether birth weight can be a reliable substitute for the direct health outcomes of interest, such as mortality, using data from all births of twins in the United States from 1983 to 2000. They note that LBW is costly because of its correlation with a host of medical conditions, lower IQ, behavioral and cognitive challenges, as well as higher infant mortality. Yet most cross-sectional analysis of LBW does not consider genetic factors as a cause of LBW, which can be ruled out using data from twins, ensuring that differences in health outcomes are driven by environmental rather than genetic factors. Another challenge is that the costs for extremely LBW babies—less than 1,000 grams—are substantial but decline substantially for each pound gained (454 grams). For babies weighing 800 to 1,000 grams, the excess hospital costs are $127,190, according to pooled data that do not control for genetic factors, but drop to $36,846 (in 2000 dollars) according to more appropriate techniques that control for genetic predisposition. The excess hospital costs decline to only $604 for babies born in the 2,000- to 2,500-gram range (in 2000 dollars).

The research on LBW suggests that the costs of fracking for infant health are far less than the benefits from shale gas development. For example, suppose that 10 percent of the 29,000 babies born to mothers living within one kilometer of a fracked well are of LBW.[8] Most of the LBW babies are in the range of 1,500 to 2,000 grams, which generate excess hospital costs of about $6,806 per child (in 2000 dollars) (Almond, Chay, and Lee 2005). Thus, 2,900 babies would be born with an excess hospital cost of $6,806 per child, which suggests about $19 million in total costs because of LBW. Our calculation assumes that all LBW babies are a result of fracking, which is certainly not the case, and so $19 million likely overstates the costs of LBW from fracking. These costs do not include those arising from increased mortality, although it is important to keep in mind that LBW does not necessarily result in higher infant mortality. In addition, Joan A. Casey and her colleagues (2015) found an association of fracking with preterm birth, but no association with infant mortality or LBW, in which case the costs would likely be

8. According to the National Center for Health Statistics, this figure was actually 8.2 percent in 2016 for the state of Pennsylvania. See https://www.cdc.gov/nchs/pressroom/sosmap/lbw_births/lbw.htm.

small. To get an idea of the costs compared to the benefits, the state of Pennsylvania has generated at least $1 billion annually in royalty revenues during the shale boom (Brown, Fitzgerald, and Weber 2017). Policy makers (and voters) may very well find these costs from LBW unacceptable, but it is unlikely that these costs would exceed the benefits from shale gas production.

There are several areas where future research would be helpful to estimate more precisely the social costs of fracking for health. Currie, Greenstone, and Meckel (2017) focus on LBW because it is the measure most commonly used to examine fetal health outcomes in the health and environmental economics literature. However, it may be more useful to consider extremely LBW babies to understand the social costs of economic activities and policy interventions because extreme LBW is much costlier to society than LBW. In addition, LBW is associated only with increased risk of adverse outcomes. A more appropriate measure may be infant mortality or measures of infant health, such as Apgar scores, which measure health outcomes more directly. To date, research has not shown a correlation between extreme LBW or Apgar scores and fracking.

It is also useful to consider the health effects of shale gas compared to those of coal mining, especially if shale gas hurts coal and if coal mining is more of a health risk than fracking. Studies of coal mining find that proximity to mines is associated with birth defects (not simply LBW) and long-run health consequences such as cancer (Hendryx and Ahern 2008). There has also been a recent resurgence of black lung disease, for reasons that are not entirely clear (Blackley et al. 2018). These studies suggest that the cost of fracking on infant mortality would be partially offset by the reduction in health risks to newborns from coal mining. "Fraccidents" are one of the challenges with greater use of semis not only in fracking counties but also in areas connected to inputs to fracking. One study finds a 7.5 percent increase in accidents involving semis in areas with well production as well as an increase in their severity (Xu and Xu 2018). However, these costs are reflected in higher insurance premiums that account, at least in principle, for the social costs of injuries from additional accidences. Lucija Muehlenbachs, Stefan Stuabli, and Ziyan Chu (2017) find that the traffic associated with a shale gas well will increase the insurance premiums of those in the vicinity by twelve cents per year, which they describe as a "small" effect, while noting that estimates imply that annual car insurance premiums of each new enrollee will increase by forty-eight cents after a typical truck's annual kilometers are driven in the enrollee's zip code. In addition, the studies cited here do not consider that trucks used for fracking are not used elsewhere, such as coal, which could offset the higher insurance premiums by lowering them in coal-mining areas.

