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REGULATORY OBSOLESCENCE THROUGH TECHNOLOGICAL CHANGE IN OIL AND GAS EXTRACTION

TIMOTHY FITZGERALD*

ABSTRACT

Extraction of oil and gas from unconventional resources, recently enabled by technological innovations, revolutionized national and global markets. However, exploration and production still proceed under legacy regulations, mostly promulgated at the state level. The mismatch of modern production realities and historic regulatory structures creates opportunities for reducing conflicts that diminish economic value. This Article identifies regulations that originated under conventional extraction, and often enhance productivity in that setting, but create waste when applied to unconventional resources. Then, it identifies contractual solutions that have evolved as resource owners and extraction firms have adapted to new technologies. Contractual innovations help inform directions for regulatory reform.

INTRODUCTION

The resurgence of U.S. oil and natural gas production pivoted on exploitation of “unconventional” resources once considered subeconomic, but rendered profitable by transformative technological advances.¹ Expanded

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¹ For background narrative on the technological development of unconventional resources and their impact, see *generally* RUSSELL GOLD, *THE BOOM: HOW FRACKING IGNITED THE AMERICAN ENERGY REVOLUTION AND CHANGED THE WORLD* (2014); DANIEL YERGIN, *THE QUEST: ENERGY, SECURITY, AND THE REMAKING OF THE MODERN WORLD* (2011); GREGORY ZUCKERMAN, *THE FRACKERS: THE OUTRAGEOUS INSIDE STORY OF THE NEW BILLIONAIRE WILDCATTERS* (2013). For a discussion of the economics of the impact of technical changes, see

production has important effects on domestic markets for both natural gas² and petroleum,³ and the impacts extend to global markets.⁴

Locating and producing petroleum and natural gas have a colorful history, of which technical change has long been a part.⁵ Regulation was imposed to help avoid frequent problems that reduced the value of oil and gas resources.⁶ Since then, technical change has revolutionized how oil and gas are produced by changing the nature of the resource being extracted.⁷ Technology changing the fundamental characteristics of the resource in place is novel. However, the technologically enabled transition to exploitation of unconventional resources creates new problems just as it obviates old ones, and the legacy regulatory framework has become obsolete in important areas. These legacy regulations need to be revised and reformed to unlock the full economic potential of unconventional resources.

This Article focuses on the regulation of oil and gas extraction. These extraction regulations prescribe the interactions among extracting firms as well as the principal-agent problems that arise between extracting firms and resource owners. Regulation has two potentially contradictory goals: one is to prescribe interactions between extracting firms; the

Timothy Fitzgerald, *Frackonomics: Some Economics of Hydraulic Fracturing*, 63 CASE W. RES. L. REV. 1337, 1337–44 (2013). *See also* John M. Golden & Hannah Jacobs Wiseman, *The Fracking Revolution: Shale Gas as a Case Study in Innovation Policy*, 64 EMORY L.J. 955, 964, 981–82 (2015) (providing a thorough investigation of the impacts of the technical innovation).

² *See* Catherine Hausman & Ryan Kellogg, *Welfare and Distributional Impacts of Shale Gas*, SPRING 2015 BROOKINGS PAPERS ON ECON. ACTIVITY 71, 88–89, 95–96, 99–100, 117–18 (2015); Charles F. Mason et al., *The Economics of Shale Gas Development*, 7 ANN. REV. RESOURCE ECON. 269, 271–72, 278 (2015).

³ *See* MICHAEL RATNER & MARY TIEMANN, CONG. RESEARCH SERV., R43148, AN OVERVIEW OF UNCONVENTIONAL OIL AND NATURAL GAS: RESOURCES AND FEDERAL ACTIONS 1, 5–6 (2015) (explaining the effects of increased domestic oil production); *see also* Lutz Kilian, *The Impact of the Fracking Boom on Arab Oil Producers*, 38 ENERGY J. 137, 143 (2017) (providing detailed analysis of the counterfactual oil price in the absence of the U.S. unconventional oil boom).

⁴ *See* Frank Asche et al., *Gas Versus Oil Prices the Impact of Shale Gas*, 47 ENERGY POL'Y 117, 119–20, 122 (2012) (discussing the impact of U.S. shale gas production on the movement of European gas prices).

⁵ *See generally* 2 HAROLD F. WILLIAMSON & ARNOLD R. DAUM, THE AMERICAN PETROLEUM INDUSTRY (2d vol. 1959); DANIEL YERGIN, THE PRIZE: THE EPIC QUEST FOR OIL, MONEY, AND POWER (2001).

⁶ *See* discussion *infra* Section I.B (discussing oil and natural gas regulations).

⁷ Jane Bocora, *Global Perspectives for the Development of Unconventional Gas*, 65 SOCIAL AND BEHAVIORAL SCIENCES 436, 437 (2012) (e.g., changing unconventional resources from inaccessible to accessible by breaking through impermeable sediments).

second is to define rights and responsibilities of firms vis-à-vis the owners of the resource. Balancing these two goals is a central challenge for regulation. While new technology has changed the first, the second has not been relieved.

The technological shock to oil and gas production is not unique in the energy industry—other sectors, notably renewable electricity generation, have experienced technological leaps in recent years.⁸ The advance for oil and gas production importantly, and perhaps uniquely, changes the nature of the resource being exploited.⁹ While the severed oil and natural gas are comparable to those developed from conventional resources, unconventional oil and gas resources are fundamentally different in ways germane to effective and efficient regulation of extraction. This underscores the motivation for reconsidering oil and gas regulations. In contrast, other energy sectors, including natural gas pipeline transportation, have realized large economic gains from altered regulatory regimes.¹⁰ Effects on the natural gas transportation industry have been large, but do not stem from technical innovations.¹¹

The current regulatory framework for oil and gas extraction is the product of more than a century of experience,¹² but it often falls short of statutory objectives and administrative implementation. By writing innovative contracts, private parties can work around some failings of the antiquated regime. Situations that do not offer opportunities for contractual remedies are excellent candidates for regulatory reform. Opportunities for reform are tempered by an important hazard. The temporal overlap between continuing extraction from conventional deposits and new exploitation of shale and other resources prevents regulators from simply switching to a new regulatory regime. This reality constrains potential reforms for existing development, but opens the door to new frontiers as more resources are identified and extracted.

⁸ Julia Pyper, *No Longer a Novelty, Clean Energy Technologies Boom All Across the US*, GTM, July 19, 2018, <https://www.greentechmedia.com/articles/read/no-longer-a-novelty-clean-energy-technologies-boom-across-the-us#gs.jcYcJT> [https://perma.cc/27MS-JHCH].

⁹ Bocora, *supra* note 7.

¹⁰ JEFF D. MAKHOLM, *THE POLITICAL ECONOMY OF PIPELINES: A CENTURY OF COMPARATIVE INSTITUTIONAL DEVELOPMENT* 72–77 (2012).

¹¹ See generally Matthew E. Oliver & Charles F. Mason, *Natural Gas Pipeline Regulation in the U.S.: Past, Present, & Future*, FOUNDATIONS AND TRENDS IN MICROECONOMICS (May 2018).

¹² David W. Miller, *The Historical Development of the Oil & Gas Laws of the United States*, 51 CALIF. L. REV. 506, 511 (1963).

I. BACKGROUND

A. *Unconventional Oil and Gas*

“Unconventional” resources are producing formations that lack sufficient permeability to economically produce without technology beyond the traditional vertical well with artificial lift.¹³ Some resources, such as shales and coals, are the source rock in which hydrocarbons originate, rather than reservoirs into which hydrocarbons migrate over time.¹⁴ These resources require varying degrees of reservoir stimulation to increase permeability, often achieved by hydraulic fracturing.¹⁵ After stimulating the reservoir in this fashion, the oil and gas trapped in the tight spaces of the rock can flow to the wellbore and then to the surface.¹⁶

The technologies that have unlocked unconventional resources were developed after long experimentation. Considerable acknowledgment is afforded to the combination of horizontal drilling and large-volume hydraulic fracturing in the Barnett Shale in Texas,¹⁷ though credit should be shared more widely.¹⁸ The generalist term “fracking” encircles a large collection of technologies, including hydraulic fracturing, horizontal and directional drilling, and advanced seismography techniques¹⁹ that have allowed profitable investment in resources that were

¹³ See, e.g., Liang Wang et al., *A Technical Review on Shale Gas Production and Unconventional Reservoirs Modeling*, 6 NAT. RESOURCES 141, 142 (2015). A parsimonious way of differentiating between conventional and unconventional resources is to compare a measure of permeability: conventional reservoirs typically have permeability in the millidarcies (passage of one one-thousandth of a cubic centimeter of fluid (having a viscosity of one centipoise) per second through a sample one square centimeter in cross-sectional area under a pressure of one atmosphere per centimeter of thickness) whereas unconventional reservoirs have permeabilities measured in micro- or nanodarcies. The unconventional resources are therefore between a thousand and million times less likely to allow fluids to move under the surface. Here we distinguish between artificial lift and enhanced oil recovery by the need for more than simple artificial lift, such as repressuring formations to replace lost reservoir pressure.

¹⁴ See discussion *infra* Section II.C (discussing characteristics of unconventional sources).

¹⁵ Bocora, *supra* note 7.

¹⁶ *Id.*

¹⁷ See GOLD, *supra* note 1, at 15 (providing background on what features of the Barnett Shale in Texas led to technological innovation); see also ZUCKERMAN, *supra* note 1, at 34.

¹⁸ See generally Golden & Wiseman, *supra* note 1, at 968–76 (detailing various technologies that contributed to unlocking unconventional resources).

¹⁹ For a relatively early description of the impacts of technical change in oil and gas extraction, see Douglas L. Bohi, *Changing Productivity in U.S. Petroleum Exploration and Development*, Resources for the Future, Discussion Paper 98-38 (1998). See also GOLD, *supra* note 1, at 5 (discussing similar topics).

subeconomic with conventional technology.²⁰ Other technologies have made important contributions to the ability to exploit unconventional resources economically: measurement-while-drilling technology, which allows for geosteering and effective control over directional and horizontal drilling; microseismic surveying, which allows for measurement and evaluation of fractures; packers and sleeves that isolate portions of the wellbore and create the possibility for “multi-stage” fracs; and thousands of other incremental innovations to elements of the exploration and production process.²¹

One result of new technological capacity has been a massive increase in domestic oil and gas production, largely from previously subeconomic resources.²² Domestic supply shocks have affected global markets, with the linkages more explicit thanks to the relaxation of a decades-old trade ban for crude oil,²³ and the new ability to export natural gas to overseas markets.²⁴ Before these pathways opened, notable basis differentials between U.S. and global oil benchmarks, and between U.S., European, and East Asian natural gas, were motivations for policy action.²⁵

²⁰ Fitzgerald, *supra* note 1, at 1337–39.

²¹ Golden & Wiseman, *supra* note 1, at 973–74 (detailing these and other innovations and summarizing that “[i]n short, an ever-expanding multiplicity of technological developments have [sic] helped increase yields or reduce costs . . .”).

²² *Where Our Natural Gas Comes From*, U.S. ENERGY INFO ADMIN., http://www.eia.gov/energy_in_brief/article/shale_in_the_united_states.cfm [<https://perma.cc/G2NH-UKY5>] (last visited Oct. 29, 2018).

