William & Mary Environmental Law and Policy Review

Volume 39 | Issue 1 Article 6

Managing the Risks of Shale Gas Development Using Innovative Legal and Regulatory Approaches

Sheila Olmstead

Nathan Richardson

Managing the Risks of Shale Gas Development Using Innovative Legal and Regulatory Approaches

Sheila Olmstead & Nathan Richardson*

Abstract

Booming production of oil and gas from shale enabled by hydraulic fracturing technology has led to tension between hoped-for economic benefits and feared environmental and other costs, with great associated controversy. Studies of how policy can best react to these challenges and how it can balance risk and reward have focused on prescriptive regulatory responses and, to a somewhat lesser extent, voluntary industry best practices. While there is undoubtedly room for improved regulation, innovative tools are relatively understudied. The liability system predates environmental regulation yet still plays an important—and in some senses predominant—role. Changes to that system, including burden-shifting rules and increased bond requirements, might improve outcomes. Similarly, new regulation can and should incorporate modern understanding of the benefits of market-based approaches. Information disclosure requirements can benefit the liability system and have independent benefits of their own. Policymakers faced with a need for policy change in reaction to shale development should carefully consider alternatives to regulation and, when regulation is deemed necessary, consider which tool is best suited.

---

* Sheila Olmstead is a visiting fellow at Resources for the Future and an associate professor at the Lyndon B. Johnson School of Public Affairs, The University of Texas at Austin. She may be contacted at 512-471-2064 or sheila.olmstead@austin.utexas.edu. Nathan Richardson is a visiting fellow at Resources for the Future and an assistant professor at the University of South Carolina School of Law. The authors thank Kate Konschnik for insightful comments and the Alfred P. Sloan Foundation for financial support.

INTRODUCTION

Shale gas development is increasing rapidly in the United States;[1] natural gas extracted from deep shale reached about one-quarter of US production by 2010 and may comprise half or more of US production by 2040.[2] Operators now can exploit these resources cost-effectively due to advances in two critical technologies: hydraulic fracturing and horizontal drilling. The use of these technologies to extract gas from deep shale formations has generated significant economic benefits, but it also has raised concerns about associated risks to the environment and human health.[3]

The wide distribution of shale plays means that many are being developed in states, such as Texas and Oklahoma, with rich histories of oil and gas exploitation and regulation, and others in states such as Ohio and Pennsylvania with little such history.[4] States have long been the primary regulators of oil and gas development and have retained that role as production has expanded, though both federal and local authorities play some role.[5] The regulatory framework for managing risks from shale gas development is accordingly highly dynamic.

Flexible, innovative legal and regulatory approaches hold great promise as cost-effective alternatives to prescriptive regulation, but it remains to be seen whether they are appropriate for managing shale gas

---

[1] *See* NATHAN RICHARDSON ET AL., THE STATE OF STATE SHALE GAS REGULATION 1, 3 (2013), *available at* http://www.rff.org/rff/documents/RFF-Rpt-StateofStateRegs_Report.pdf.
[2] U.S. ENERGY INFORMATION ADMINISTRATION, ANNUAL ENERGY OUTLOOK 2014 MT-23 (2014), *available at* http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf.
[3] *See, e.g.*, ALAN KRUPNICK ET AL., PATHWAYS TO DIALOGUE: WHAT THE EXPERTS SAY ABOUT THE ENVIRONMENTAL RISKS OF SHALE GAS DEVELOPMENT (2013), *available at* http://www.rff.org/Documents/RFF-Rpt-PathwaystoDialogue_FullReport.pdf.
[4] *See* RICHARDSON ET AL., *supra* note 1, at 3–4.
[5] *Id.* at 5–6.

risks. This paper examines two main categories of innovative approaches that can be used to regulate environmental risks: liability rules and market-based regulations. For each approach, we discuss theoretical advantages and disadvantages, and we explore actual and potential applications for the regulation of risks from shale gas development.

I. LIABILITY RULES

Virtually all public discussion of the risks of shale development centers on the proper role for regulation: which risks need to be regulated and how stringent should that regulation be?[6] Nevertheless, liability, not regulation, is probably the most important driver of operator practices aimed at reducing risks—and this likely would remain the case under even the most ambitious proposals for more extensive regulation.

Large areas of drilling-related activity are unregulated or only lightly regulated, like drilling equipment and, in most states, fracking fluids.[7] Even when state drilling regulations are quite detailed, such as those aimed at ensuring well integrity, operators retain significant discretion. But operators always face the threat of lawsuit if their activity results in harms to others or to the environment.[8] Lawsuits over drilling and related activities, such as truck accidents, are common.[9] Operators therefore have a strong incentive to exercise due care in almost all activities, regardless of regulation.

This is not to suggest that regulation is not useful and in many cases necessary, but rather that the two systems—regulation and liability—work together to shape patterns of behavior and thereby reduce risks. Much work has been done on the effects of liability rules in the environmental context, especially on Superfund and related state laws.[10] But debates over

---

[6] *See* Nick Snow, *Shale Gas Renaissance Makes Governments Examine Regulatory Roles*, OIL & GAS J. (Aug. 19, 2013), http://www.ogj.com/articles/2013/08/shale-gas-renaissance-makes-governments-examine-regulatory-roles.html, *archived at* http://perma.cc/4JG7-ZFF2.

[7] *See* Ian Urbina, *Regulation Lax as Gas Wells' Tainted Water Hits Rivers*, N.Y. TIMES (Feb. 26, 2011), http://www.nytimes.com/2011/02/27/us/27gas.html?pagewanted=all&_r=0, *archived at* http://perma.cc/4ZAT-TB3R.

[8] *See* Jennifer Hayes, Note, *Protecting Pennsylvania's Three Rivers' Water Resources from Shale Gas Development Impacts*, 22 DUKE ENVTL. L. & POL'Y F. 385, 388–89, 392–93, 402–03 (2012).

[9] *See* Hannah J. Wiseman, *Risk and Response in Fracturing Policy*, 84 U. COLO. L. REV. 729, 734–35, 754–56, 763, 796, 800 (2013).

[10] Lewis A. Kornhauser & Richard L. Revesz, *Multidefendant Settlements Under Joint and Several Liability: The Problem of Insolvency*, 23 J. LEGAL STUD. 517, 517–19 (1994); Hilary Sigman, *Liability Funding and Superfund Cleanup Remedies*, 35 J. ENVTL. ECON.

how best to manage new risks imposed by expanding shale development have largely missed a consideration of the liability system—and of options available for improving its ability to manage new risks.