Overland transportation is also a source of environmental costs. Although studies of shipping oil and gas focus on spills and accidents, there are also important costs of shipping from air pollution and greenhouse gases. A recent study of shale oil coming out of the Bakken Shale in North Dakota finds that shipping by rail results in twice the environmental costs as for pipelines (Clay et al. 2017). Fracked natural gas is typically shipped through pipelines, which suggests lower costs for shale gas than for shale oil shipped by overland transportation.

Shale gas development may also increase crime through demographic shifts (increase in the young or male population or both, which implies higher crime), criminal migration, increasing inequality, and a reduction in police per capita with increases in population. Alexander James and Brock Smith (2017) find the shale boom increases property and violent crimes, with an estimated cost of $2 million in the average county with shale gas development. However, their analysis, which is based on county-level data from all U.S. states from 2000 to 2013, suggests that the benefits from shale far exceed the costs of crime. They calculated that income per capita is $1,911 higher in treatment counties as a result of the shale boom, which translates into about $80.5 million in benefits based on the average population in shale-producing counties. Thus, the $2 million in costs because of crime is only about 2.5 percent of the income gains from fracking.

Alexander Bartik and his colleagues (2016) find that fracking imposes a cost on communities because of higher crime and lower property values equal to a decline of between 1.9 and 3.1 percent of mean household income, but they also find that, overall, fracking would result in benefits of $1,300 to $1,900 annually per household, which is about 2.5 to 3.7 percent of mean household income. These results suggest that, despite growth in crime, there are still net gains from shale development. However, the studies of crime are also limited because they do not explicitly consider the reduction in crime: shale attracts more violence-prone men, but these same men are leaving other regions, where the crime may thus decline. The decline in crime in non-shale-producing regions offsets some of the costs of increased crime in shale-producing counties.

In some parts of the country, earthquakes result from shale gas development. The mechanisms include the fracturing process itself or when water is left in the ground, which changes the equilibrium of the rock formations, resulting in shifts (Hand 2014). However, the earthquakes caused by fracking in the United States have been small both in magnitude and in economic costs. In Oklahoma, there have been hundreds of so-called microquakes. Nonetheless, these microquakes have received significant press coverage, including a *New York Times* article that proclaimed "Drilling Is Making Oklahoma as Quake Prone as California" (Wines 2016). However, to our knowledge, these quakes have not resulted in significant loss of property value, and none has resulted in any injuries. In addition, the challenge does not affect all shale plays equally. For example, the first reported shale-related earthquake in Pennsylvania occurred in April 2016, nearly a decade after the shale boom commenced (Frazier 2017). The seismic activity was imperceptible to people on the surface, although the gas company shut down production on that well as soon as the Pennsylvania Department of Environmental Protection notified it of the seismic activity.

Finally, it is necessary to consider the impact of fracking on the global environment, which requires thinking in terms of the energy transition. Fracking has been a boon to natural gas, so utilities have switched away from dirtier fuels such as coal.

Because the negative externalities from natural gas are lower than coal, the net effect is likely to be positive.

Hausman and Kellogg (2015) explain that there are two channels to assess greenhouse gas emissions. First, there are costs from methane leaks because methane is a powerful greenhouse gas. Second, there are effects from combustion of natural gas. On one hand, there is a scale effect that increases global emissions because natural gas is cheaper and total energy use increases. On the other hand, natural gas promises to displace coal. The coal effects depend on export behavior. If all coal is exported, then there may be no displacement of the environmental effects of coal use. However, if coal is just killed off with lower prices, then there are gains from cleaner energy use. Using the highest estimates of methane leaks, assuming that all coal is exported, and considering scale effects, we can arrive at a net cost of $28 billion in 2013 because of the global environmental impact. Under more reasonable assumptions (including that some coal production is killed off), however, the net cost of fracking on the environment may be as low as $3 billion in any given year.

Do the Benefits of Fracking Exceed the Costs?

Shale gas development appears to produce substantial benefits in excess of the costs. Hausman and Kellogg's (2015) study finds benefits of $48 billion per year. Even with the high estimate of net costs of $28 billion, the net benefits from fracking are $20 billion per year and could be as much as $45 billion. Another way to measure the benefits from the shale boom are with royalties, which according to Jason P. Brown, Timothy Fitzgerald, and Jeremy G. Weber (2016) in the aggregate suggest $39 billion in royalty payments in 2014, thus also suggesting benefits in excess of costs.