²³ Together these changes are likely to have affected decisions by OPEC to keep high production targets even as global oil prices fell in 2014 and 2015. See Stanley Reed, *OPEC, Keeping Quotes Intact, Adjusts to Oil’s New Normal*, N.Y. TIMES (June 5, 2015), <https://www.nytimes.com/2015/06/06/business/international/opec-oil-prices.html> [<https://perma.cc/T4XK-WWWG>]. The ban on crude exports from the lower forty-eight had been in place for forty years, and was incrementally eased in 2014 to allow certain firms to export certain light grades (condensates). In December 2015 the remaining restrictions on exports were lifted by Congress. *America Lifts Its Ban on Oil Exports*, THE ECONOMIST (Dec. 18, 2015), <https://www.economist.com/finance-and-economics/2015/12/18/america-lifts-its-ban-on-oil-exports> [<https://perma.cc/4VGJ-8VAU>].

²⁴ Zuckerman discusses the background to reverse the flow of liquefied natural gas (“LNG”) from import to export. See ZUCKERMAN, *supra* note 1, at 24–28, 40, 45. Cheniere Energy exported the first LNG cargo from a continental U.S. port in March 2016. *Export Projects Update March (2016)*, LNG ALLIES, <http://www.lngallies.com/epu-2016-03-31/> [<https://perma.cc/7DB6-58NR>] (last updated Mar. 31, 2016). For further analysis of how this affects global LNG and gas markets, see Kenneth B. Medlock et al., *The global gas market, LNG exports and the shifting US geopolitical presence*, 5 ENERGY STRATEGY REV. 14 (2014).

²⁵ On basis differentials in the oil market, see Bahattin Buyuksahin et al., *Physical Markets, Paper Markets and the WTI-Brent Spread*, 34 ENERGY J. 129 (2013). On gas market differentials between Europe and United States, see Timothy Fitzgerald & Randal R.

Relatively high prices and new technology led to a rapid proliferation of potential extraction sites, many of which are located in known geological provinces where conventional development failed or was only marginally productive (e.g., Bakken).²⁶ New drilling programs pressed into regions such as Pennsylvania and Ohio that were largely unfamiliar with the industry and its practices.²⁷ Mineral interest owners, surface landowners, local residents, and the general public in those places turned to oil and gas regulators for relief from transgressions real and perceived.²⁸ Because unconventional wells typically have much higher decline rates than historic conventional wells (meaning production naturally declines faster over time than conventional wells),²⁹ many more wells are needed to sustain production.³⁰ Residents' objections are usually centered on the drilling of thousands of new wells rather than the amount of production from each well. Because of relatively rapid production decline rates, developing unconventional resources requires a large number of wells.³¹ Drilling such wells is subject to a wide variety of state regulations.³²

B. *Oil and Gas Regulation*

Regulation of oil and gas extraction activities has historically been the domain of states.³³ Regulation is loosely coordinated through the

Rucker, *U.S. Private Oil and Natural Gas Royalties: Estimates and Policy Relevance*, 40 OPEC ENERGY REV. 3 (2016).

²⁶ Brooklyn J. Anderson & Gene L. Theodori, *Local Leaders' Perceptions of Energy Development in the Barnett Shale*, 24 S. RURAL SOC. 113, 125 (2009).

²⁷ *The Marcellus Shale, Explained*, STATE IMPACT PENN., <https://stateimpact.npr.org/pennsylvania/tag/marcellus-shale/> [<https://perma.cc/EC3G-5FM4>] (last visited Oct. 29, 2018).

²⁸ See, e.g., Kathryn J. Brasier et al., *Residents' Perceptions of Community and Environmental Impacts from Development of Natural Gas in the Marcellus Shale: A Comparison of Pennsylvania and New York Cases*, 26 J. OF RURAL SOC. SCI. 32, 34–35, 42, 54–55 (2011); Jeffrey B. Jacquet, *Review of Risks to Communities from Shale Energy Development*, 48 ENVTL. SCI. & TECH. 8321, 8322–25 (2014); Dianne Rahm, *Regulating Hydraulic Fracturing in Shale Gas Plays: The Case of Texas*, 39 ENERGY POL'Y 2974, 2978–80 (2011).

²⁹ Richard G. Newell et al., *Trophy Hunting vs. Manufacturing Energy: The Price-Responsiveness of Shale Gas*, 5, 12–14 (Resources for the Future, Working Paper No. 16-32, 2016). See also Charles F. Mason & Gavin Roberts, *Price Elasticity of Supply and Productivity: An Analysis of Natural Gas Wells in Wyoming 2* (Resources for the Future, Working Paper No. 17-28, 2017).

³⁰ Mason & Roberts, *supra* note 29, at 2.

³¹ *Id.*

³² See Nathan Richardson et al., *The State of State Shale Gas Regulation*, Resources for the Future Report 1 (2013).

³³ See ROBERT BRADLEY JR., OIL, GAS & GOV'T: THE U.S. EXPERIENCE (1996). The third

Interstate Oil and Gas Compact Commission.³⁴ The Commission was founded in 1935 to help coordinate state efforts to prevent waste of oil and gas resources.³⁵

States have primary regulatory authority for oil and gas production within their boundaries.³⁶ Overlapping federal oversight has been contemplated, but aside from federally owned minerals, in most cases federal regulations do not directly pertain to oil and gas production activities.³⁷ New federal rules have been discussed, including regulations for methane leaks³⁸ and proposals regarding hydraulic fracturing,³⁹ but the future of these regulations and the extent to which they will change current industry practice is currently unclear. Primary regulatory oversight remains with the states.⁴⁰

The motivation for regulation of oil and gas production should lead the analysis of the efficacy of those regulations. Pertinent detail of the mechanisms by which regulation takes force follows.

chapter covers the history of state-level regulation, with pages 127–28 covering the economic disincentives created by state-level conservation regulation. *Id.* For a more recent analysis of the same issues, see Richardson et al., *supra* note 32, at 11–13. The appendix material provides a state-by-state summary of oil and gas regulation across a number of dimensions. *Id.*

³⁴ Blakely M. Murphy, *Administrative Mechanism of the Interstate Compact to Conserve Oil and Gas: The Interstate Oil Compact Commission, 1935–1948*, 22 TULSA L. REV. 384, 385–86 (1948).

³⁵ These regulations may very well have been promulgated after considerable waste had occurred. See Gary D. Libecap & Steven N. Wiggins, *Contractual Responses to the Common Pool: Prorationing of Crude Oil Production*, 74 AM. ECON. REV. 87, 93–96 (1984) (standing as evidence for either the effectiveness of the regulation or that the waste had already occurred and was curtailed by private forces before the regulation was in place).

³⁶ *Oil and gas regulation in the USA*, LEXOLOGY, <https://www.lexology.com/library/detail.aspx?g=ec3d300b-9a94-4a86-b222-390650dcd245> [<https://perma.cc/VE3Y-67PS>] (last visited Oct. 29, 2018).

³⁷ Robert W. Swenson, *Legal Aspects of Mineral Resources Exploitation*, in HISTORY OF PUBLIC LAND LAW DEVELOPMENT 700–02 (1968) (providing a detailed history of the development of statutory law for development of federally owned oil and gas minerals).

³⁸ See Waste Prevention, Production Subject to Royalties, and Resource Conservation, 81 Fed. Reg. 83,008, 83,008-012 (Nov. 18, 2016) (to be codified at 43 C.F.R. pts. 3100, 3160, & 3170).

³⁹ Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands, 43 C.F.R. §§ 3160–3165 (2015). The BLM issued a final rule on hydraulic fracturing, applicable to federal and Indian minerals in 2015. *Id.* Some groups hoped this standard would be widely adopted by states as well.

⁴⁰ See Thomas E. Kurth et al., *American Law and Jurisprudence on Fracking—2012*, 58 ROCKY MTN. MIN. L. INST. 1, 25–68 (2012) (examining the similarities and differences between numerous state laws regarding hydraulic fracturing).

1. Why Regulate Oil and Gas Extraction Activities?

Extraction, transport, and processing of oil and gas is subject to a range of regulation that varies across states.⁴¹ Historically, three motivations inspired regulation.⁴²

a. Uncertain Values

Imperfect information is a defining characteristic across a number of dimensions, starting with geological risk. Determining the location and richness of deposits is the focus of exploration efforts.⁴³ Even after discovery, substantial uncertainty about the future path of both costs and output prices potentially influences the expected value of a given deposit.⁴⁴ The revenue risk has two parts. One is production risk, which stems from imperfectly known geology.⁴⁵ Wells may perform well or poorly; they may start strong and peter out early. Until wells are drilled and produce, the time profile of production is not known.⁴⁶ The second part is price risk arising from the market.⁴⁷ Prices might swing at the whim of distant market forces, or because of manipulation by other actors such as local transportation firms.⁴⁸ The cause of the price change does not matter to the small producer so much as the magnitude and direction.

⁴¹ See BRADLEY, *supra* note 33 (providing a summary of cross-state variation in Chapter 3). See also Richardson et al., *supra* note 32, at 90–93.

⁴² One important study covers the development of property rights to petroleum resources but focuses entirely on common pool problems and the development of rights to address the economic problems created therein. Gary D. Libecap & James L. Smith, *The Economic Evolution of Petroleum Property Rights in the United States*, 31 J. LEGAL STUD. S589, S589–94 (2002). A more recent and broader view considers both common pool externalities and pecuniary externalities stemming from market power attributable to the downstream transportation and processing sectors. John R. Boyce, *Externality Regulation in Oil and Gas*, in ENCYCLOPEDIA OF ENERGY, NATURAL RESOURCE, AND ENVIRONMENTAL ECONOMICS 7–8 (2013). Even in a perfectly competitive setting, output price variation has been an important concern in securing the value of oil and gas deposits. *Id.*

⁴³ *Overview of oil and gas exploration and production process*, in ENVT'L MGMT. IN OIL & GAS EXPLORATION AND PROD. 4.

⁴⁴ *Overview of oil and gas exploration and production process*, *supra* note 43, at 7.

⁴⁵ *Id.* at 6–7.

⁴⁶ *Id.*

⁴⁷ *Shale Gas and Other Unconventional Sources of Natural Gas*, UNION OF CONCERNED SCIENTISTS, <https://www.ucsusa.org/clean-energy/-/coal-and-other-fossil-fuels/shale-gas-unconventional-sources-natural-gas#.W9YNBxNKjow> [<https://perma.cc/S78B-BF75>] (last visited Oct. 29, 2018).

⁴⁸ See Boyce, *supra* note 42, at 7–8.

A collection of statutory and administrative law developed to deal with the information problems arising from geologic uncertainty; “[i]t is unfortunate that our law as to oil and gas developed before scientific information was available as to the exact nature of oil and gas reservoirs.”⁴⁹ However, the reality is that some law had to be in place. Specific investments in learning required security, and law developed to provide it as uncertainty was resolved by drilling. Experience with exploration, production, and improving technology to evaluate resources *ex ante* has reduced the extent of the geological uncertainty.⁵⁰ Thanks in part to a century of experience, and the technologies that have allowed for exploitation of unconventional resources, changing the regulatory frame may now be feasible and offer benefits.

On the price risk front, risks for products and inputs are better-managed today than historically, thanks to futures markets and an extension of techniques of financial engineering to sell risk.⁵¹ The majority of producers now use hedges or volumetric production payments to limit exposure to volatile output prices.⁵² Improved risk management is a reality for inputs as well as outputs. As an example, long-term contracts for

⁴⁹ A.W. Walker, Jr., *Property Rights in Oil and Gas and Their Effect on the Police Regulation of Production*, 16 TEX. L. REV. 370, 370 (1938). Although this observation was made while conventional resources were still relatively abundant, the alternative to rulemaking under uncertainty is hard to consider because of the high transaction costs inherent in developing scientific information.