A. Regulation Versus Liability in General

But how do the two systems work together? When is liability appropriate and adequate, and when is regulation needed instead? Law and economics scholar Steven Shavell addressed these questions in a landmark article,[11] identifying four criteria on which to base an evaluation of which tool is superior for a particular situation:

- *Information asymmetry*. Where private parties have greater knowledge about risky activities than prospective regulators, liability is favored over regulation. Regulation without good information is likely to be too lax or too strict, and courts are usually better able to determine the required level of care (and whether it was met) in a particular situation than are regulators across all actual and possible situations.[12]
- *Ability to pay*. If those responsible for harms can escape liability because they are unable to pay to remedy those harms, liability will give inadequate incentives to change behavior.[13]
- *Threat of suit*. Similarly, if those responsible for harms can escape liability because they are never sued at all, liability once again will give inadequate

& MGMT. 205, 205–06 (1998); Howard F. Chang & Hilary Sigman, *Incentives to Settle Under Joint and Several Liability: An Empirical Analysis of Superfund Litigation*, 29 J. LEGAL. STUD. 205, 205–06 (2000); Howard F. Chang & Hilary Sigman, *The Effect of Joint and Several Liability Under Superfund on Brownfields*, 27 INT'L REV. L. & ECON. 363, 363–64, 382–83 (2007); Anna Alberini & David Austin, *Accidents Waiting to Happen: Liability Policy and Toxic Pollution Releases*, 84 REV. ECON. & STAT. 729, 729, 740 (2002).

[11] Steven Shavell, *A Model of the Optimal Use of Liability and Safety Regulation*, 15 RAND J. ECON. 271 (1984) [hereinafter Shavell, *A Model of the Optimal Use of Liability and Safety Regulation*].

[12] Steven Shavell, *Liability for Harm versus Regulation of Safety*, *in* ECONOMIC ANALYSIS OF THE LAW SELECTED READINGS, 59, 60–61 (Donald A. Wittman, ed., 2003) [hereinafter Shavell, *Liability for Harm versus Regulation of Safety*].

[13] *Id.* at 61–62.

incentives. The best and most relevant example is activity that creates widely dispersed harms. Victims may lack standing to sue, ability to organize a class action, or ability to connect the harm suffered to the party responsible, for example.[14]

- *Costs*. Both liability and regulation have costs—litigation costs on the one hand, and administrative and enforcement costs on the other.[15] Litigation costs can be very high but are only incurred in the case of harm, while regulation requires the ongoing "public expense of maintaining the regulatory establishment" and private compliance costs.[16]

Shavell observes that in most real-world settings, a mix of liability and regulation is used. He argues that as a general rule, the choice between the two in a given area seems to reflect these criteria; society generally, if not always, gets the regulation or liability decision right.[17]

B. Regulation Versus Liability in Shale Development

The dichotomy just discussed is probably true in the oil and gas context as well. For most risks, private parties have better information than regulators, even sophisticated state-level agencies.[18] This points in favor of a liability system, and, indeed, most operator decisions are made in the shadow of liability risk.

But other factors point toward regulation. In many cases, operators have excellent information but potential victims do not, and it is hard for courts to determine if operators exercised due care.[19] An important reason is the simple fact that activity occurs underground, where only equipment

---

[14] *Id.* at 62–63.
[15] *Id.* at 63.
[16] *Id.*
[17] *See* Shavell, *Liability for Harm versus Regulation of Safety*, *supra* note 12, at 68.
[18] *See* Wiseman, *supra* note 9, at 741.
[19] *See* Charles B. Jimerson & Mark F. Moss, *Top 5 Issues in Today's Hydraulic Fracturing Litigation*, JIMERSON & COBB, P.A. (Dec. 19, 2013), http://www.jimersoncobb.com/blawg/2013/12/top-5-issues-in-todays-hydraulic-fracturing-litigation/, *archived at* http://perma .cc/NN87-95WN.

under the control of operators can observe it.[20] Another challenge is that many operators are small independents whose resources may be inadequate to cover large damage awards.[21] Perhaps the strongest factor in favor of regulating some oil and gas activities is that they may lead to significant but widely dispersed harms.[22] Liability is likely to be an inefficient and impractical means of addressing such problems as fugitive methane emissions, or contamination of rivers and streams with flowback fluids. This is of course not unique to oil and gas drilling—most environmental regulation can point to dispersed harms as its *raison d'être*, and in fact one way of describing the growth of environmental regulation is a response to an inability of the traditional liability system to address widespread environmental harms associated with industrial society.

Whether regulation or liability is superior in cost terms for shale gas risks—or any others—is harder to determine. Shavell struggled somewhat to come up with general principles in his 1984 article, concluding that, on balance, liability is likely to be less costly.[23] This may be true for many one-off, small scale events but is almost certainly not true when harms are dispersed because class actions are notoriously complex. Even allowing for class-action lawsuits, costs of a pure liability approach may be extremely high.[24]

In fact, Shavell's third criterion—threat of suit[25]—could be viewed as a special case of his cost pillar. When potential plaintiffs find it difficult to sue, the cause is often the high cost of legal action in the face of collective action problems or procedural barriers that courts erect to protect against difficult-to-resolve suits. In other cases, inadequate threat of suit might arise from information asymmetries. If you don't know who is polluting your water, you can't sue.

On the other hand, where information is readily available to private parties and instances of harm are relatively rare compared to the level of activity, liability is likely to be much less costly than detailed

[20] *Id.*
[21] *See generally* Sarah M. Forbes, *"The United States and China: Moving toward Responsible Shale Gas Development,"* BROOKINGS INST. (Sept. 2013), *available at* http://www.brookings.edu/~/media/events/2014/2/06%20china%20clean%20energy/uschina%20moving%20toward%20responsible%20shale%20gas%20development_sforbes.
[22] *See* Urbina, *supra* note 7; *see* Hayes, *supra* note 8, at 391 (stating that over a four-year period, shale developers used 29 chemicals that are "known or possible human carcinogens").
[23] Shavell, *Liability for Harm versus Regulation of Safety*, *supra* note 12, at 63, 65.
[24] Peter S. Menell, *The Limitations of Legal Institutions for Addressing Environmental Risks*, 5 J. ECON. PERSP. 93, 93–94, 101 (1991).
[25] Shavell, *Liability for Harm versus Regulation of Safety*, *supra* note 12, at 61–62.

regulation. Good examples are truck accidents and aboveground damage to landowners' property, both of which are generally handled by or negotiated in the shadow of the tort system.

Therefore the intuition that the division of labor, as it were, between liability and regulation follows Shavell's principles seems to hold in the oil and gas context just as Shavell asserts it does generally.[26] This is not to say that some activities currently regulated might not be better handled through liability, or that there is no need for additional regulation because the current liability system is adequate. Either claim requires far more evidence than the above anecdotal review could provide.

Nor is it to say that this division of regulatory labor arose by design. In most cases, regulation is imposed when the liability system comes to be viewed as inadequately addressing a given risk—usually in circumstances poorly suited to liability under Shavell's criteria—not *de novo* creation of a new regulatory regime based on a theoretical framework. One of the liability system's great virtues is that it is the default—new activities and technologies are "regulated" by it even if they outpace top-down regulation.