There are, of course, other externalities besides the global commons. Some of the most important ones include worsening water quality, lowered housing prices, greater crime, lower birth weights, and accidents. The costs of worsening water quality have been small (one estimate of the costs was purchasing of $19 million in bottled water) and have largely been addressed through regulating the recycling of water used in the fracking process. Housing prices decline substantially for groundwater-dependent homes within one and a half kilometers of a well but increase when homes do not depend on groundwater. Moreover, these effects depend in part on whether local governments capture the rents from fracking. In Texas, home values improved substantially, in part because the shale boom was a boon for local schools. Thus, it would be reasonable to conclude that the housing-market effects are a wash when considering the U.S. shale boom overall rather than just one small part of it in southwestern Pennsylvania. The effect on crime also appears to be small. According to the study referenced earlier, the losses associated to increasing crime amount to only about 2.5 percent of the gross gains from fracking, and Brittany Street (2018) finds that the North Dakota shale boom resulted in a significant reduction in crime, especially in the months in the immediate aftermath of the beginning of the leasing process. Fraccidents are addressed largely through an increase in insurance premiums, with total costs to consumers from higher premiums estimated to be about forty-eight cents per customer in shale-intensive regions, which we can safely conclude is a small effect, especially when compared to consumer benefits in the neighborhood of $150 per U.S. consumer as a result of the shale boom.

The health costs are a bit more complicated. Although policy makers and voters might be unwilling to accept any costs from low birth weight, the social cost of LBW babies is small under reasonable assumptions about the costs. The simple calculation we gave earlier suggests that the costs from LBW are small compared to the benefits of fracking.

The resource-curse literature suggests some caution. The gains from shale gas development today will likely be offset by declining human capital investment, especially in the regions with the greatest dependence on shale production. The declining human capital may lead to lower productivity in the long run. Nonetheless, most of the studies reviewed indicate that a well is associated with several jobs, and the jobs created per new well exceed the jobs lost in the manufacturing sector. It is not yet possible to assess the long-run effects of resource dependence, but the available evidence suggests that the shale boom does not have the makings of a resource curse, except perhaps in the most shale-dependent counties of shale-producing parts of Pennsylvania and perhaps boomtowns mining the Bakken Shale in North Dakota.

From an Economics to a Political Economy of the Shale Boom

If we now presume the benefits from fracking exceed its costs, the question is why. In a broad sense, the shale boom can be understood as a consequence of economic and political institutions: the former contributed mainly to the growth of fracking, while the latter help to understand the internalization of externalities from the shale boom.

Economic Institutions and the Shale Boom

Several exceptional features of the property regime governing minerals in the United States contributed to the shale boom. Unlike in most of the world, much of the mineral estate in the United States is privately owned, which creates incentives for owners to lease their mineral rights to gas companies (Murtazashvili 2017). Another way that the U.S. mineral-rights regime is exceptional is that the property regime governing it has been in place for a long time, having been established during the nineteenth century (Libecap 2018b).

To get an idea of the importance of private-property rights, it is useful to compare the U.S. mineral-rights regime with the U.K. regime. In the United States, the gains to mineral-rights owners from the process of contracting with gas companies are determined largely by markets, subject to requirements about royalty rates. In contrast, mineral rights in the United Kingdom are uniformly state owned. Although the government in the United Kingdom has in place revenue-sharing arrangements, the payments to individuals are determined by bureaucratic priorities rather than by markets. According to one study, U.S. owners of minerals gained twice as much as their counterparts in the United Kingdom even after redistribution of rents from the government (Harleman and Weber 2017). In analyzing U.S. data, Alan R. Collins and Kofi Nkansah (2015) find that when one does not own mineral rights, one is less likely to support shale gas development.

There are also benefits to not having to deal with the government during the leasing process. Timothy Fitzgerald (2010, 2012) analyzes this issue using data from coalbed methane extraction in the western United States, finding that government-owned leases are less valued in markets, presumably because of more transaction costs when dealing with the government. Fitzgerald's research indicates that widespread private ownership of mineral rights facilitated contracting among gas companies and owners prior to the shale boom.

However, the U.S. property system allows the severing of the surface and mineral estates, which may increase transaction costs. The effect of transaction costs on macroeconomic variables is hard to estimate empirically, but we have strong theoretical and empirical support for the claim that they can have important consequences on contracting behavior (Libecap 2018a). In the case of oil and gas, divided estates require identification of owners, some of whom may be absentee.

Although absentee ownership and the severing of the surface and mineral estate present obstacles to effective contracting, the market for mineral rights has developed ways to address this problem—for example, the rise of the landmen. The Coase theorem suggests that property rights will find their highest-value use, provided transaction costs are low, where transaction costs are defined as the costs of establishing and allocating property rights (Allen 2002, 2015). Landmen reduce these costs by easing the contracting process. Private-property rights to minerals, along with the presence of the landmen, facilitated a rapid process of the assignment of these rights to gas companies just prior to the shale boom.