⁵⁰ In Texas, the dry hole rate fell from over 10 percent (one in ten wells drilled was dry) in 2005 to under 1 percent (less than one well in one hundred was dry) by 2007. Author’s calculations from Texas Railroad Commission data. See also Richard Norgaard, *Resource Scarcity and New Technology in U.S. Petroleum Development*, 15 NAT. RESOURCES J. 265, 265–67 (1975) (citing dry hole statistics for the entire U.S. in 1939 and 1968 of 16 percent and 43 percent, respectively). Author’s calculations from EIA drilling productivity data indicate aggregate dry hole percentage across oil and gas wells as high as 43 percent (1969) falling to below 10 percent in 2007 and 2008. *Petroleum & Other Liquids: Drilling Productivity Report*, U.S. ENERGY INFO. ADMIN., <http://www.eia.gov/petroleum/drilling/?src=home-b1> [<https://perma.cc/4K3B-YMDY>] (last visited Oct. 29, 2018).

⁵¹ *Oil and Gas Futures: Reducing Risk in a Volatile Market*, DRILLINGINFO, <https://info.drillinginfo.com/oil-futures-reducing-risk-volatile-market/> [<https://perma.cc/YH7D-63M4>] (last visited Oct. 29, 2018).

⁵² There is a technological change story here as well, in the technology of finance. See Christopher L. Culp & J. Paul Forrester, *Structured Financing Techniques in Oil & Gas Project Finance: Future Flow Securitizations, Prepaids, Volumetric Production Payments, and Project Finance Collateralized Debt Obligations*, in ENERGY AND ENVTL. PROJECT FIN. L. AND TAX’N 536 (2009). On VPPs specifically, see Pete Speer, *Volumetric Production Payments—Analytical Implications and Adjustments for E&P Companies* (Working Paper, 2006), <http://ssrn.com/abstract=975271> [<https://perma.cc/VZL2-QNUR>].

inputs like drilling rigs not only lock in relationship-specific productivity gains,⁵³ but also provide certainty about input costs for producers.

b. Commonality of Resource

Extraction from conventional deposits is rival, but not fully excludable. Extraction is often characterized as a common pool resource such as a depletable fishery or grazing common.⁵⁴ When oil and gas resources have many owners, as many conventional resources do, regulation has historically been viewed as one means to protect correlative rights.⁵⁵ In their study of the development of property rights to common pool petroleum reservoirs, Libecap and Smith (2002) delineate four possible end results of a common pool reservoir:

[T]here were four distinct property rights scenarios, each with its own costs and benefits, that provided alternative “resolutions” of the common-pool production externality: (1) extractive anarchy, in which actions by individual producers intending to exploit the rule of capture go unrestrained; (2) conservation regulation, in which government prohibits producers from engaging in specific wasteful actions that anarchy might invite; (3) buy-outs, in which a single producer purchases all others’ holdings in the common pool and thus internalizes the externality; and (4) unitization, in which the separate producers exchange their individual holdings in the reservoir for agreed shares of a single, commonly managed enterprise that encompasses the entire pool.⁵⁶

Unitization is not always voluntary and can be imposed by regulation.⁵⁷ A complementary view is that three regimes are possible: extractive

⁵³ As an example of relationship-specific gains in drilling, see Ryan Kellogg, *Learning by Drilling: Interfirm Learning and Relationship Persistence in the Texas Oilpatch*, 126 Q. J. ECON. 1961, 1961–63 (2011).

⁵⁴ Robert Holahan & Gwen Arnold, *Transforming Goods: Common-pool Resources and Private Goods in the Production of Oil and Gas*, http://paperroom.ipsa.org/papers/paper_31081.pdf [<https://perma.cc/6PWY-HE3B>].

⁵⁵ Gary D. Libecap, *The tragedy of the commons: property rights and markets as solutions to resource and environmental problems*, 53 AUSTRAL. J. OF AGRIC. AND RESOURCE ECON. 129, 131–32 (2009).

⁵⁶ Libecap & Smith, *supra* note 42, at S591.

⁵⁷ Gary D. Libecap & James L. Smith, *Regulatory Remedies to the Common Pool: The Limits to Oil Field Unitization*, 22 ENERGY J. 1, 5 (2001).

anarchy, regulation, or contractual solutions. Regulation can take the prototypical form of prescription of productive activities. Compulsory unitization is another form of regulation, and forces producers to reach a particular type of contractual solution.⁵⁸ Contractual solutions include voluntary unitization agreements and buyouts.⁵⁹ This underscores the tradeoff between regulatory and contractual solutions to common pool problems. Conservation regulation and buy-outs stand in stark contrast to one another in this regard. Recognizing that the efficiency loss attendant with extractive anarchy may differ for conventional versus unconventional deposits is key to understanding the motive for regulatory reforms.

Because the contents of the subsurface are uncertain *ex ante*, the rule of capture was adopted to dictate how oil and gas become private property.⁶⁰ The rule of capture holds that there is no liability for producing oil and gas that was originally in place under the land of another, so long as the producing well itself does not trespass.⁶¹ The rule was adapted to oil and gas from previous applications to groundwater and wildlife.⁶² Like oil and gas, in those original settings the transaction costs associated with verifying ownership *ex ante* are quite high, so the *ex post* rule of capture was adopted.⁶³

However, the capture rule led to concerns that correlative rights would be impinged upon by aggressive neighbors.⁶⁴ Such incentives could lead to rapid extraction and dissipated rents, as neighbors engage in a race to drill and as a result deplete virgin pressure faster than the rate

⁵⁸ *Compulsory Pooling Laws: Protecting the Conflicting Rights of Neighboring Landowners*, NAT'L CONF. OF ST. LEGE., <http://www.ncsl.org/research/energy/compulsory-pooling-laws-protecting-the-conflicting-rights-of-neighboring-landowners.aspx#understanding> [https://perma.cc/NGM9-8NSR] (last visited Oct. 29, 2018).

⁵⁹ *Compulsory Pooling Laws: Protecting the Conflicting Rights of Neighboring Landowners*, *supra* note 58. See generally Owen L. Anderson, *The Anatomy of an Oil and Gas Drilling Contract*, 25 TULSA L. REV. 359–76 (1990).

⁶⁰ On the adoption of the rule, see TERENCE DAINITH, *FINDERS KEEPERS?: HOW THE LAW OF CAPTURE SHAPED THE WORLD OIL INDUSTRY* 18–50 (2010).

⁶¹ The standard definition of the rule comes from Hardwicke: “The owner of a tract of land acquires title to the oil and gas which he produces from wells drilled thereon, though it may be proved that part of such oil or gas migrated from adjoining lands.” Robert E. Hardwicke, *The Rule of Capture and Its Implications as Applied To Oil and Gas*, 1935 A.B.A. SEC. MINERAL AND NAT. RES. L. PROC. 1, 5 (1935).

⁶² A broader discussion of the rule of capture and comparison to other resources is found in Dean Lueck, *The Rule of First Possession and the Design of the Law*, 38 J.L. & ECON. 393, 394–95 (1995).

⁶³ *Id.* at 396.

⁶⁴ Bruce M. Kramer & Owen L. Anderson, *The Rule of Capture—An Oil and Gas Perspective*, 35 ENVTL. L. 899, 910 (2005).

that would allow for maximum recovery.⁶⁵ Boyce (2013) identifies three consequences of employing the rule of capture: excessive drilling to protect resource in place from capture by neighbors; rapid destruction of reservoir pressure; and the necessity of expensive investments in storage for produced volumes.⁶⁶

c. Depletion

Oil and natural gas found in either conventional or unconventional deposits are nonrenewable resources.⁶⁷ They can most cheaply be stored in the ground,⁶⁸ but such storage depends on secure property rights *in situ*. Property rights for common pool conventional resources are inherently insecure because a neighbor can always extract.⁶⁹ Once oil and gas are extracted, the patient owner has lost his or her product. The theoretical measure of the value of the marginal unit extracted is the user cost, or the opportunity cost of extracting today what could be saved and extracted in the future.⁷⁰ For deposits that are small relative to the current market size, this value is near the opportunity cost of extraction today.

2. Regulatory Mechanisms for Oil and Gas Production

Boyce (2013) provides a summary of regulatory interventions, achieved through a mix of statutory and administrative rules at both federal and state levels.⁷¹ He focuses on seven dimensions: casing and plugging, spacing, prorationing, unitization, pooling, common carriers, and waste.⁷² Although Boyce commingles regulations addressing two concurrent problems in oil and gas extraction (common pool and downstream

⁶⁵ Boyce, *supra* note 42, at 9–10.

⁶⁶ *Id.*

⁶⁷ *Non-renewable energy*, NAT'L GEOGRAPHIC, <https://www.nationalgeographic.org/encyclopedia/non-renewable-energy/> [<https://perma.cc/M8K5-A783>] (last visited Oct. 29, 2018).

⁶⁸ See *Underground Natural Gas Storage: Facts & Figures*, INGAA, <https://www.ingaa.org/File.aspx?id=27274&v=3c5b7072> [<https://perma.cc/49BR-2PUV>].

⁶⁹ See Boyce, *supra* note 42, at 9–10 (rule of capture leads neighbors to engage in a race to drill).

⁷⁰ Karim Pakravan, *Estimation of user's cost for a depletable resource such as oil*, 6 ENERGY ECON. 35 (1984).

⁷¹ See Boyce, *supra* note 42, at 9–10.

⁷² Pakravan, *supra* note 70, at tbl.2. See also BRADLEY, *supra* note 33, at 1919–33 app. B (providing a longer list of federal statutes pertaining to oil and gas). However, because most regulation of oil and gas production is state-level, the federal statutes have limited application, largely limited to federal minerals.

market power), several types of regulations are clearly applicable to commonality of the resource.⁷³ These include well spacing, pooling requirements, and unitization.⁷⁴ In addition, two classes of regulations relate to the inherent non-renewability of the resources: waste statutes and prorationing rules.⁷⁵

Bradley (1996) makes finer distinctions about the implementation of state regulation, but focuses on the same group of problems: spacing minimums, pooling, allowables (prorationing), and unitization.⁷⁶ The following discussion focuses on spacing, pooling, unitization, waste, and prorationing.

Regulations are intended to correct problems arising from extractive anarchy, like overinvestment in wells.⁷⁷ Despite the best intentions, regulations often fail to achieve their goals, and that failure creates real costs. The costs of oil regulation have been recognized for decades and are nontrivial.⁷⁸ The economic value unlocked by the technological advances in oil and gas will be diminished by continued regulation in counterproductive dimensions.

a. Well Spacing

Too many wells in a reservoir can deplete virgin reservoir pressure without corresponding increased production, leaving valuable oil trapped underground and requiring pressure to be recreated by various costly means.⁷⁹ One way to avoid excessive mining of reservoir pressure is to limit the number of wells that can access the subsurface reservoir.⁸⁰

⁷³ See generally, e.g., Miller, *supra* note 12 (explaining mineral leasing and public benefit regulations).

⁷⁴ Stephen Alan Ungerman, *Oil and Gas—Proration—The Railroad Commission’s Authority to Protect Correlative Rights*, 21 *SOUTHWEST L.J.* 372 (1967) (explaining that Texas adopted rules on prorationing and waste to promote efficient use and conservation of oil and gas as nonrenewable resources).

⁷⁵ BRADLEY, *supra* note 33, at 141–43 (well spacing requirements developed to prevent excessive mining).

⁷⁶ BRADLEY, *supra* note 33, at 1948–49 app. F. Bradley uses a finer typology of thirteen categories in Appendix C. *Id.* at 1934–35 app. C.

⁷⁷ See Golden & Wiseman, *supra* note 1, at 1040.

⁷⁸ Morris A. Adelman, *Efficiency of Resource Use in Crude Petroleum*, 31 *S. ECON. J.* 101, 105 (1964) (stating that losses from regulation are over \$4 billion annually).