C. *Policy Options for the Shale Liability System*

We therefore have a legal system for addressing risks of shale development in which regulation and liability operate in symbiotic parallel, addressing different risks and harms. Within this system, good principles exist for deciding whether a given activity is best left to control by liability or regulation, though decisions in individual cases may be difficult. In broad terms, the current balance between liability and regulation appears to follow those principles.

Therefore, rather than fueling already-contentious debates about whether additional regulation is needed, it is useful to discuss how the existing system for reducing risks can be made more efficient and effective. Policy options for improving regulation of shale development are widely discussed, but options for improving the liability system are relatively underexamined. Given the significance of liability in managing development risks and encouraging exercise of care by operators, this is unfortunate. This section explores some such options, organized broadly around Shavell's previously described principles.

---

[26] *See* Shavell, *A Model of the Optimal Use of Liability and Safety Regulation*, *supra* note 11, at 274–76.

1. Information Asymmetry

When private actors have better access to information than regulators, liability is more effective, all else equal.[27] But information asymmetry between private parties can create problems—wrongdoers may escape liability because victims are not aware they have been injured, cannot determine who is responsible, or cannot acquire sufficient evidence to support their case. Even if this information can be obtained, doing so may be costly. As we already noted, this is particularly true for disparate harms, like air and surface water pollution. But even where harms are relatively localized, as in some cases of groundwater or soil contamination, information is often difficult to locate. Disclosure, burden shifting, and strict liability can improve the function of the liability system in situations of information asymmetry. Such situations are common in shale development, where levels of expertise between operators and potential victims differ greatly.

Beneficial changes in firms' behavior often emerge directly from disclosure.[28] But disclosure also provides information to prospective plaintiffs in legal action. If groundwater is contaminated by specific compounds, for example, fracking fluid disclosure rules, requirements that firms report spills and other such accidents, and wastewater transportation tracking and record-keeping regulations can help victims identify and sue those responsible for environmental damage. Without such disclosure requirements, it might be difficult or impossible for such litigation to succeed. Civil discovery can help plaintiffs uncover information but can be costly for both sides.[29]

Another approach in cases of information asymmetry is to shift presumptions or burdens of proof in litigation. For example, most states require testing of water wells near drilling operations to identify groundwater contamination.[30] In contrast, Pennsylvania does not require predrilling water well testing but instead shifts the burden of proof onto defendant operators if such testing is not done.[31] Ordinarily, a plaintiff

---

[27] Shavell, *A Model of the Optimal Use of Liability and Safety Regulation*, *supra* note 11, at 274–76.
[28] Lori S. Bennear & Sheila S. Olmstead, *The Impact of the "Right to Know": Information Disclosure and the Violation of Drinking Water Standards*, 56 J. ENVTL. ECON. & MGMT. 117, 120, 129 (2008).
[29] Stephen Yeazell, *Getting What We Asked For, Getting What We Paid For, and Not Liking What We Got: The Vanishing Civil Trial*, UCLA PUB. L. & LEGAL THEORY SERIES, Oct. 10, 2004, at 6, 8, 12–14.
[30] *See, e.g.*, OHIO ADMIN. CODE 1501:9-1-02(F) (2014) (requiring sampling of all wells within 300 feet prior to drilling).
[31] 58 PA. CONS. STAT. § 3218 (2012).

would have to show an operator caused the injury in question to prevail in litigation. But in Pennsylvania, any contamination is presumed to have been caused by drilling unless the defendant operator can rebut this presumption with pre-drilling test evidence.[32]

In most cases, the operator will have better information than potential victims about groundwater quality and other geological and hydrological conditions. Placing the burden of proof on operators therefore likely reduces litigation-related costs and decreases the chance that a wrongdoer will escape liability because plaintiffs cannot establish causation. This may be one reason why energy developers in Pennsylvania typically engage in extensive pre-development groundwater testing at significant private cost,[33] although these data are not publicly available, and post-development testing is only performed in the case of a complaint. Such burden-shifting approaches may be useful in other contexts in which litigation would be a better, cheaper alternative to regulation, but for information asymmetries.

Perhaps the most common approach to information asymmetry in litigation is the imposition of strict liability—that is, liability without regard to whether a defendant has exercised due care. Strict liability is traditionally applied to "ultra-hazardous" activities, on the basis that such activities carry a very high duty of care.[34] In a few states, oil drilling has been classed as ultra-hazardous,[35] but in others courts handle drilling under the general negligence standard.[36]

Contrary to the intuition of many, imposing strict liability theoretically should not result in operators taking additional care.[37] But it does have one important advantage—it simplifies litigation. Plaintiffs may lack sufficient information to prove a defendant operator failed to exercise due care, but under strict liability they must only prove they were injured and that the defendant caused that injury. However, strict liability also affects activity levels: since those engaged in the activity are subject to greater

---

[32] *Id.*

[33] PA. STATE UNIV. COLL. OF AGRIC. SCIS. SCHOOL OF FOREST RES., *Gas Well Drilling and Your Private Water Supply*, WATER FACTS #28 (Mar. 2, 2010), http://www.eesi.psu.edu/seminars-conferences/earthtalks-spring2009-marcellus-supplements/gasdrilling.pdf.

[34] Neal J. Manor, *"What the Frack?" Why Hydraulic Fracturing is Abnormally Dangerous and Whether Courts Should Allow Strict Liability Causes of Action*, 4 KY. J. EQUINE, AGRIC. & NAT. RESOURCES L. 459, 468–71 (2011–2012).

[35] *See, e.g.*, Franks v. Indep. Prod. Co., 96 P.3d 484, 492 (Wyo. 2004) ("Wyoming law recognizes that the drilling of an oil and gas well is an ultrahazardous activity").

[36] *See, e.g.*, Turner v. Big Lake Oil Co., 96 S.W.2d 221, 225–26 (Tex. 1936) (declining to apply strict liability doctrine to oil drilling).

[37] Steven Shavell, *Strict Liability Versus Negligence*, 9 J. LEGAL STUD. 1, 7–8, 11 (1980).

liability, at the margin, some will simply choose not to engage in it.[38] This may be a good thing if other factors, such as lack of information on the part of plaintiffs or the existence of judgment-proof defendants, mean that activity levels are greater than socially optimal. But if these factors are not present, strict liability carries a hidden cost.

2. Ability to Pay

Policymakers have long been aware of problems created by reliance on the liability system when potential damages exceed the ability of defendants to compensate victims. Oil and gas development is a classic example: damages from spills or contamination can be great, and many independent operators have limited resources. Traditional tools for addressing this problem are financial responsibility, insurance requirements, and bonding.