Another potential challenge to shale gas development is that owners may hold out when drillers are negotiating leases. This challenges the economically efficient drilling unit, which requires a large number of contiguous plots. However, most states have introduced pooling laws to overcome these holdup problems and have applied them to shale gas, as in Texas, where the well-established forced-pooling laws have been extended to the Barnett Shale (Blackwell 2010). Although forced pooling limits owners' rights to negotiate terms, it has the advantages of facilitating contracting and of balancing owners' demands with the desire for economic development (Sylvester and Malmsheimer 2015).[9]

9. Although forced pooling seems to have many efficiency properties, the efforts to apply forced pooling to shale have nonetheless been met with political and legal challenges in several states (Trachtenberg 2011).

The contracting process has in general facilitated shale gas development. One issue, referenced earlier, is that leases do not necessarily respond immediately to changes in prices. There also remains a question of how well informed individuals are and whether they learn (Arnold, Farrer, and Holahan 2018). One option is to use regulations to create a more uniform system of leases that could in principle overcome biases in the leasing process, including racial and gendered ones (Vissing 2015). In addition, although there are some benefits from a long history of regulations governing oil and gas, "regulatory obsolescence" is a challenge because the institutions governing mineral rights are more than a century old and have not necessarily evolved to reflect the demand of contracting in oil and gas (Fitzgerald 2018).

Political Institutions and the Shale Boom

Policy experimentation is important in response to real and perceived institutional and regulatory obsolescence. Our review of the literature on external costs also suggests that regulators have many options to address the costs of shale gas development. For example, regulators could provide people with better information on the relationship between groundwater and fracking to change the perceptions driving the reduction in property values in houses near to wells that depend on groundwater. Local regulators could also experiment with regulations on proximity to wells, such as requiring housing be set back one and a half kilometers from active wells to address potential costs from poorer health. Another issue for which there are many regulatory options is seismic activity, which is a challenge in Oklahoma but not much of an issue in Pennsylvania. In addition, some issues, such as the costs of fraccidents, appear to have been addressed through insurance markets, although regulations to reduce accidents may be worthwhile to consider.

The U.S. regulatory institutions appear especially appropriate for addressing these sorts of challenges. One of the defining features of the American political system is that it is fundamentally polycentric (V. Ostrom 1994). The Bloomington School highlights the role of polycentric governance in providing effective responses to the challenges of social life (E. Ostrom 2005; V. Ostrom 2008; Aligica 2014). Its defining features are multiple levels of government acting independently and yet affecting each other's behavior through competition and cooperation (Aligica and Tarko 2012, 2013).

Polycentrism has the potential of increasing the net benefits of fracking by reducing the uncertainty associated with the extraction process. In this, fracking is akin to a "knowledge commons." Once created and publicized, knowledge is characterized by nonrivalry and nonexcludability, which is at the same time a fundamental factor in the generation of a dynamic economy (thanks to the knowledge externalities of innovation) and in the underproduction of knowledge (because innovators cannot capture fully the benefits of their contribution) (Hess and Ostrom 2007).

It is also possible to think about a regulatory knowledge commons—that is, knowledge about how to regulate (Murtazashvili and Piano 2019). There is uncertainty with shale gas production because its effects differ from the effects of conventional oil and gas extraction. Rather than use uncertainty to prevent shale gas development, a market-oriented approach allows development and then allows the state and local governments to experiment with regulations of shale gas development. In this regard, the diversity of regulation of shale gas is a solution to social problems, including the information problem confronting government about how to regulate shale gas development.

The states have responded reasonably well to the challenges of shale gas development. The regulatory response in Pennsylvania is illustrative. One major fear during the shale boom is groundwater contamination. The industry standard is to use steel with cement casing surrounds for wells to prevent migration of natural gas to groundwater. In Pennsylvania, state regulatory agencies monitor well casings and gas leakage, issuing fines for wells that fail inspections. Only about 1 to 2 percent of wells are issued warnings regarding construction, and when violations are found, gas leakage is mostly minor and can be remedied (Vidic et al. 2013). The state also established setbacks to regulate well activity near surface water through Act 13, which in 2012 provided a framework to govern shale gas development. Those setbacks promised to reduce risk of water contamination and solved a coordination problem by providing a model zoning ordinance for the hundreds of communities with shale gas production.[10] Another regulatory feature is the monitoring of seismic activities and the use of a stoplight system that allows for caution after a quake or for stopping production.