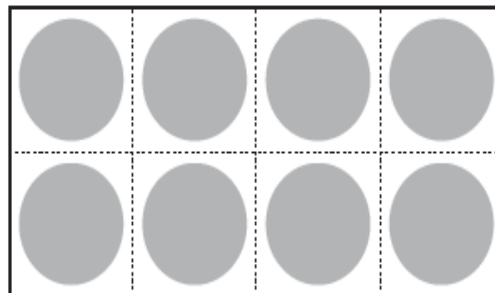
⁷⁹ Soren T. Anderson et al., *Hotelling Under Pressure* 1–2 (Nat’l Bureau of Econ. Research, Working Paper No. 20280, 2014).

⁸⁰ *Oil and Gas Basics: Drilling and Spacing Units*, MARTINDALE, https://www.martindale.com/natural-resources-law/article_Bass-Law_1537320.htm [<https://perma.cc/U2TX-6NTY>] (last visited Oct. 29, 2018).

Avoiding the forests of derricks that sprang up historically, notably in urban oil fields like Long Beach and Oklahoma City, was the primary motivation for well spacing requirements.⁸¹ Initial spacing requirements were still tight by today's standards (one or two acres).⁸² During World War II, spacing units were increased in size to reduce demand for steel.⁸³ The success of those larger spacing units (40 acres for oil and 640 acres for gas) led to wide adoption of larger spacing units in the postwar years.⁸⁴

Spacing units are the smallest spatial unit in regulatory standards.⁸⁵ They are imposed to avoid interference between wells by spreading the wells across the field so that each can maximize recovery.⁸⁶ The spacing unit varies in size based on geologic characteristics at the field level.⁸⁷ More transmissivity implies larger spacing units, to avoid inter-well interference. In a world of vertical wells, the drained area is circular, so spacing units are an exercise in fitting circles into squares.⁸⁸

Figure 1: Drainage of Traditional Spacing Units



New technology has two implications for traditional spacing units. First, orientation matters for directional wells, and the drained area is no longer circular. A horizontal well drilled in one corner of a rectangular

⁸¹ *Understanding Spacing in Oklahoma*, OSEBERG, <https://oseblog.oseberg.io/understanding-spacing-oklahoma> [<https://perma.cc/5RGY-ZFQ9>]. See also BRADLEY, *supra* note 33, at 141–43 (discussing other motivations for the development of well-spacing regulations).

⁸² BRADLEY, *supra* note 33, at 142.

⁸³ *Id.* at 239–40.

⁸⁴ Boyce, *supra* note 42, at 18.

⁸⁵ *Oil and Gas Basics*, *supra* note 80.

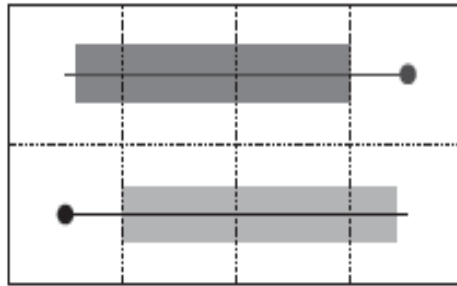
⁸⁶ *Id.*

⁸⁷ *Id.*

⁸⁸ *Id.*

parcel will drain a slightly different area than one drained on the adjacent corner. Second, pad drilling means that spacing units include several wells rather than one,⁸⁹ and the notion that the spatial separation of wells is avoiding inter-well interference is false.⁹⁰ Within a unit, the operator has the incentive to maximize value because there is no external cost.

Figure 2: Drainage of Horizontal Spacing Units



Even though unconventional resources have less transmissivity, larger spacing units have been adopted as unconventional resources have come into play.⁹¹ With horizontal drilling and ever-longer laterals on wells, spacing units have grown to 1280 acres and even larger.⁹² These larger units cannot be drained by a single well, even if that well is fractured.⁹³ Technology has outstripped the spacing unit because the unit no longer represents the area drained by a single well.⁹⁴ If interfering wells maximize profits, then the operator, not the regulator, is best-positioned to determine that.⁹⁵

⁸⁹ Investing News Network, *Multi-Well Pad Drilling Technology and North America's Shale Oil Boom*, INN (May 9, 2018), <https://investingnews.com/daily/resource-investing/energy-investing/oil-and-gas-investing/multi-well-pad-drilling-technology-and-improving-north-americas-drilling-efficiency-and-shale-oil-boom/> [<https://perma.cc/6JQD-7JVQ>].

⁹⁰ Frank Sylvester & Robert W. Malmshemer, *Oil and Gas Spacing and Forced Pooling Requirements: How States Balance Energy Development and Landowner Rights*, 40 U. DAYTON L. REV. 47, 55–57 (2015).

⁹¹ See *Oil and Gas Basics*, *supra* note 80 (a single spacing unit can encompass multiple wells).

⁹² Sylvester & Malmshemer, *supra* note 90, at 55–57.

⁹³ INTERSTATE OIL AND GAS COMPACT COMM'N LEGAL & REG. AFF. COMM., *Horizontal Well Development Pooling, Spacing, and Unitization: A Regulatory Toolbox for Key Policy, Regulatory, and Statutory Considerations*, IOGCC (June 2015), <http://iogcc.ok.gov/Web/sites/iogcc/images/PSToolboxFINAL.pdf> [<https://perma.cc/V8E9-GAGR>].

⁹⁴ *Overview of oil and gas exploration and production process*, *supra* note 43, at 10.

⁹⁵ Some evidence exists that greater fracture densities, as from multiple wells, may enhance production. See Erdal Ozkan et al., *Comparison of fractured horizontal-well*

A direct example of the conflict between existing regulations and new technology is the increased need for exceptions to well spacing requirements. In Texas, the statewide spacing requirements—1200 feet between wells and 467 feet to the nearest property line—are established under an administrative rule known as Rule 37.⁹⁶ Specific fields can be regulated under different rules. As the area drained by a single well has changed, particularly with the advent of directional drilling,⁹⁷ the statewide spacing rules are wholly inadequate. Instead of working to coordinate a large group of adjoining mineral owners, many operators resort to a regulatory exception to the standard spacing rule.⁹⁸ The ad hoc nature of such exceptions, which are granted by acknowledging that the statewide or field spacing rule is inadequate for the modern realities of development, allow for fragmentation of the landscape and increase the potential for leaving a valuable resource trapped in small underground areas. The exceptions also allow for legal drainage of oil and gas from adjoining tracts. Texas is the largest producing state without forced pooling.⁹⁹

b. Pooling Requirements

To form spacing units when mineral ownership is fragmented (a problem unique to the U.S.),¹⁰⁰ most states have regulatory provisions to avoid holdout by mineral owners and force those owners into a spacing unit with nearby owners.¹⁰¹ This prevents recalcitrant mineral owners from trying to hold up an operator for better lease terms (and by extension, delaying the benefit of ownership to other mineral owners already in the unit).¹⁰² States adopted rules that allowed owners wanting development

performance in conventional and unconventional reservoirs, in SPE WESTERN REGIONAL MEETING (2009). Whether the increased production is worth the cost of additional wells is a pertinent question, likely to be answered by experimentation.

⁹⁶ 16 TEX. ADMIN. CODE § 3.37 (2016).

⁹⁷ *Mineral & Surface Rights Relationships*, N.D. ST. UNIV., <https://www.ag.ndsu.edu/ndoilandgaslaw/surface-mineralrights/mineralandsurfacereationship> [https://perma.cc/K8X5-BDZT] (last visited Oct. 29, 2018).

⁹⁸ 16 TEX. ADMIN. CODE § 3.37(3). See also Brady Paul Behrens, *Rule 37 Exceptions and Small Mineral Tracts in Urban Areas: An Argument for Incorporating Compulsory Pooling into Special Field Rules in Texas*, 44 TEX. TECH L. REV. 1053, 1064 (2012).

⁹⁹ *Texas Takes a Different View Towards Compulsory Unitization Legislation*, TJOJEL (Mar. 24, 2017), <http://tjogel.org/texas-takes-a-different-view-towards-compulsory-unitization-legislation/> [https://perma.cc/6837-RQEE].

¹⁰⁰ *Compulsory Pooling Laws: Protecting the Conflicting Rights of Neighboring Landowners*, *supra* note 58.

¹⁰¹ *Id.*

¹⁰² Thomas J. Miceli & Kathleen Segerson, *Land Assembly and the Holdout Problem Under Sequential Bargaining*, 14 AM. L. ECON. REV. 372, 373 (2012).

to force their neighbors into producing units, for which those forced owners would be paid their duly owed share of production.¹⁰³ Pools rely on the regulatory notion of a spacing unit, and the pooling regulations came along after spacing units had been brought in.¹⁰⁴ Oklahoma and New Mexico were early adopters of statewide compulsory pooling rules in 1935, along with their adoption of well spacing rules.¹⁰⁵ Several other states followed after World War II.¹⁰⁶ Compulsory pooling was not needed until the well spacing rules arose because mineral owners could drill offsetting wells.

Forced pooling of wary and unwilling mineral owners has been an issue for unconventional resources, particularly because spacing units have become larger to accommodate horizontal drilling.¹⁰⁷ The chances of finding a single owner dwindle as required acreage increases. With long laterals for horizontal wells in unconventional reservoirs, the likelihood of finding a conforming surface tract is similarly small. Neither surface use nor conventional oil and gas production is conducive to such boundaries. This means that compulsory pooling or a similar mechanism is relatively more important in a world of unconventional extraction.¹⁰⁸

c. Unitization

Operational consolidation through a unit operating agreement, compulsory if a voluntary agreement is not forthcoming, has been considered a solution to suboptimal production incentives arising from common

¹⁰³ Boyce, *supra* note 42, at tbl.2.

¹⁰⁴ SHARON O. FLANERY & RYAN J. MORGAN, OVERVIEW OF POOLING AND UNITIZATION AFFECTING APPALACHIAN SHALE DEVELOPMENT 13–15, https://www.stepto-johnson.com/sites/default/files/null/A_National_Survey_of_Statutory_Pooling_and_Unitization.pdf [<https://perma.cc/4RCC-KRY6>].

¹⁰⁵ Boyce, *supra* note 42, at tbl.2.

¹⁰⁶ Libecap & Smith, *supra* note 42, at S606–07 (contrasting the economic benefits of voluntary and compulsory unitization).

¹⁰⁷ As an example, consider North Dakota spacing units that were expanded to 1280 acres, but now have been combined into overlapping spacing units of 2560. This allows drilling of offset laterals along the boundary of the 1280 acre units. For variation across states, see Sylvester & Malmsheimer, *supra* note 90, at 60, 68, 71 tbls.2, 4–5.

¹⁰⁸ Weaver points out that while Texas has long avoided compulsory unitization, it does have a compulsory pooling rule. JACQUELINE LANG WEAVER, UNITIZATION OF OIL AND GAS FIELDS IN TEXAS 124 (1985). Bradley reports that Kansas is the only major producing state without compulsory pooling (Maryland does not either), even though voluntary pooling is allowed. BRADLEY, *supra* note 33, at 206–07 tbl.4.9. Kansas does have a compulsory unitization rule. *Id.* In contrast, Texas is joined by Pennsylvania as forcing pooling but not unitization (North Carolina and Maryland are also in this category). *Id.*

resource pools and the rule of capture.¹⁰⁹ The unit operating agreement spells out the rights and responsibilities of different working interests, with the end result that a single entity is designated as the operator of the field or deposit, with all partners sharing accordingly in the net benefits of that extraction.¹¹⁰ Limits in the ability of unitization to address all pertinent externalities in extraction have been detailed,¹¹¹ but unitization is generally regarded by economists as preferable to continued extraction from an uncontrolled common pool.¹¹² The dissipation of rents under competitive extraction conditions was a major motivation for imposing compulsory unitization statutes.¹¹³

The gains from unitization are especially pronounced in conventional reservoirs because of the importance of pressure maintenance.¹¹⁴ In the unconventional context pressure maintenance is less important because wells are not tapping into a commingled reservoir. However, economies of scale, which can be an important economic justification for conventional fields as well,¹¹⁵ take on a special prominence. The combination of drilling and completion technologies can be very specific to particular geological formations. Firms that recognize more productive combinations of inputs are likely to reduce costs per unit recovered. This mechanism opens the door to gains from unitization, though the time profile likely differs from the conventional case. The costs of delay are likely smaller for unconventional resources.

d. Waste Statutes

The economic choice for oil and gas is *when* to extract;¹¹⁶ the assumption that resources could be left in the ground and extracted in the future underlies the concepts of efficient resource use.¹¹⁷ Resources can be wasted, either in place or once they have been severed from the ground and produced. Damaging reservoirs, e.g., squandering valuable

¹⁰⁹ Dean Lueck & Philip Schenewerk, *An Economic Analysis of Unitized and Non-Unitized Production*, in SPE ANN. TECHNICAL CONF. AND EXHIBITION 67, 67–68 (1996).