Generally, when an operator applies for a permit to drill a well, it must show evidence of adequate financial resources or insurance to pay related claims.[39] Operators also may be required to post a bond in association with the permit. For example, Pennsylvania requires operators to file a bond of $4000 for each well permit.[40] Operators in Colorado alternatively can file a "blanket bond" of $25,000 covering all wells in the state.[41] Texas requires a similar $25,000 blanket bond for up to ten wells.[42]

Bonding can reduce the ability of operators with limited resources to escape liability and therefore increase incentives to take due care to avoid harms, but only when funded appropriately. An amount of $4000 is certainly insufficient to cover the expected damages from a serious accident at a well, and since it is far less than any firm's assets, likely provides no incentive to take additional care. A $25,000 blanket bond is probably even less effective since large operators may have thousands of wells. Stronger financial responsibility requirements can improve the ability of the liability system to generate adequate incentives for operators.

3. Threat of Suit

The primary reason operators might expect to escape suit for harms they cause, and therefore face inadequate incentives to reduce risks, is the disparate nature of many such harms, such as air and surface water

---

[38] *Id.*
[39] U.S. ENVTL. PROT. AGENCY, FEDERAL FINANCIAL RESPONSIBILITY DEMONSTRATIONS FOR OWNERS AND OPERATORS OF CLASS II OIL-AND GAS-RELATED INJECTION WELLS 3–6 (1990), *available at* http://www.epa.gov/r5water/uic/forms/ffrdooc2.pdf.
[40] 58 PA. CONS. STAT. § 3225 (2012).
[41] 2 COLO. CODE REGS. § 404-1:703 (2014).
[42] TEX. NAT. RES. CODE ANN. § 91.1042 (West 2005).

pollution. This is the source of the appeal of much oil and gas regulation, yet no policy can change the distributed nature of risks from the activity.

Nevertheless, some policy changes can increase the effectiveness of the liability system. For example, the cost and complexity of pursuing class-action claims might be reduced for certain kinds of injury related to shale development. As noted above, information disclosure rules are also useful in that they enable actual and potential victims to find out about harms, identify responsible parties, and establish causation in litigation.

4. Costs

Almost all of the tools and policy options discussed above for resolving information asymmetries, addressing inability to pay, and preventing operators from escaping liability also help reduce the costs of litigation. Information disclosure regulations lessen the need to rely on expensive discovery to acquire information. In theory, burden shifting rules put the burden of evidence gathering on the party able to meet it at least cost. Strict liability can greatly simplify cases by eliminating the need to prove duty of care and breach of that duty.

Other measures to reduce cost include expediting litigation, most obviously by appointing and funding enough state and federal judges to manage current and future caseloads. In states and districts with large amounts of drilling activity and related litigation, specialist courts or dockets might also improve the ability of courts to efficiently handle such cases.

II. PRESCRIPTIVE ADMINISTRATIVE REGULATION (OF SHALE GAS DEVELOPMENT)

Until the 1990s, the standard approach to environmental regulation was limited to policy instruments that economists call "command-and-control" or prescriptive approaches, which regulate behavior or performance of individual facilities.[43] While there are many such approaches, they fall into two general classes: technology standards and performance standards.

A technology standard requires firms to use a particular pollution abatement technology. "For example, the 1977 Clean Air Act Amendments required new power plants to install large flue-gas desulfurization devices ("scrubbers") to remove sulfur dioxide from stack gases."[44] In the shale

---

[43] U.S. ENVTL. PROT. AGENCY, GUIDELINES FOR PREPARING ECONOMIC ANALYSES 4-1 to 4-3 (2010), *available at* http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf.

[44] Sheila Olmstead, *The Role of Market Incentives in Environmental Policy*, *in* THE OXFORD

context, technology standards may require a particular type of cement in well casing. Other types of command-and-control regulations, such as setback requirements, are similarly uniform across firms, though they do not deal specifically with technology.

A performance standard allows polluters more freedom. Rather than requiring a specific number of feet of setback or a specific casing technology, for example, a performance standard might require that concentrations of specified pollutants in streams near drilling sites not exceed a certain level or that a pressure test on the cement casing not exceed a given reading. In theory, regulators can vary technology or performance standards across regulated firms, though in practice they have tended to implement uniform standards.

Command-and-control policy instruments are not all equal in economic terms. For example, performance standards are generally better than technology standards at minimizing emissions control costs for a given amount of abatement.[45] Some performance standards are better than others in effectiveness and cost-effectiveness terms.[46] For reasons discussed in Section 4, however, economic theory strongly favors market-based over command-and-control policy instruments, even performance standards.

A recent analysis suggests that 81 percent of observed shale gas regulations at the state level are prescriptive.[47] Prescriptive approaches are common at the federal level, as well. For example, the Bureau of Land Management's recent proposed rules for hydraulic fracturing on federal lands require operators to maintain specific types of logs and meet particular well construction standards.[48]

Among these prescriptive approaches however, performance standards are practically nonexistent. Even when states do frame shale-related regulations as performance standards, they often appear to be unenforceable. In order to be effective, a performance standard must set a well-defined, measurable standard. For example, requiring firms to limit venting or flaring to circumstances where it is economically necessary or

HANDBOOK OF U.S. ENVIRONMENTAL POLICY 553, 557 (Sheldon Kamieniecki & Michael E. Kraft eds., 2012).

[45] *See* David Besanko, *Performance versus Design Standards in the Regulation of Pollution*, 34 J. PUB. ECON. 19, 20, 43 (1987); Lori Bennear & Cary Coglianese, *Flexible Environmental Regulation*, *in* THE OXFORD HANDBOOK OF U.S. ENVIRONMENTAL POLICY 582, 583, 587–88 (Sheldon Kamieniecki & Michael E. Kraft eds., 2012).

[46] *See* Gloria E. Helfand, *Standards versus Standards: The Effects of Different Pollution Restrictions*, 81 AM. ECON. REV. 622, 629, 633 (1991).

[47] RICHARDSON ET AL., *supra* note 1, at 14.

[48] Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands, 78 Fed. Reg. 31636 (proposed May 7, 2013) (to be codified at 43 C.F.R. pt. 3160).

to avoid such practices when they create a risk to public health does not create an enforceable rule, though it might guide regulators' case-by-case permitting decisions. Conversely, a performance standard that effectively precludes all but a single compliance mechanism is a performance standard in name only. The US Environmental Protection Agency established updated New Source Performance Standards in 2012 for oil and gas wells,[49] though in practice these are structured so that a single technological approach, "green completion," will be adequate to meet them.[50]

Setting these quasi-performance standards aside, out of 27 states surveyed by Nathan Richardson and colleagues, only Alabama, Montana, Nebraska, and Texas use performance standards, and none of them uses a performance standard for more than one regulatory element in the survey.[51] Since these standards are so rare, drawing conclusions about their rationale would be unwise.