Air pollution is also a challenge for shale gas but certainly not one for which the government lacks regulatory experience or capacity. On one hand, the U.S. Environmental Protection Agency (EPA) regulates air pollution from fracking. Either the EPA or the states could adopt straightforward regulations governing how far houses must be set back from wells. The EPA can also address the potential global externalities of shale production —most importantly the danger of fugitive methane. Because pollution from fracking is a global commons issue, there is a stronger case for uniform standards imposed from the national government.

There are also standard ways to deal with costs imposed by more trucks on the roads. The costs of accidents are arguably internalized through insurance markets, but there are still costs of declining infrastructure from a dramatic increase in the number of trucks. One is simply to tax the externality. The choice in the type of taxation is between a severance fee and an impact fee. There is tremendous variation

10. The Pennsylvania Supreme Court eventually ruled the zoning provisions of Act 13 unconstitutional—a ruling that was challenged by the state's Department of Environmental Protection because it left many localities without a zoning framework to govern shale gas development (Cusick 2014).

(Rabe and Hampton 2015). Pennsylvania adopted an impact fee that required communities to use funds for categories tied specifically to the external costs of shale gas development. One of these costs was infrastructure. The impact fee provides $200 to $300 million annually to address the externalities associated with fracking (Pennsylvania Department of Environmental Protection 2016). These funds could be used for things such as potholes that result from more semis on the roads.

There are important variations in the regulations that can be adopted (Davis 2012). Some regulations work better than others. A recent study suggests that cap-and-trade regulations of the environmental impact of fracking would result in 32 percent cost savings compared to command-and-control policies (Milt and Armsworth 2017). There are also opportunities to further reduce the costs of the shale boom, such as reducing adverse health effects by imposing housing setbacks from active wells. Setbacks would also involve costs—they mean less drilling—but they could also eliminate a cost that some may find unacceptable in any amount while still allowing fracking to proceed.

Although polycentricity encourages experimentation, it is important to keep in mind that the local units are not immune from capture or the perverse incentives created by political institutions. However, Richard Revesz's (2001) insight about the perceived need for federal environmental regulation remains relevant: the states remain powerful environmental regulators, and there ought not be a reflexive jump to the federal government when it comes to regulating the environment. This also applies to shale gas development.

There remain other ways to further reduce the external costs from shale gas development. One is to encourage more development of fracking on farmland. One recent study finds the net benefits of fracking are greatest in rural areas, in part because there is less population density and fewer risks to the human population (Rakitan 2018). Yet such regulations regarding the appropriate locations for fracking may not even be necessary. There has been much fracking in suburban areas near Dallas–Fort Worth, and it has resulted in, among other things, a fairly substantial boon for schools, which benefit from increased taxes as property values increase.

Conclusion

According to our analysis, the benefits of fracking likely exceed its costs. There are also several fairly clear regulatory approaches that could further limit these costs, such as property setbacks from active wells. For example, regulators in New York could impose setbacks along these lines and then allow fracking to proceed, which would likely reduce most of the costs from poor infant health, increase home prices for those who will lease their land, and fight global warming by promoting an industry that reduces the use of coal. So why does the opposition persist?

The novelty of fracking technology is no longer a compelling explanation for the regulatory delays. The moratorium in New York made more sense when the technology was new. But regulators in states such as New York now have much more evidence of the consequences of fracking from other states, including neighboring Pennsylvania, and so the fact that the shale boom was technologically driven is not necessarily a convincing explanation why the bans in several states have continued.

The reasons for continued regulatory delay most likely reflect political considerations. Polycentric political institutions provide a laboratory for experimentation. Yet the decision to allow shale gas development is still made by democracies. Peter J. Boettke (2018) reminds us that there are in general few reasons to expect public administrators to respond seamlessly to new economic opportunities. Bryan Caplan's (2006) work on the democratic process offers a similar point about why we ought not to expect democracies to produce efficient policies. His explanation has less to do with rational voters than with the disincentives for voters to behave rationally in democracies. Many voters in New York are happy with the moratorium, and although shale has benefits that exceed the costs, these gains may be small for voters as a whole. The aggregate gains to the average New Yorker may be a few hundred dollars per capita, which is large in the aggregate but may not be enough to get the average voter to shift from his or her deeply held ideological beliefs about fracking. Thus, even though the benefit–cost analysis of fracking appears to show substantial net benefits, voters do not necessarily decide based on these costs, which again returns us to a key point of this paper: the importance of considering issues of economic development from both an economic perspective and a political economy perspective.

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