¹¹⁰ *Id.* at 73.

¹¹¹ Libecap & Smith, *supra* note 57, at 24–25.

¹¹² C.Y. Cynthia Lin, *Strategic Decision-Making with Information and Extraction Externalities: A Structural Model of the Multi-Stage Investment Timing Game in Offshore Petroleum Production* 8–9 (working paper) (2012).

¹¹³ Libecap & Wiggins, *supra* note 35, at 88.

¹¹⁴ WEAVER, *supra* note 108, at 20–29.

¹¹⁵ *Id.* at 33.

¹¹⁶ Lin, *supra* note 112, at 1–5.

¹¹⁷ *Id.*

virgin pressure, is one way resources can be wasted.¹¹⁸ Another possibility is that resources can be lost after they are produced.¹¹⁹

An important distinction to draw is the difference between physical and economic waste. Courts have focused on limiting physical waste of resources even while ignoring economic waste.¹²⁰ Physical waste is loss of products, often after they have been produced.¹²¹ Economic waste includes the opportunity cost of producing resources by means that do not minimize costs.¹²² Two specific forms of waste are included: one is failing to extract recoverable resources because of suboptimal decisions; the second is overinvestment in wells and other infrastructure.¹²³

The history of oil and gas extraction in the United States includes episodes of massive physical waste of severed production by modern standards.¹²⁴ Several wells in Caddo Parish, Louisiana, burned out of control for several years starting in 1905.¹²⁵ The Lakeview gusher in California spewed oil out of control for seventeen months from 1910–11.¹²⁶ At least four million barrels of oil are estimated to have been lost from a single well, even as a similar amount was salvaged.¹²⁷ By comparison, the Deepwater Horizon oil spill in 2010 discharged something on the order of five million barrels of oil into the Gulf of Mexico, most of which was lost.¹²⁸

¹¹⁸ *Id.*

¹¹⁹ *Id.*

¹²⁰ WEAVER, *supra* note 108, at 269.

¹²¹ *Id.*

¹²² *Id.*

¹²³ *Id.*

¹²⁴ Foreign efforts produced some of the most egregious waste of resources: gushers at Baku, in Iraq and Iran, in Venezuela, and (continuing) gas flaring in Nigeria. *See, e.g., Nigeria's Flaring Reduction Target: 2020*, THE WORLD BANK, <http://www.worldbank.org/en/news/feature/2017/03/10/nigerias-flaring-reduction-target-2020> [https://perma.cc/Q6NH-UJXU] (last visited Oct. 29, 2018) (discussing the waste from continuing flaring in Nigeria). One lesson that might be learned from this is the incentive that private mineral ownership provides to reduce waste.

¹²⁵ *See* U.S. GEOLOGICAL SURVEY, BULLETIN REPORT 619, THE CADDO OIL AND GAS FIELD: LOUISIANA AND TEXAS 10 (1916).

¹²⁶ Kenneth I. Takahashi & Donald L. Gautier, *A Brief History of Oil and Gas Exploration in the Southern San Joaquin Valley of California*, in PETROLEUM SYS. AND GEOLOGIC ASSESSMENT OF OIL AND GAS IN THE SAN JOAQUIN BASIN PROVINCE, CALIF. 11–12 (2007).

¹²⁷ Takahashi & Gautier, *supra* note 126, at 10–13. The Lakeview well produced between 8.4–9.4 million barrels, with estimates that half of the oil was lost to evaporation or spillage. *Id.* at 12. The peak flow rate was 125,000 barrels each day—roughly twice the peak flow from the Macondo well blowout of *Deepwater Horizon* fame. *Id.* at 11; Sherry L. Larkin, *Deepwater Horizon Oil Spill*, in ENVTL. AND NATURAL RES. ECON.: AN ENCYCLOPEDIA (2014). The Macondo well is estimated to have leaked 4.9 million barrels into the Gulf of Mexico over a period of three months. *Id.* at 106.

¹²⁸ Larkin, *supra* note 127, at 106.

Even when a disaster was not occurring, historically free disposal of products was much more widespread. Data from the Energy Information Administration indicate that flaring and venting of associated gas was five times more widespread in the 1930s and 1940s than it is today.¹²⁹

The physical waste associated with massive blowouts, fires, and other disasters created the impetus for regulations intended to avoid waste. Techniques for well construction were not well-developed when these disasters occurred early in the history of extraction.¹³⁰ Drilling techniques had to be improved to avoid such waste. Avoiding the mistakes of past wells did not necessarily prevent the waste from gushers, blowouts, and fires. Techniques also had to be developed to kill out-of-control wells and extinguish fires.

There are fewer disasters today,¹³¹ but waste statutes are still relevant. One important factor is that most unconventional wells produce both oil and gas; conventional, associated gas is the closest analogy, in contrast to unassociated gas deposits and conventional oil deposits with little or no associated gas.¹³² Oil now (and aside from a few isolated episodes, historically) has a higher economic value on a thermal equivalency basis.¹³³ In addition to output price motivation, there is also a cost advantage for oil. It requires less permanent infrastructure to move after extraction than does gas—oil is relatively easily trucked or shipped by rail; gas requires pipelines.¹³⁴ As a result, in some unconventional resource

¹²⁹ *Natural Gas: U.S. Natural Gas Vented and Flared*, U.S. ENERGY INFO. ADMIN., <http://www.eia.gov/dnav/ng/hist/n9040us2a.htm> [<https://perma.cc/Z6L3-3QDQ>] (last visited Oct. 29, 2018).

¹³⁰ The American Petroleum Institute standards program is an example of a nonregulatory means of improving technology and sharing knowledge among industry participants. Standards apply to a wide range of technical aspects, and have been incorporated into state regulations in some cases. See *About API*, AM. PETROLEUM INST. (2017), <https://www.api.org/about> [<https://perma.cc/B3BK-ZF3J>].

¹³¹ *Natural Gas: U.S. Natural Gas Vented and Flared*, *supra* note 129.

¹³² See *Associated gas: Definition*, 2B1 CONSULTING, <https://www.2b1stconsulting.com/asociated-gas/> [<https://perma.cc/RL9Y-A53B>] (last visited Oct. 29, 2018).

¹³³ *Barrel of Oil Equivalent (BOE)*, INVESTOPEDIA, <https://www.investopedia.com/terms/b/barrelofoilequivalent.asp> [<https://perma.cc/S3XE-H7V8>] (last visited Oct. 29, 2018). The premium is sometimes described as a “liquid premium,” founded in the reality that petroleum can be refined into a range of products. See *Oil: Crude and Petroleum Products, Explained*, U.S. ENERGY INFO. ADMIN., https://www.eia.gov/energyexplained/index.php?page=oil_home#tab1 [<https://perma.cc/2EW6-EPZV>] (last visited Oct. 29, 2018). However, methane has more limited uses. *Uses of Methane Natural Gas*, SCIENCING, <https://sciencing.com/uses-methane-natural-gas6134860.html> [<https://perma.cc/9R53-8WRR>] (last visited Oct. 29, 2018).

¹³⁴ Alexandra B. Klass & Danielle Meinhardt, *Transporting Oil and Gas: U.S. Infrastructure Challenges*, 100 IOWA L. REV. 947, 950 (2015).

areas, large quantities of natural gas are effectively unwanted byproducts of oil production. In many cases this gas is flared, or burned off, at the wellhead.¹³⁵

Two areas that have received substantial attention for increased levels of gas flaring are the Bakken shale in North Dakota and the Eagle Ford shale in South Texas.¹³⁶ North Dakota has accounted for as much as 40 percent of all flaring in the United States in recent years.¹³⁷ This phenomenon can be interpreted as a resurgence of physical waste of products; a key legal question surrounding these activities is whether the cost of capturing, processing, and marketing those products exceeds their value. It is possible that avoiding physical waste promotes economic waste. In some circumstances, the investments necessary to recover and market co-produced methane reduce the net value of oil production.¹³⁸

e. Prorating Rules

Resource discoveries have historically shifted supply and led to lower prices.¹³⁹ Efforts to limit supply in support of prices have two problems. First, an overall production target or cap (lower than the competitively supplied quantity) must be agreed upon.¹⁴⁰ Then, the aggregate

¹³⁵ Dana R. Caulton et al., *Methane Destruction Efficiency of Natural Gas Flares Associated with Shale Formation Wells*, 48 ENVTL. SCI. & TECH. 9548, 9548 (2014). Flaring and venting are very similar from the perspective of the operator who manages to externalize all costs associated with free disposal. *Id.* at 9549. There can be a safety concern: vented gas may pose a combustion risk in certain situations. *Id.* at 9548. From an environmental perspective, flaring is preferable. *Id.* at 9553. Methane is a much more potent greenhouse gas than carbon dioxide, so venting gas is likely to have a much greater impact on climate change emissions than flaring does. *Id.* Combustion efficiency of flares is around 98 percent. *Id.* at 9548.

¹³⁶ Simon Tomlinson, *What a waste! Picture from space reveals how new U.S. oil field is burning off enough gas to power Chicago AND Washington—because it's cheaper than selling it*, DAILY MAIL, May 13, 2015, <https://www.dailymail.co.uk/news/article-2269517/The-picture-space-shows-U-S-oil-field-burning-gas-power-Chicago-AND-Washington-cheaper-selling-t.html#ixzz2JP2tnUbj> [<https://perma.cc/7D4C-5J2U>].

¹³⁷ Author's calculations using NDIC and EIA data. For greater detail, see Timothy Fitzgerald & Case Stiglbauer, *Flaring of Associated Gas in the Bakken Shale* (Tex. Tech Univ., Working Paper).

¹³⁸ *Energy Sector Methane Recovery and Use*, INT'L ENERGY AGENCY 3 (2009), https://www.iea.org/publications/freepublications/publication/methane_brochure.pdf [<https://perma.cc/VH5G-GU6R>] (last visited Oct. 29, 2018).

¹³⁹ UNIV. OF TEX. AUSTIN, *New Oil and Gas Production Technologies*, STRAUSS CTR., <https://www.strausscenter.org/energy-and-security/-new-oil-and-gas-production-technologies.html> [<https://perma.cc/D8AB-XWPF>] (last visited Oct. 29, 2018).