Another even more flexible approach is case-by-case permitting, under which operators must submit a formal permit application that is subject to the regulator's approval. Unlike performance standards, this form of regulation is widely used for shale gas development activities, accounting for 14% of regulations in the 27 states surveyed, and up to 20–25% of regulations in some individual states.[52]

Case-by-case permitting allows both operators and regulators some discretion in the manner in which requirements are satisfied, but the level of performance is not uniformly specified across firms. One benefit of this approach is that operators and regulators can tailor their technologies and practices to local conditions and priorities. It has important drawbacks, however. It is administratively costly since each permit must be independently reviewed. It also frequently lacks transparency because it is difficult for the industry, much less the interested public, to know what practices and technologies are required.

III. MARKET-BASED ADMINISTRATIVE REGULATION (OF SHALE GAS DEVELOPMENT)

By contrast to the prescriptive approaches described above, market-based policy instruments are decentralized, focusing on aggregate or

---

[49] Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews, 77 Fed. Reg. 49490 (Aug. 16, 2012) (to be codified at 40 C.F.R. pts. 60, 63).
[50] *Id.*
[51] RICHARDSON ET AL., *supra* note 1, at 15.
[52] *Id.*

market-level outcomes such as total emissions, rather than the activities of individual facilities. A wide array of policy instruments falls within this category: taxes, environmental markets (such as tradable pollution permit programs), and information disclosure policies are common examples.

The principle that market-based instruments are more cost-effective than command-and-control policies in the short run is well-developed in economic theory.[53] Market-based tools have this advantage because they exploit cost differences across regulated firms. In the context of pollution control, the firms with the lowest abatement costs exercise the most control, and those with the highest costs control less, paying more for permits or higher tax bills. This short-run cost-effectiveness advantage tends to be emphasized in public policy debates, and it is a critical argument in favor of market-based instruments.

However, the greatest potential cost savings from these types of environmental policies may be achieved in the long run, when firms' compliance technologies are not fixed. Because they require firms to pay to pollute, market-based tools provide strong incentives for regulated firms to invest in new technologies that reduce pollution abatement costs over time, either creating these innovative technologies themselves or adopting cheaper pollution control technologies developed by other firms.[54]

A. *Environmental Taxes*

The classic economic prescription for the management of environmental market failures is to tax negative externalities and subsidize positive externalities, with the efficient tax, or subsidy, equal to the marginal damages, or benefits, at the efficient level of the externality.[55] To our

---

[53] *See* Thomas D. Crocker, *The Structuring of Atmospheric Pollution Control Systems*, *in* THE ECONOMICS OF AIR POLLUTION, 61, 63, 76–79 (H. Wolozin ed., 1966); Peter Bohm & Clifford F. Russell, *Comparative Analysis of Alternative Policy Instruments*, *in* 1 HANDBOOK OF NATURAL RESOURCE AND ENERGY ECONOMICS 395, 420–21, 441 (A.V. Kneese & J.L. Sweeney eds., 1985); T.H. Tietenberg, *Economic Instruments for Environmental Regulation*, 6 OXFORD REV. ECON. POL'Y 17, 17, 21, 23, 31 (1990); Robert W. Hahn & Robert N. Stavins, *Economic Incentives for Environmental Protection: Integrating Theory and Practice*, 82 AM. ECON. REV. 464, 464–65 (1992); Robert N. Stavins, *Experience with Market-Based Environmental Policy Instruments*, *in* 1 HANDBOOK OF ENVIRONMENTAL ECONOMICS 356, 359, 420–21 (Karl-Gören Mäler & Jeffrey R. Vincent eds., 2003).

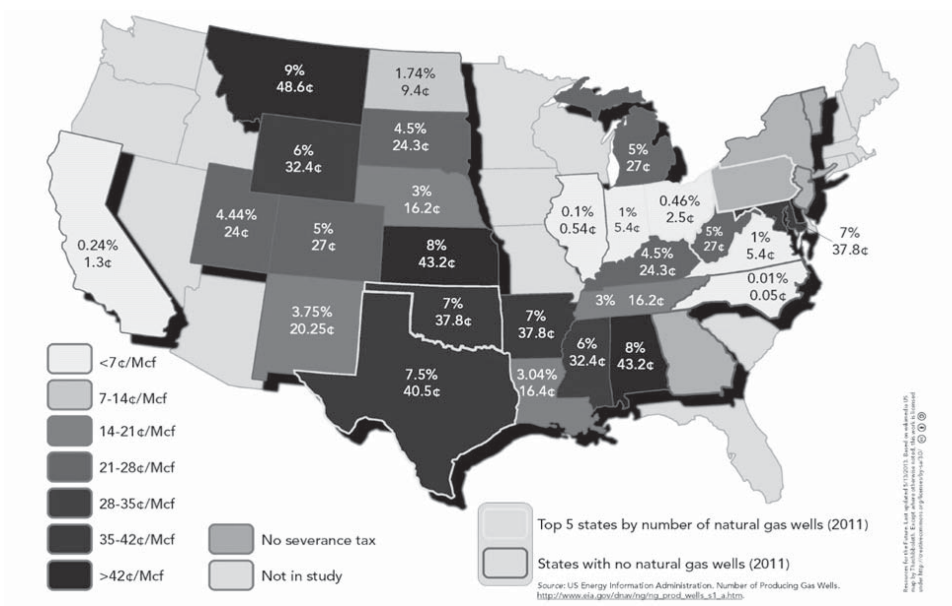
[54] *See* Paul B. Downing, & Lawrence J. White, *Innovation in Pollution Control*, 13 J. ENVTL. ECON. & MGMT. 18, 19 (1986); Scott R. Milliman & Raymond Prince, *Firm Incentives to Promote Technological Change in Pollution Control*, 17 J. ENVTL. ECON. & MGMT. 247, 247 (1989).

[55] *See generally* A.C. PIGOU, THE ECONOMICS OF WELFARE 14 (4th ed. 1932); William J.

knowledge, no taxes are used to regulate negative impacts of shale gas development *per se* in the United States. But oil and gas production is subject to many local, state, and federal taxes that potentially could be used as tools to mitigate potential risks from shale gas development.

A severance tax is one candidate. While pollution taxes tend to be charged on the flow of emissions from a particular source to air or water, severance taxes are typically charged on the quantity or market value of a nonrenewable natural resource stock removed from the environment.[56] The severance tax is the most widely adopted state oil and gas tax.[57] Twenty-six out of 31 states reviewed by Richardson et al.,[58] currently have severance taxes on natural gas (see Figure 1).

Figure 1. State Severance Taxes at $5.40/Mcf Natural Gas Price[59]



Baumol, *On Taxation and the Control of Externalities*, 62 AM. ECON. REV. 307, 307–08, 311 (1972); Agnar Sandmo, *Optimal Taxation: An Introduction to the Literature*, 6 J. PUB. ECON. 37, 38, 50–51 (1975).