¹⁴⁰ See John Vafai, *Production Control in the Petroleum Industry: A Critical Analysis*,

production target must be allocated amongst the various producers. Prorating rules work to limit aggregate output from an area and then allocate production pro rata to existing producers.¹⁴¹

These regulations were intended to maintain higher prices. Rules were adopted after discoveries of large fields led to supply shocks and prices fell accordingly.¹⁴² Voluntary rules were an initial option—early efforts were made by the American Petroleum Institute (“API”) to reach voluntary agreements to limit output, but these were not successful and were superseded by state regulations.¹⁴³ Oklahoma was the earliest adopter of prorating rules in 1913; other producing states followed suit by the mid-1930s.¹⁴⁴ A notable exception was California, which was and remains an important oil producer.¹⁴⁵ The failure of state regulations in some states led to federal intervention to try to limit oil output and support prices during the 1930s.¹⁴⁶

Rules were more easily agreed to in locations where production was concentrated among relatively few and homogeneous firms.¹⁴⁷ In other places, especially the expansive East Texas field with hundreds of small producers, the incentive to free-ride on production cuts by others undermined negotiations for production caps, and prorating was only achieved by government intervention.¹⁴⁸ The federal oil regulation experience was not well-received by the industry, and memory of that period led the industry to remain committed to state-by-state regulation in post-war years.¹⁴⁹

Prorating rules still exist in many states, even though they are not binding because the overall cap is not met.¹⁵⁰ Even if a large enough number of unconventional wells were drilled to increase production to

SANTA CLARA LAWYER 189, 215 (1971) (discussing production targets in the context of OPEC member states).

¹⁴¹ BRADLEY, *supra* note 33, at 87–106.

¹⁴² James D. Hamilton, *Historical Oil Shocks* 7–8 (Nat'l Bureau of Econ. Research, Working Paper No. 16790, 2011).

¹⁴³ WILLIAMSON & DAUM, *supra* note 5, at 336–38.

¹⁴⁴ Ronald L. Cook, *Proration—The Regulation of Oil And Gas Production*, SOC. PETROLEUM ENG'RS (1978), <https://www.onepetro.org/conference-paper/SPE-7167-MS> [<https://perma.cc/A5KC-TTTE>].

¹⁴⁵ *Id.*

¹⁴⁶ WILLIAMSON & DAUM, *supra* note 5, at 548–51.

¹⁴⁷ Libecap & Wiggins, *supra* note 35, at 91–94.

¹⁴⁸ See WILLIAMSON & DAUM, *supra* note 5, at 543–49 (providing a description of how prorating was imposed in the East Texas field during 1930–1936).

¹⁴⁹ BRADLEY, *supra* note 33, at 95–103.

¹⁵⁰ Before the recent price decline for oil and subsequent reduction in U.S. production, the resurgence in oil production to near all-time highs made the prospect of binding prorating rules for the first time in forty-five years a nontrivial possibility.

the point that old rules would bind, enforcement might not be a good idea, as discussed below.

3. Environmental Regulation

An additional class of regulations relate to broader environmental impacts associated with the oil and gas production process. As an industrial process, oil and gas extraction impacts air, water, wildlife, cultural, and other resources. There are a number of proposals for new regulation of unconventional oil and gas development based on concerns about environmental impacts.¹⁵¹ In most cases, these proposals apply equally to conventional and unconventional resources. The balance of the discussion here focuses on the resource-based issues as opposed to the environmental issues.

II. TECHNOLOGICALLY INDUCED REGULATORY OBSOLESCENCE

A. *The Wellhead No Longer Exists as a Pertinent Regulatory Concept*

The individual well is a focal element of the regulatory system. Individual wells are permitted before drilling, and production is reported at the well level.¹⁵² A single vertical borehole with multiple laterals is an increasingly common production technique.¹⁵³ Is it a single well or several? If the latter, how are the laterals to be identified and treated? Inconsistency on this important fundament to the regulatory regime is evidenced by the uneven application of API numbers to horizontal wells and laterals across states.¹⁵⁴

¹⁵¹ See, e.g., Hannah J. Wiseman, *Untested Waters: The Rise of Hydraulic Fracturing in Oil and Gas Production and the Need to Revisit Regulation*, 20 FORDHAM ENVTL. L. REV. 115 (2009). See also T.J. Centner & Genti Kostandini, *Local Governments Want Authority to Address Problems: The Case of Horizontal Drilling and Hydraulic Fracturing in the United States*, 49 LAND USE POL'Y 227 (2015); Thomas W. Merrill & David. M. Schizer, *The Shale Oil and Gas Revolution, Hydraulic Fracturing, and Water Contamination: a Regulatory Strategy*, 98 MINN. L. REV. 145 (2013); Rahm, *supra* note 28.

¹⁵² *Crude Oil and Well Counts (since 1935)*, R.R. COMM'N OF TEX., <http://www.rrc.state.tx.us/oil-gas/research-and-statistics/production-data/historical-production-data/crude-oil-production-and-well-counts-since-1935/> (last updated Feb. 28, 2018) [<https://perma.cc/4VZN-C29D>].

¹⁵³ *Overview of oil and gas exploration and production process*, *supra* note 43.

¹⁵⁴ See, e.g., Samantha Malone et al., *Data Inconsistencies from states with unconventional oil and gas technology*, J. ENVTL. SCI. & HEALTH 501, 501 (2015).

When natural gas was regulated with a wellhead price, the wellhead existed. However, since natural gas regulation was lifted in 1978, the regulatory notion of a wellhead has slipped into the abstract.¹⁵⁵ Operators engage in complex accounting gymnastics to calculate netback prices to the wellhead. When gas and liquids are sold miles from the wellhead, the costs of transportation and processing are allocated against sale proceeds.¹⁵⁶ This drives a wedge between the gross and net value of the products. That is especially pertinent to the royalty owner, who is paid on a netback basis.¹⁵⁷

Unconventional oil and gas are co-produced in varying proportions. Fluctuations in market prices and physical proportions of the products determine their relative importance across space and time. As such, trying to characterize wells as oil or gas wells from a regulatory standpoint is not as clear as for conventional oil and unassociated gas wells. Of course, some wells will produce more oil than gas, and the converse. However, what really matters is how the stream of extracted products is processed and sold. This connects the individual wellhead (or pad) to gas processing for methane and natural gas liquids.¹⁵⁸ The wellhead is more integrated in the supply chain than ever, but the regulatory regime treats wells autonomously.

B. The Basic Regulatory Unit Relies on Commonality Not Relevant to Unconventional Resources

Well spacing requirements are a primary regulatory mechanism for avoiding common pool waste.¹⁵⁹ They can be adjusted across fields to account for underlying geology—while one field might have 40-acre

¹⁵⁵ Carol A. Dahl & Thomas K. Matson, *Evolution of the U.S. Natural Gas Industry in Response to Changes in Transaction Costs*, 74 LAND ECON. 390, 395 (1998).

¹⁵⁶ Byron C. Keeling, *In the New Era of Oil and Gas Royalty Accounting: Drafting a Royalty Clause that Actually Says What the Parties Intend It to Mean*, 69 BAYLOR L. REV. 516, 532 (2017).

¹⁵⁷ Corazón Morales Siddayao, *Is the netback value of gas economically efficient?*, 21 ORG. OF THE PETROLEUM EXPORTING COUNTRIES ENERGY REV. 151, 153 (Sept. 1997).

¹⁵⁸ *Natural Gas Liquids Primer—With a Focus on the Appalachian Region*, U.S. DEP'T. OF ENERGY 1, 2, 23 (2017), <https://www.energy.gov/sites/prod/files/2017/12/f46/NGL%20Primer.pdf> [<https://perma.cc/8S6R-GBSE>]. Raw or “wet” natural gas often contains methane and other related compounds collectively known as natural gas liquids (“NGLs”). *Id.* These include valuable products: ethane, butane, isobutane, propane, pentane, and natural gasoline. *Id.* In order to separate the NGLs from the methane, the wet gas must be processed in a fractionation (or gas) plant. *Id.*

¹⁵⁹ BRADLEY, *supra* note 33, at 141–43 (well spacing requirements developed to prevent excessive mining).

spacing (one well for each forty surface acres) a neighboring field with different geologic characteristics could have, more sensibly, 160-acre spacing. The discretion to set spacing unit size and to allow exemptions to the standard is generally exercised by the state oil and gas regulatory body.¹⁶⁰ Underlying the logic of the spacing unit is that each unit covers the area drained most effectively by a single well.¹⁶¹

The extent to which one well will interfere with, or reduce the production of, another is learned by experience. When spacing units were introduced in the 1920s and 1930s, they were much smaller than today.¹⁶² Spacing units have no uniform standard size and have been amended to allow new wells that do not interfere with existing ones.¹⁶³

Unconventional resources use directional and horizontal drilling to provide greater exposure of the wellbore to the source rocks.¹⁶⁴ There are economies of scale with using a common surface location for several wells. The result is “pad drilling” that disturbs less surface than numerous vertical wells.¹⁶⁵ However, with multiple wells on the same pad, typically all wells are located in one drilling unit.¹⁶⁶ The notion of spacing corresponding to an area drained by a single well has fallen by the wayside.

One reason for spacing units was to keep potentially competing conventional drillers far enough apart so their wells did not interfere with each other.¹⁶⁷ Pad drilling avoids this complication because a single firm will operate all wells on a given pad.¹⁶⁸ The firm must determine the optimal number of wells to drill on a single spacing unit. That decision is determined by technological choices, such as measuring the azimuth of a frac, which can be affected by varying inputs.¹⁶⁹ Pad drilling is effectively preemptory unitization. Technology and cost economies have solved one of the long-term problems oil and gas regulation sought to address.

Once a spacing unit contains more than one well, the timing of drilling additional wells is an open question. A single well in a spacing

¹⁶⁰ See Behrens, *supra* note 98, at 1055 (providing an example of this concept in Texas).

¹⁶¹ *Oil and Gas Basics*, *supra* note 80.

¹⁶² Boyce, *supra* note 42, at 18.

¹⁶³ *Oil and Gas Basics*, *supra* note 80.

¹⁶⁴ *Overview of oil and gas exploration and production process*, *supra* note 43, at 7.

¹⁶⁵ Al Pickett, *Technologies, Methods Reflect Industry Quest to Reduce Drilling Footprint*, AM. OIL & GAS REP., July 2010.

¹⁶⁶ *Id.*

¹⁶⁷ *Overview of oil and gas exploration and production process*, *supra* note 43, at 7.

¹⁶⁸ Pickett, *supra* note 165.

¹⁶⁹ See Seyed Hassan Fallahzadeh et al., *Near Wellbore Hydraulic Fracture Propagation from Perforations in Tight Rocks: The Roles of Fracturing Fluid Viscosity*, 10 ENERGIES 359 (2017).

unit might be used as evidence of development, even if that well cannot extract all of the resources in place.¹⁷⁰ The firm can keep the entire acreage leased in this way, and this practice has been an anecdotal explanation for wasteful drilling patterns to avoid having to lease acreage again, perhaps under terms more favorable to the mineral owner.¹⁷¹ Smith (2014) presents an option pricing model to suggest that this behavior is not likely to make a difference for a large number of wells.¹⁷²

The mineral owner may be concerned with the drilling of relatively few wells, or the holding of acreage with a single well. The value of the mineral estate is maximized if it is fully exploited. A mineral owner only leases acreage if the owner wants to produce the minerals and recognize the value.¹⁷³ In that case, the mineral owner would like all of the oil and gas extracted, and will be concerned if an insufficient number of wells is drilled to do so. The traditional recourse for the mineral owner is a Pugh clause, by which undrilled acreage can be released.¹⁷⁴ But if the undrilled wells are in a spacing unit that already contains one producing well, then the mineral owner does not have the ability to exercise a Pugh option.¹⁷⁵ So, the traditional contractual remedy is handicapped by the abuse of the spacing unit.

Permitting several wells on a spacing unit also poses an interesting problem for the force-pooled mineral owner. Suppose an owner is forced into a production unit, but perhaps only one well is drilled because of poor performance, or an unexpected price shock. The force-pooled mineral owner will be paid proportionally for production. However, suppose the single well does not enter her property—she is paid from the producing unit rather than extraction from her own minerals. Recall that the forced pooling occurred to avoid holdout for an area drained by a single

¹⁷⁰ James L. Smith, *The Option to Hold a Petroleum Lease by Production: A User's Guide to the Shale Gas Drilling Boom* 8 (Nov. 28, 2014) (unpublished working paper) (on file with the Department of Finance, Southern Methodist University), available at <http://ssrn.com/abstract=2531997> [<https://perma.cc/Y522-F5JX>].