[56] *See* UJJAYANT CHAKRAVORTY ET AL., STATE TAX POLICY AND OIL PRODUCTION: THE ROLE OF THE SEVERANCE TAX AND CREDITS FOR DRILLING EXPENSES 6 (2009), *available at* http://www .americantaxpolicyinstitute.org/pdf/energy_conference/chakravorty-gerking-leach.pdf.

[57] *Id.*

[58] RICHARDSON ET AL., *supra* note 1, at 66–67.

[59] RICHARDSON ET AL., *supra* note 1, at 66, Map 21.

State and local governments rely heavily on severance tax revenues to fund public goods.[60] They may also be justified in theory as a way to capture the intertemporal external cost related to the depletion of a nonrenewable natural resource ("scarcity rent" in economic terms) in the case of shale development. The fact is that a unit of gas removed from shale today is not there to extract tomorrow. Private firms operating in competitive markets do internalize this cost as they make choices about how to allocate their extraction activities over time.[61] However, the public sector, as owner of subsurface minerals in some instances and as steward of such resources more generally, can capture and invest these rents to promote the economically sustainable use of nonrenewable resources,[62] remedy environmental harms,[63] or simply provide ongoing income that might smooth the boom-and-bust cycle common to resource-based economies. In theory, the optimal severance tax also could account for negative gas production externalities to the extent that those externalities are related to the quantity or value of production from a given well. Methane emissions and emissions of local and regional air pollutants, such as nitrogen oxides (NO_x) and volatile organic compounds, are good examples.

Unfortunately, severance taxes at current US levels appear to have little impact on producer behavior. Recent analyses refute older studies comparing state and federal oil and gas taxes in the 1990s that suggested the severance tax had relatively strong impacts on production in comparison to the federal corporate income tax or state property taxes on oil and gas reserves.[64] The newer analyses account for tax interaction effects and other complicating factors and show that production is quite inelastic to even large changes in the severance tax, though they may have somewhat more impact on drilling activity than on production.[65]

---

[60] *See* Mitch Kunce, *Effectiveness of Severance Tax Incentives in the U.S. Oil Industry*, 10 INT'L TAX & PUB. FIN. 565, 565 (2003) [hereinafter Kunce, *Effectiveness of Severance Tax Incentives in the US Oil Industry*].

[61] *See* Harold Hotelling, *The Economics of Exhaustible Resources*, 39 J. POL. ECON. 137, 164–67 (1931).

[62] *See* John M. Hartwick, *Intergenerational Equity and the Investing of Rents from Exhaustible Resources*, 67 AM. ECON. REV. 972, 972–74 (1977); Robert Solow, Lecture at the 40th Anniversary of Resources for the Future: An Almost Practical Step Toward Sustainability (Oct. 8, 1992).

[63] *See* David A. Gulley, *Severance Taxes and Market Failure*, 22 NAT. RESOURCES J. 597, 598–99 (1982).

[64] *See* Robert Deacon, *Taxation, Depletion and Welfare: A Simulation Study of the US Petroleum Resource*, 24 J. ENVTL. ECON. & MGMT. 159, 172–73, 179 (1993).

[65] *See* Kunce, *Effectiveness of Severance Tax Incentives in the US Oil Industry*, *supra* note 60, at 565–66, 583; Mitch Kunce et al., *Environmental and Land Use Regulation in*

A second challenge is that the most significant potential risks related to shale gas development are not necessarily linked to producing wells.[66] In fact, once a shale gas well is in production, many risks from the development process are no longer relevant. Local air pollution and congestion from truck traffic are good examples, as are surface water risks from impoundments used for hydraulic fracturing. Other risks, such as habitat fragmentation from well pads or pipelines, can no longer be affected by a tax on production. Thus, a severance tax will not provide effective incentives on the margin for mitigation of these risks, though the revenues could be used for corrective action or public investments in risk reduction.

In 2012, Pennsylvania chose a different option that may avoid these two challenges. The state implemented an impact fee on gas production from the Marcellus Shale, which counties or municipalities may vote to adopt.[67] The fee is imposed on every producer in adopting localities and applies to all spudded unconventional gas wells. The amount of the fee depends on the average annual price of natural gas and is charged on a per-well basis, regardless of production.

The constitutionality of this fee is currently under review before the Pennsylvania Supreme Court,[68] but to the extent that there are fixed external costs to shale gas well development, the impact fee approach may be economically justifiable. Such a fee could vary spatially. For example, higher fees could be implemented in areas such as sensitive habitats that have higher anticipated social costs of well development. Fees also could increase over time as the land footprint of shale gas development consumes a greater fraction of formerly open space, increasing the marginal value of remaining open space.

B. Environmental Markets

While environmental taxation had been proposed since the early part of the last century, the rise of environmental trading markets began later, when the Nobel Prize–winning economist Ronald Coase noted that the mere existence of externalities in a market could, under certain very restrictive conditions, induce private negotiation of efficient outcomes in

---

Nonrenewable Resource Industries: Implications from the Wyoming Checkerboard, 80 LAND ECON. 76, 86, 90–91 (2004); CHAKRAVORTY ET AL., *supra* note 56, at 335–37.

[66] *See* ALAN KRUPNICK ET AL., PATHWAYS TO DIALOGUE: WHAT THE EXPERTS SAY ABOUT THE ENVIRONMENTAL RISKS OF SHALE GAS DEVELOPMENT 4, 17, 20 (2013), *available at* http://www.rff.org/Documents/RFF-Rpt-PathwaystoDialogue_FullReport.pdf.

[67] Act of Feb. 14, 2014 (Act 13 of 2012), Pub. L. 87, No. 13 (codified as amended at 58 PA. CONS. STAT. § 2302).

[68] Robinson Twp., Washington Cnty. v. Commonwealth, 83 A.3d 901 (Pa. 2013).

cleaning up pollution.[69] A key condition was well-defined property rights, which fostered the development of systems of marketable pollution permits known as "cap-and-trade" systems; although there are other variations on the same theme.[70] The conceptual framework of emissions trading programs is well-described in the literature.[71] The regulator sets an aggregate cap on pollution and allocates or auctions the implied number of pollution permits to the regulated community.[72] The pollution permits are transferable, and each firm will buy and sell permits based on a comparison of market permit prices with its own marginal abatement costs.[73] When the permit market clears, each firm will have equated its own marginal pollution abatement cost with the prevailing permit price, resulting in equal marginal costs across firms and the least-cost allocation of control responsibility to meet the aggregate cap.[74]

No emissions trading programs have been established specifically to regulate risks from shale gas development, but current and future applications may be relevant, requiring or facilitating the participation of energy developers directly or indirectly.