¹⁷¹ *Id.*

¹⁷² *Id.* at 3–4, 8, 15.

¹⁷³ Timothy Fitzgerald, *Oil and Gas Leasing*, 1 MONT. STATE UNIV. (2017), <http://msuextension.org/publications/AgandNaturalResources/MT201209AG.pdf> [<https://perma.cc/VY72-TKXJ>].

¹⁷⁴ Timothy Fitzgerald, *Importance of Mineral Rights and Royalty Interests for Rural Residents and Landowners*, CHOICES, 4th Quarter 2014, at 3.

¹⁷⁵ Gregory C. Cox, *Top O&G Leasing Issues: Pooling and Pugh Clauses*, LAW360 (2014), <https://www.gtlaw.com/-/media/files/insights/published-articles/020906law360-top-og-leasing-issues-pooling-and-pugh-clauses.pdf> [<https://perma.cc/A9HR-KQJS>].

well.¹⁷⁶ But the single well is a myth, and the mineral owner has been coerced into a lease that she cannot break via Pugh clause (because there is only one spacing unit).¹⁷⁷ And, because the remaining minerals are physically located in her portion of the unit, the other mineral owners will demand the unit remain intact so that they will be paid for unit production not directly tied to their property.

C. *Other Commonality Concerns*

The geophysical characteristics of unconventional resources—low permeability and transmissivity—should attenuate commonality concerns. If hydrocarbons are trapped in place, then migration to a neighboring wellbore should not be a major concern. The reliance of unconventional extraction on hydraulic fracturing¹⁷⁸ complicates that simple reality. Reservoirs are fractured for the exact purpose of increasing transmissivity, allowing those trapped hydrocarbons to flow to the wellbore.¹⁷⁹ The fracture is man-made, so the idea of a fracture as trespass allowing theft of mineral resource is quite real. The very same microseismic technology that allows engineers to carefully monitor fractures and reservoir stimulation could allow for verification that trespass occurred.¹⁸⁰

Any hopes that new technologies would lift the mantle of commonality from oil and gas extraction were dashed by the Texas Supreme Court in *Coastal v. Garza*.¹⁸¹ The decision upheld the rule of capture as the primary means of establishing ownership, even where trespass by fracture occurred.¹⁸² The primary logic of the court in this case was that it was not possible to determine where fractures are in the subsurface, and

¹⁷⁶ *Compulsory Pooling Laws: Protecting the Conflicting Rights of Landowners*, *supra* note 58.

¹⁷⁷ *Pugh(eee) . . . Get those lands outta here: A look at the Pugh Clause*, OIL & GAS. R., <https://www.theoilandgasreport.com/tag/pugh-clause/> [<https://perma.cc/522U-JA3M>] (last visited Oct. 29, 2018).

¹⁷⁸ UNIV. OF TEX. AUSTIN, *Hydraulic Fracturing*, STRAUSS CTR., <https://www.strausscenter.org/energy-and-security/hydraulic-fracturing.html> [<https://perma.cc/SET9-TYJC>] (last visited Oct. 29, 2018).

¹⁷⁹ *Hydraulic Fracturing*, *supra* note 178.

¹⁸⁰ Keith B. Hall, *Hydraulic Fracturing: If Fractures Cross Property Lines, Is There an Actionable Subsurface Trespass?*, 54 NAT. RESOURCES J. 361, 362–70 (2014).

¹⁸¹ *Coastal Oil & Gas Corp. v. Garza Energy Trust*, 268 S.W.3d 1, 13, 16–17 (Tex. 2008). For a more complete treatment of this case, see Christopher J. Kulander, *Common Law Aspects of Shale Oil and Gas Development*, 49 IDAHO L. REV. 367, 384–88 (2013).

¹⁸² *Coastal Oil*, 268 S.W.3d at 2, 42.

therefore where oil and gas originate and end up.¹⁸³ Most other states have followed this decision to stick with the rule of capture rather than recognize new technical ability and different underlying resource characteristics.¹⁸⁴ This forces the mineral owner into an administrative setting to obtain relief, because the capture itself is legal.¹⁸⁵

Boyce (2013) identifies three traditional solutions to the common pool problem: consolidation by buying out neighbors and internalizing any pertinent externalities; voluntary prorationing of output through negotiation; and voluntary unitization, a contractual joint venture.¹⁸⁶ Each represents a nonregulatory approach.¹⁸⁷ Unitization (and its cousin, communitization) has been seen as a viable alternative to losses attributable to common pool reservoirs.¹⁸⁸ The means by which unitization is achieved is a key concern, as the transaction costs might outweigh the benefits of unitization.¹⁸⁹ Firms may not be able to reach voluntary agreements because of imperfect information about the nature of deposits,¹⁹⁰ or because of competing property claims to the common pool resource.¹⁹¹ Preemptory unitization has long been advocated as a means to minimize duplication of infrastructure and waste.¹⁹²

D. *What Is Waste?*

Unconventional resources are generally mixtures of oil, gas, and other valuable liquids (natural gas liquids, including propane and ethane).¹⁹³ This contrasts with the traditional binary classification of oil and

¹⁸³ Kulander, *supra* note 181, at 388–89. Technical changes in microseismicity mean that this is not strictly true. *Id.*

¹⁸⁴ Colleen E. Lamarre, *Owning the Center of the Earth: Hydraulic Fracturing and Sub-surface Trespass in the Marcellus Shale Region*, 21 CORNELL J.L. PUB. POL'Y 457, 462 (2011).

¹⁸⁵ *Oil and Gas Basics*, *supra* note 80.

¹⁸⁶ Boyce, *supra* note 42, at 10–11.

¹⁸⁷ *Id.* While both instruments might seem to address the incentive to overproduce, Boyce demonstrates the theoretical superiority of prorationing to unitization when products are sold in a monoposonistic setting. *Id.*

¹⁸⁸ Libecap & Smith, *supra* note 42, at S606–07.

¹⁸⁹ Gary L. Libecap & Steven N. Wiggins, *The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization*, 93 J. POL. ECON. 690, 691, 693, 695 (1985).

¹⁹⁰ Steven N. Wiggins & Gary D. Libecap, *Oil Field Unitization: Contractual Failure in the Presence of Imperfect Information*, 75 AM. ECON. REV. 368, 368–69 (1985).

¹⁹¹ Gary D. Libecap & James L. Smith, *The Self-Enforcing Provisions of Oil and Gas Unit Operating Agreements: Theory and Evidence*, 15 J. L., ECON., & ORG. 526, 544 (1999).

¹⁹² DAINTITH, *supra* note 60, at 429–31.

¹⁹³ See *Natural Gas Liquids Primer—With a Focus on the Appalachian Region*, *supra* note 158, at 2, 19, and accompanying text (explaining NGLs).

gas wells. Even if an unconventional well produces a majority of thermal equivalent units as gas, the “wet” nature of unconventional raw gas streams can imply that the share of the total value from dry gas is much lower.¹⁹⁴

Waste of oil and gas resources is generally prohibited.¹⁹⁵ But unconventional resources present new problems. The days of uncontrollable blowouts are largely gone; technical means for preventing and addressing such accidents have vastly improved, and the number of virgin conventional reservoirs capable of producing a “gusher” has dwindled.¹⁹⁶ Instead of overt waste like a blowout, the jointness of production leads to concerns about waste of one product.

North Dakota has been an exemplar of a rural resource boom distant from existing infrastructure.¹⁹⁷ As a consequence, flaring of natural gas expanded dramatically—to the point that, in recent years, in excess of 30 percent of all gas has been flared at the wellhead.¹⁹⁸ Increased flaring has also been observed in Texas (albeit at lower levels than in North Dakota), especially in the Eagle Ford shale.¹⁹⁹ These are more than just unfortunate coincidences. By treating unconventional resource development as a collection of autonomous wells, rather than an integrated production process including gathering and transmission pipelines, along with appurtenant fractionation plants, some product will be wasted. This leaves regulators in the (ill-suited) position to determine if the waste is merely physical or economic. North Dakota has moved in the direction

¹⁹⁴ *Id.*

¹⁹⁵ See, e.g., N.D. CENT. CODE § 38-08-03 (2016). The definition of waste (N.D. CENT. CODE § 38-08-02.19 (2016)) is: “a) Physical waste, as that term is generally understood in the oil and gas industry b) The inefficient, excessive, or improper use of, or the unnecessary dissipation of reservoir energy c) The locating, spacing, drilling, equipping, operating, or producing of any oil or gas well or wells in a manner which causes, or tends to cause, reduction in the quantity of oil or gas ultimately recoverable from a pool under prudent and proper operations, or which causes or tends to cause unnecessary or excessive surface loss or destruction of oil and gas d) The inefficient storing of oil e) The production of oil or gas in excess of transportation or marketing facilities or in excess of reasonable market demand.”

¹⁹⁶ Gillian Schout et al., *Impact of an historic underground gas well blowout on the current methane chemistry in a shallow groundwater system*, PNAS, Nov. 27, 2017, at 296.

¹⁹⁷ See John McChesney, *Oil Boom Puts Strain in North Dakota Towns*, NPR (Dec. 2, 2011), <https://www.npr.org/2011/12/02/142695152/oil-boom-puts-strain-on-north-dakota-towns> [<https://perma.cc/78E2-TRXP>].

¹⁹⁸ ENERGY AND ENVTL. RES. CTR., *Flaring*, UNIV. OF N.D. (2013), <https://www.undeerc.org/bakken/pdfs/NDIC-NDPC-Flaring-Fact-Sheet.pdf> [<https://perma.cc/QA64-DW3L>].

¹⁹⁹ See Bret Wells, *Please Give US One More Oil Boom—I Promise Not to Screw It Up This Time: The Broken Promise of Casinghead Gas Flaring in the Eagle Ford Shale*, 9 TEX. J. OIL, GAS, & ENERGY L. 319, 320–21 (2014).

of a more holistic treatment of new wells, conditioning well approvals on broad plans to capture and market associated gas.²⁰⁰

In light of the greater integration of the supply chain, it is important to recognize that oil and gas commissions do not directly regulate pipelines and infrastructure. State public utility commissions usually have primary responsibility, though interstate transmission lines are regulated by the Federal Energy Regulatory Commission.²⁰¹ Oil and natural gas pipelines are subject to different oversight. Balkanization of regulatory authority makes consideration of economic waste difficult because value depends on vertical linkages. Identified waste at an intermediate point in the supply chain may not be waste at all, but can be an artifact of downstream constraints or regulation.

E. Water and Oil Mix More Than They Used to

One result of the transition to unconventional resources and extraction techniques is that water is an essential input in the production process.²⁰² Oilfield brines have long been produced as a byproduct of conventional technologies—they continue to be generated as “produced water” that has been identified as a key pathway for potential environmental damage.²⁰³ Hydraulic fracturing operations require base water as well (which can be recycled from produced water in some cases).²⁰⁴ Recognition of the technical jointness of oil and gas and water means that calls for regulatory reform with tighter linkages between the two sectors have abounded.²⁰⁵ The two resources have separate regulatory regimes. In fact, water often has two: one for source water and one for disposal.²⁰⁶

²⁰⁰ U.S. DEP'T OF THE INTERIOR BUREAU OF LAND MGMT., *Sundry Notice Flaring Requests* 6, BLM (2017), https://eplanning.blm.gov/epl-front-office/projects/nepa/62240/108472/132791/NDFO_Flaring_EA.pdf [<https://perma.cc/UKS8-H72Z>].