Shale gas operators and service companies are subject to Clean Air Act regulations for local and regional air pollutants, some of which have been implemented through tradable permit policies. For example, the 2003–2008 NO_x Budget Trading Program was designed to reduce aggregate NO_x emissions and their regional transport in the eastern United States, in an effort to increase regional compliance with federal ambient ozone standards.[75] Marcellus shale development is expected to contribute 12% of regional NO_x and volatile organic compound emissions responsible for the formation of ground-level ozone by 2020.[76] If future trading

---

[69] Ronald H. Coase, *The Problem of Social Cost*, 3 J. L. & ECON. 1, 41–44 (1960).
[70] *See* J. H. DALES, POLLUTION, PROPERTY, AND PRICES, 93–96 (1968); W. David Montgomery, *Markets in Licenses and Efficient Pollution Control Programs*, 5 J. ECON. THEORY 395, 395, 401–03, 411 (1972); *How Cap and Trade Works*, ENVTL. DEF. FUND, http://www.edf.org/climate/how-cap-and-trade-works (last visited Oct. 27, 2014), *archived at* http://perma.cc/RN2H-DD6J.
[71] *See generally* T. H. TIETENBERG, EMISSIONS TRADING: PRINCIPLES AND PRACTICE (2d ed. 2006).
[72] DALES, *supra* note 70, at 93.
[73] *Id.* at 93–94.
[74] *See* Montgomery, *supra* note 70, at 401–03.
[75] U.S. ENVTL. PROT. AGENCY, NOX BUDGET TRADING PROGRAM/NOX SIP CALL, 2003–2008 (2014), *available at* http://www.epa.gov/airmarket/progsregs/nox/sip.html, *archived at* http://perma.cc/XMS2-2CWD.
[76] Anirban Roy et al., *Predictions* of the *Impacts of Future Marcellus Shale Natural Gas Development on Regional Ozone,* American Geophysical Union Fall Meeting, San Francisco,

programs were to emerge, sources in the shale gas production chain could be incorporated, even though prior policies focused on coal-fired power plants and other large industrial point sources.

Given the significant concerns raised about methane emissions in the shale gas production chain,[77] participation of shale gas operations in existing markets for greenhouse gas emissions would seem to be an obvious candidate for extending the advantages of market-based regulation to this new sphere. For example, one could imagine operators generating emissions credits from green well completions that could be used as offsets in existing markets, such as California's new cap-and-trade program,[78] or the European Union's Emissions Trading System.[79]

If shale gas development is responsible for water pollution emissions in watersheds with water quality trading programs, operators may be affected by these programs. The Clean Water Act prevents shale gas operators from discharging effluent directly to rivers and streams, but water quality trading policies could be relevant to shale gas development in watersheds with Total Maximum Daily Loads ("TMDLs") under the Clean Water Act that focus on contaminants such as sediment, dissolved solids, and chloride from both point and non-point sources.[80] Links between shale gas development, sedimentation, and chloride in rivers and streams have been established in the literature,[81] and flowback and produced water are high in dissolved solids. Together, these contaminants are the focus of ten to fifteen percent of TMDLs currently being implemented.[82] A handful of current water quality trading programs allow trading in sediment loads, but none focus on chloride or total dissolved

---

CA (Dec. 3–7, 2012), http://fallmeeting.agu.org/2012/eposters/eposter/gc23b-1069/, *archived at* http://perma.cc/9WSE-23HM.

77 David Allen et al., *Measurements of Methane Emissions at Natural Gas Production Sites in the United States*, 110 PROCEEDINGS OF THE NAT'L ACAD. SCI. 17768, 17768–69 (2013), *available at* http://www.pnas.org/content/110/44/17768.full.pdf+html.

78 CALI. ENVTL. PROT. AGENCY, AIR RES. BD., COMPLIANCE OFFSET PROGRAM (2014), http://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm, *archived at* http://perma.cc/H98R-JCT3.

79 EUROPEAN COMM'N, QUESTIONS AND ANSWERS ON THE REVISED EU EMISSIONS TRADING SYSTEM (2014), *available at* http://europa.eu/rapid/press-release_MEMO-08-796_en.htm, *archived at* http://perma.cc/U49Y-2L2F.

80 33 U.S.C. § 1313 (2012).

81 Sheila M. Olmstead, *Shale Gas Development Impacts on Surface Water Quality in Pennsylvania*, 110 PROCEEDINGS OF THE NAT'L ACAD. SCI. 4962, 4962–66 (2013), *available at* http://www.pnas.org/content/110/13/4962.full.pdf+html.

82 U.S. ENVTL. PROT. AGENCY, *National Summary of Impaired Water and TMDL Information (2014)*, *available at* http://iaspub.epa.gov/tmdl_waters10/attains_nation_cy.control?p_report_type=T, *archived at* http://perma.cc/9CE9-ZQ7Z.

solids.[83] However, use of these flexible policy instruments could reduce the cost of compliance with any new regulations addressing surface water pollution from shale gas development.

Risks related to the quantity of water used in hydraulic fracturing are an additional concern and are another area where markets could help. These concerns are more relevant in arid regions than in those with a more plentiful water supply.[84] In some jurisdictions in the western United States, water users have the ability to lease and transfer water rights to other users.[85] In theory, such markets can result in water moving to its highest-valued uses.[86]

Because irrigation has traditionally dominated water consumption, especially in the West, farmers stand to benefit most from the ability to engage shale gas operators—who need reliable sources of water for hydraulic fracturing—in leases or sales. If withdrawals for energy development pose a risk to agriculture in arid states, water markets could help to mitigate that risk, compensating rights holders for any expected decreases in productivity. Water leases and transfers between irrigators and growing western cities may provide a template for such transactions with energy developers.[87] A small number of documented trades already have taken place between agricultural users and energy developers in North Dakota; Colorado and Utah also have seen some participation of energy developers in water rights markets.[88] Trading is likely occurring on a much larger scale than what is implied by these documented instances, particularly in states such as Texas, where groundwater is private property.[89]

For water users, the decision to transfer water depends on the relative impacts of development, the value of agricultural production with less water, and the price that energy developers are willing to pay. While the

---

[83] Karen A. Fisher-Vanden & Sheila M. Olmstead, *Moving Pollution Trading from Air to Water: Potential, Problems, and Prognosis*, 27 J. ECON. PERSP. 147, 151, 155 (2013).
[84] Jean-Philippe Nicot & Bridget R. Scanlon, *Water Use for Shale-Gas Production in Texas, US*, 46 ENVTL SCI. & TECH. 3580, 3580, 3585 (2012).
[85] *See* Brandon Scarborough, *Water Markets: Restoring Streams Through Trade*, PERC Policy Series No. 46, 2010, at 2.
[86] L. M. HARTMAN & D. SEASTONE, WATER TRANSFERS: ECONOMIC EFFICIENCY AND ALTERNATIVE INSTITUTIONS 7 (1970); Jedidiah Brewer et al., *Water Markets in the West: Prices, Trading, and Contractual Forms*, 46 ECON. INQUIRY 91, 91–92 (2008).
[87] *See* Brewer et al., *supra* note 86, at 91–92.
[88] WESTERN GOVERNORS' ASSOCIATION, WATER TRANSFERS IN THE WEST: PROJECTS, TRENDS AND LEADING PRACTICES IN VOLUNTARY WATER TRADING 10, 88 (2012).
[89] *Water in Texas—Who Owns It?*, TEXAS GROUNDWATER PROTECTION COMMITTEE (Sept. 12, 2014), http://www.tgpc.state.tx.us/subcommittees/POE/FAQs/WaterOwnership_FAQ.pdf.

seller of water benefits from trade, other water users, such as those who share infrastructure maintenance costs, may suffer unexpected consequences from water trading. Downstream junior rights holders who benefit from irrigation return flows may also experience damages if water used for hydraulic fracturing is not returned to rivers and streams, or if water quality is degraded. A careful examination of the distributional consequences of water markets as they relate to shale gas development is needed.

C. Information Disclosure Policies

Information disclosure policies have been developed to inform consumers about the public and private benefits of their consumption activities, as well as to influence the behavior of polluting firms. Policies aimed at firms' behavior are most relevant to the regulation of risks from shale gas development, though such policies also can indirectly influence consumers of goods and services produced by these firms. There is growing evidence for the effectiveness of such policies in changing firms' behavior.[90]

An important example of this type of disclosure policy studied by many researchers is the requirement that manufacturing facilities publicly disclose toxic chemical releases under the US Toxics Release Inventory ("TRI") program.[91] Though releases have decreased dramatically since the TRI began, it has been difficult to determine whether the TRI is actually responsible for these decreases in toxic emissions because data are not available for releases before the program began or for unregulated facilities.[92]

Federal and state legislators have implemented information disclosure requirements in an effort to mitigate shale gas development risks. Since 2005, the injection of fracturing fluids other than diesel fuel has been exempt from the disclosure requirements of the Safe Drinking Water Act, the federal statute that typically addresses risks to drinking water supplies from deep underground injection.[93] However, the Bureau of Land Management draft rules for hydraulic fracturing operations on public

---

[90] Nicholas Powers et al., *Does Disclosure Reduce Pollution? Evidence from India's Green Rating Project*, 50 ENVTL. RESOURCE ECON. 131, 136 (2011); Lori Bennear & Cary Coglianese, *Measuring Progress: Program Evaluation of Environmental Policies*, 47 ENV'T. 22, 25–27 (2005).

[91] U.S. ENVTL. PROT. AGENCY, TOXIC CHEMICAL RELEASE INVENTORY REPORTING FORMS AND INSTRUCTIONS 1 (2013).

[92] Bennear & Coglianese, *supra* note 90, at 29.

[93] Energy Policy Act of 2005, Pub. L. No. 109-58, § 322, 42 U.S.C. 15801 (2005).

lands, issued in May 2012, include a fracking fluid disclosure requirement, and fifteen states currently require disclosure of this kind.[94]

Unfortunately, as with the TRI, no data are available on the contents of fracturing fluids before these state and federal policies came into force, and because all hydraulic fracturing operations tend to be covered by these rules, no data are available on fluids used by firms that do not disclose their contents. Thus, it will be difficult to gauge the impact of disclosure on operators' behavior. A potential method is to exploit the variation in timing of the adoption of disclosure rules by states, controlling carefully for other differences across states—perhaps looking at wells in the same shale play but within states with different disclosure rules.

One possibility is that disclosure results in public attention to operators using toxic chemicals, creating pressure for behavioral change from consumers or shareholders. Such impacts have been measured empirically for the TRI, which is available online in an easy-to-interpret format.[95] FracFocus has emerged to play a similar role for fracking fluid disclosure requirements, and its website allows users to obtain PDFs of fracking fluid chemical lists by well.[96] Since disclosure through FracFocus has occurred for some locations since 2011, an empirical assessment of its effects on shareholder or consumer behavior may now be feasible. Similarly, researchers could compare practices on federal land under the proposed Bureau of Land Management disclosure rule[97] to those on nearby private land where disclosure is not required.

CONCLUSIONS

New regulation may be required to mitigate shale gas development risks, most notably those with widespread associated harms. But for other risks, small changes to the liability system may be simpler and more cost-effective. When regulatory approaches are favored, market-based policies can significantly reduce costs.

---

[94] RICHARDSON ET AL., *supra* note 1, at 6, 43–44.
[95] *Pollution in Your Community*, SCORECARD: THE POLLUTION INFORMATION SITE, http://scorecard.goodguide.com (last visited Oct. 27, 2014), *archived at* http://perma.cc/9KF-UPJG.
[96] *What Chemicals are Used*, FRACFOCUS, http://fracfocus.org/chemical-use/what-chemicals-are-used (last visited Oct. 27, 2014), *archived at* http://perma.cc/VX6G-RMFZ.
[97] DEPARTMENT OF THE INTERIOR: BUREAU OF LAND MANAGEMENT, OIL AND GAS: HYDRAULIC FRACTURING ON FEDERAL AND INDIAN LANDS (2014), *available at* http://www.blm.gov/pgdata/etc/medialib/blm/wo/Communications_Directorate/public_affairs/hydraulicfracturing.Par.91723.File.tmp/HydFracSupProposal.pdf.

The vast majority of existing regulations governing oil and gas development are prescriptive. The most significant examples of market-based approaches to risk mitigation thus far are water rights trading and information disclosure regulations. Severance taxes are ubiquitous, but in their current form, any impacts on environmental risk are probably minimal. Air and water pollution trading programs under the Clean Air Act and Clean Water Act may eventually be relevant to shale gas operations. If shale gas operators reduce methane emissions through green completions, these activities could generate greenhouse gas abatement credits that could, in theory, be used for compliance with climate-related cap-and-trade policies.

A key research priority for understanding the potential for further innovation in liability and market-based approaches to shale gas risk mitigation is impact evaluation of those few innovative policies that have already been implemented. What has been the effect on operator behavior of Pennsylvania's shifting of the burden of proof regarding groundwater contamination near gas wells onto operators? How do the minimal bonding and insurance requirements that are in place in various states affect energy developers' behavior, and what would be the impact of increases in such requirements? Where energy developers are leasing and purchasing water rights from farmers and other rights holders, what have been the effects on water management costs, and on any affected third parties? How has fracking fluid information disclosure affected shale gas development practices?

Though theory offers substantial support for innovative approaches, empirical evidence for their effectiveness and cost-effectiveness in practice is essential.