²⁰¹ *Pipelines for New Energy*, ENERGY & INFRASTRUCTURE (2016), <http://www.energyandinfrastructure.com/sections/columns/1/467-pipelines-for-new-energy> [<https://perma.cc/GQ85-MVRB>].

²⁰² *Hydraulic Fracturing*, *supra* note 178.

²⁰³ Sheila M. Olmstead et al., *Shale gas development impacts on surface water quality in Pennsylvania*, 110 PROC. NAT'L ACAD. SCI. 4962, 4962 (2013).

²⁰⁴ *An overview of hydraulic fracturing and other formation stimulation technologies for shale gas production*, JOINT RES. CTR. OF THE EURO. COMM'N at 7 (2013), [http://publications.jrc.ec.europa.eu/repository/bitstream/JRC86065/an%20overview%20of%20hydraulic%20fracturing%20and%20other%20stimulation%20technologies%20\(2\).pdf](http://publications.jrc.ec.europa.eu/repository/bitstream/JRC86065/an%20overview%20of%20hydraulic%20fracturing%20and%20other%20stimulation%20technologies%20(2).pdf) [<https://perma.cc/2FC5-Z2N2>].

²⁰⁵ Jeffrey C. King et al., *Factual Causation: The Missing Link in Hydraulic Fracture-Groundwater Contamination Litigation*, 22 DUKE ENVTL. L. & POL'Y F. 341, 358–60 (2012).

²⁰⁶ For example, source water and disposal pertaining to the Marcellus Shale are governed by different regulatory regimes. Kevin J. Garber & Jean M. Mosites, *Water Sourcing and*

In some states, source water falls into different regulatory regimes depending on whether it comes from surface or ground water.²⁰⁷ The gains from integrating these regimes are a topic unto themselves.

III. CONTRACTUAL REMEDIES

Technical changes make existing regulations obsolete, but do not eliminate all problems. Unconventional resources present some novel issues. Interested parties have worked to contract around the new realities. Two contractual interactions are discussed: the principal-agent problem between mineral owner and developer addressed by the oil and gas lease; and the interactions between different oil and gas companies, which are less circumscribed.

A. *Oil and Gas Leases*

The mineral owner and developer engage in a contract—usually an oil and gas lease—to outline rights and responsibilities of each.²⁰⁸ Not every mineral owner signs a lease to take a royalty interest. Some decide to participate in development, which means they bear costs as well as receive benefits. Participation is relatively rare, so most mineral owners are bound by a lease. Some interactions are zero-sum, affecting only the distribution of gains, whereas others affect the total amount of surplus created.²⁰⁹ From a social perspective, the latter are far more important. Zero-sum interactions may be salient to the owner, such as requiring third-party validation of product pricing rather than accepting netback pricing at the wellhead.

The positive-sum interactions pertain to the efficient exploitation of the resource. Because commonality is not the primary concern for unconventional resources,²¹⁰ the primary considerations are the dynamics of the leasing and development process, and the complementarity of wells and related infrastructure.

Wastewater Disposal for Marcellus Shale Development in Pennsylvania, 32 ENERGY & MIN. L. INST. 339, 341 (2011).

²⁰⁷ *Id.*

²⁰⁸ Anderson, *supra* note 59, at 382–94.

²⁰⁹ See Benjamin Holliday, *New Oil and Old Laws: Problems in Allocation of Production to Owners of Non-Participating Royalty Interests in the Era of Horizontal Drilling*, 44 ST. MARY'S L.J. 771, 779–80, 788–89 (2013).

²¹⁰ See discussion *supra* Section II.B.

1. Sticky Leases

The stickiness of oil and gas leases is one potential impediment to social efficiency. The stickiness stems from long-term commitments to the developer, which provide valuable security and reduce the chances for holdup. Defining the secondary term of a lease by production leaves substantial discretion for the lessee. The lessor has a limited number of ways to opt out early.²¹¹ One of the few ways is the Pugh clause.²¹² This clause allows the mineral owner to separate drilled and undrilled acreage.²¹³ The undrilled acreage can then be leased again, perhaps to a different firm, or under more favorable terms.²¹⁴ The Pugh clause allows separation of undrilled acreage outside the spacing unit—if the undrilled acreage is *inside* the spacing unit, the mineral owner is out of luck.²¹⁵

2. Infrastructure

Unconventional resource development relies heavily on a network of infrastructure over a larger spatial extent than that of the individual mineral owner or lessor. To develop an unconventional play efficiently, wells, pipelines, frac plants, water source and disposal facilities, compressor plants, transmission lines, rail loading terminals, and electric power lines are all needed, often extending over a large area.²¹⁶ These complementary investments are at risk of hold-up if negotiated sequentially.²¹⁷ Contracts with a large number of parties—mineral and surface owners over a large area—are likely to benefit from efforts to reduce transaction costs. Landowner coalitions and joint ventures by firms reduce the number of parties and may be conducive to simpler contracts for complementary infrastructure.

B. *Inter-firm Contracts*

Oil and gas development offers an array of contracts that have evolved to solve problems between firms. Joint operating agreements,

²¹¹ *Pugh(eee) . . . Get those lands outta here, supra* note 177.

²¹² *Id.*

²¹³ See discussion *supra* Section II.B.

²¹⁴ *Pugh(eee) . . . Get those lands outta here, supra* note 177.

²¹⁵ *Id.*

²¹⁶ See *Unconventional Resources Development—Managing the Risks*, EXXONMOBIL (Sept. 2014), https://cdn.exxonmobil.com/~media/global/files/energy-and-environment/unconventional_resources_development_risk_management_report.pdf [<https://perma.cc/JJ9F-NN59>].

²¹⁷ Current efforts to expand gathering and transmission lines in North Dakota are a prime example—this inability to install infrastructure has contributed to the flaring problem and waste. See Fitzgerald & Stiglbauer, *supra* note 137.

farmouts, dry hole or bottom hole contributions, production sharing agreements, allocation agreements, and other contracts are regularly used to share either inputs or outputs.²¹⁸ Conversion to unconventional resources does not necessarily preclude these same contractual remedies from being employed. Adaptation of traditional contracts to the new technical realities is not yet fully clear.

The inevitable comparative advantages of various firms in the constituent parts of the exploration and production process could lend themselves to valuable joint ventures. Chesapeake Energy developed an enviable reputation in leasing and contracts, while other firms excelled in drilling, avoiding steep production decline rates, and other distinct aspects of the production process.²¹⁹ Allowing discretion to companies to engage in various arrangements and combine specializations could yield low-cost solutions to some of the problems identified here. The same could happen via acquisitions.

IV. CONSIDERATIONS FOR REFORM

One possible reform is to require unitization. Preemptory unitization has its own shortcomings, but the federal exploratory case may offer some guidance. As early as the 1920s, Henry Doherty wanted to extend the principles of federal exploratory unitization to all development.²²⁰ The shortcomings of voluntary agreements are recognized.

Even if full-blown unitization is not feasible, recognizing the complementary nature of investments and increasing the spatial scale of the regulatory scheme from the individual wellhead to the project level would make a number of aspects easier to handle. Expanded regulatory units including several or dozens of well pads and attendant infrastructure would more closely reflect the viable economic unit than a spacing unit allowing a single well to drain a specific area. The regulatory units should be larger than the current expanded spacing units, large enough to include the necessary infrastructure investments. This would, in turn,

²¹⁸ Joint operating agreements are the basis of unitization agreements, which are discussed above. A farmout is a partnership in which a new partner is brought in to fulfill some conditions (often drilling a new well) in exchange for part of the working interest. Dry or bottom hole contributions specify payments to be made when a well is dry or reaches total depth. Production share contracts, or other allocations of output, are also used in various settings. For detailed information about oilfield terminology, see HOWARD R. WILLIAMS ET AL., *WILLIAMS & MEYERS MANUAL OF OIL AND GAS TERMS* (2006).

²¹⁹ ZUCKERMAN, *supra* note 1, at 191.

²²⁰ DAINITH, *supra* note 60, at 268–70.

provide incentives for firms to enter into contractual arrangements like joint operating agreements. Environmental concerns that come with development might also be more easily addressed at this scale.

Other alternatives exist. If a shared property paradigm is adopted, the result is apt to look more like compulsory unitization.²²¹ There may be room for broader market-based approaches like bonding and insurance, though these are targeted at environmental rather than resource concerns.²²²

The economic stress of low prices has put emphasis on places where the unconventional model works.²²³ It has also increased incentives to cut cost and boost productivity. Weathering the price shocks, first for gas and now for oil, has solidified unconventional resources in the future mix. The results have been impressive, both in terms of technological gains, and in terms of the greater resiliency of production to lower prices.

Now may be a good time for regulatory agencies to take a breather and consider larger changes. Instead of piling on additional layers of regulation (e.g., federal fracking rules), regulations appropriate for new technology would provide greater benefits. Given the recent change in prospects for additional federal regulation with the Trump administration,²²⁴ states may well have an opportunity to be laboratories for experimentation on the oil and gas front.

This review also identifies some opportunities for research in answering questions around the edges and testing refutable hypotheses. As an example, recent work on the efficiency implications of unit operating agreements finds long-run productivity higher in unitized fields, though short-run mechanisms for those long-term gains have limited statistical support.²²⁵ Before expanded compulsory unitization is proposed, identifying how short-term dynamics (which may be more important in the fast decline of unconventional resources) operate is useful.

²²¹ Peter M. Gerhart & Robert E. Cheren, *Recognizing the Shared Ownership of Sub-surface Resource Pools*, 63 CASE W. RES. L. REV. 1041, 1078–81 (2013).

²²² David A. Dana & Hannah J. Wiseman, *A Market Approach to Regulating the Energy Revolution: Assurance Bonds, Insurance, and the Certain and Uncertain Risks of Hydraulic Fracturing*, 99 IOWA L. REV. 1523, 1546–47 (2014).

²²³ See, e.g., *The Marcellus Shale, Explained*, *supra* note 27.

²²⁴ See, e.g., Eric Lipton & Hiroko Tabuchi, *Driven by Trump Policy Changes, Fracking Booms on Public Lands*, N.Y. TIMES (Oct. 27, 2018), <https://www.nytimes.com/2018/10/27/climate/trump-fracking-drilling-oil-gas.html> [<https://perma.cc/3TYR-SFQT>].

²²⁵ Andrew T. Balthrop & Kurt E. Schnier, *A Regression Discontinuity Approach to Measuring the Effectiveness of Oil and Natural Gas Regulation to Address the Common-Pool Externality*, 44 RESOURCE & ENERGY ECON. 118, 119 (2016).

CONCLUSION

The oil and gas sector will continue to be a significant part of the energy mix. Continued technological progress is probable, but a repeat of the recent technological leap that allowed unconventional resources to become economic seems less likely. As such, now it is time to take stock of the reality of the traditional regulatory regime for oil and gas extraction. The current regulatory framework for oil and gas extraction is a legacy of more than a century of experience. As technological change has revolutionized oil and gas production, the regulatory framework has become obsolete in important areas. Private parties have an opportunity to contract around some of these failings. Those areas that do not allow for contractual remedies are excellent candidates for regulatory reform.

The United States has managed deregulation, or perhaps more accurately re-regulation, of parts of the energy sector toward a more efficient market. Interstate natural gas pipelines are a crucial example.²²⁶ The extraction sector is ripe for regulatory reforms that could solidify the market-based exchange going forward as unconventional resources loom ever more important in the resource base.

²²⁶ Jeff D. Makhholm, *Decoupling for Energy Distributors: Changing 19th Century Tariff Structures to Address 21st Century Energy Markets*, 29 ENERGY L.J. 157, 166 (2008).

