THE ECONOMIC EVOLUTION OF PETROLEUM PROPERTY RIGHTS IN THE UNITED STATES

by

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ABSTRACT

We examine Harold Demsetz's (1967) prediction that property rights emerge and are refined as the benefits of doing so exceed the costs in the context of oil and gas resources in the U.S. Familiar influences on the development of petroleum property rights, technology, market demand, and politics, provide support for the hypothesis, and those issues are examined. Our primary contribution is to demonstrate the important role of a less familiar factor, the presence in the reservoir of both oil and gas with differentially volatile prices. This factor has affected the nature of the property rights assigned with unitization, an institutional arrangement to internalize the common pool externality. Information asymmetries and conflicting price expectations have resulted in unit agreements that would not have been predicted in a strict neo-classical sense. Our analysis provides new insights regarding the nature of voluntary unitization contracts, inherent limits to producers' ability to internalize externalities, and the welfare implications of compulsory unitization.

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I. INTRODUCTION.

In 1967, Harold Demsetz advanced the thesis that development of property rights flows from underlying changes in the relative prices of goods and the technologies that are used to produce them. Institutional change takes place whenever there are net gains from doing so, and through this process new property rights are created to replace those no longer attuned to economic conditions. Demsetz noted, however, that the actual arrangement adopted depends upon transactions costs and preferences for state or private ownership.[1] The empirical richness of this well-known hypothesis is in the straightforward link between the *existence* of property rights and underlying economic forces. Even more important, these same forces account for the *specific form* of property rights, or what Demsetz calls the "coalescing of property rights into particular bundles and to the determination of the ownership structure that will be associated with these bundles."[2]

We apply this framework to describe the evolution of property rights and regulatory arrangements in the extraction of petroleum and natural gas from common pools in the United States as relative prices, knowledge, and technology changed. Whereas the theory of oil and gas property rights and complications introduced by migratory hydrocarbons and the rule of capture have been discussed before, our examination of the impact on the problem of having both oil and natural gas in a reservoir is new.[3] Although we find an evolutionary pattern that generally corroborates Demsetz'

[1] Harold Demsetz, Toward a Theory of Property Rights, 57 Amer. Econ. Rev. 350 (1967).
[2] Demsetz, *supra* note 1, at 347.
[3] See, for example, Charles Donahue, Jr., Thomas E. Kauper, and Peter W. Martin, Property: An Introduction to the Concept and the Institution (1974, 325-59). For additional discussion of the common law rule of capture, see Jacqueline Lang Weaver, Unitization of Oil and Gas Fields in Texas: A Study of Legislative, Administrative, and Judicial Policies (1986); and Dean Lueck, The Rule of First Possession and the Design of the Law, 38 J. Law & Econ. 393 (1995).

predictions, we show how the process of institutional change is affected by political demands from competing constituencies in ways not anticipated using a strict balancing of economic costs and benefits. We also identify a further complication: it is not just technology and the *level* of prices, but the *unpredictability* (volatility) of relative prices that has shaped the development of property rights to petroleum resources in the United States. Finally, our analysis reveals an important distinction, in terms of property rights and the efficiency of resulting contracts, between compulsory and voluntary unitization that has not been understood previously.[4]

Although unitization has been recognized as an effective contractual arrangement to reduce the losses associated with common pool extraction, its implementation has not been smooth.[5] Many parties have resisted unitizing reservoirs and assigning field operations to a single firm with all others holding shares in the net revenues of production. Negotiations may take years. To facilitate initial agreement, unitization contracts often purposefully distinguish between multiple participating areas and/or time-phases of production in assigning property rights. These practices, however, can result in subsequent discord and rent dissipation if the arrangements become inconsistent with apparent efficient production from the unit. In face of these problems, state governments have adopted legislation to force unitization via majority rules. Shares in the unit become

[4] The legal, economic, and engineering commentary and analyses of the earliest and most influential advocates of unitization (for example, John F. Carll, Henry L. Doherty, Ray Lyman Wilbur, Robert R. Penn, J. Edgar Pew, W. P. Z. German, T. Murray Robinson, Joe S. Bain, and Stephen L. McDonald) suggest nothing like the formation of the "partitioned" units which are commonplace today.

[5] Unitization is discussed in a variety of places. For example, see Stephen L. McDonald, Petroleum Conservation in the United States: An Economic Analysis (1971); James L. Smith, The Common Pool, Bargaining, and the Rule of Capture, 25 Econ. Inq. 631 (1987); and Gary D. Libecap, Unitization, in The New Palgrave Dictionary of Economics and the Law 641 (Peter Newman ed. 1998), and is examined in more detail in Gary D. Libecap and James L. Smith, The Self-Enforcing Provisions of Oil and Gas Unit Operating Agreements: Theory and Evidence, 15 J. Law, Econ. & Org. 526 (1999), and Gary D. Libecap and James L. Smith, Regulatory Remedies to the Common Pool: The Limits to Oil Field Unitization, 22 Energy J. 1 (2001).

new property rights, replacing those held under common pool extraction. In this manner, the regulatory process has affected the development of property rights, but as we show, the welfare effects are not as straightforward as the Demsetz framework suggests. In particular, when the coercive power of the state is used to force trades and unitization when there are separate holdings of oil and natural gas in the reservoir, the parties may not be made better off.[6] Hence, what otherwise appears to be an obvious government solution to a breakdown in private bargaining fails to bring a Pareto improvement.

Our analysis expands on a point raised, but not really developed by Demsetz: "In general, transacting costs can be large relative to the gains because of 'natural' difficulties, difficulties in trading, or they can be large because of legal reasons."[7] The development of property rights in oil and gas reservoirs encountered all three problems: "natural" difficulties because of geological conditions, difficulties in trading because of volatile relative prices and asymmetric information, and regulatory-imposed difficulties.

II. COMMON POOL EXTRACTION AND THE EVOLUTION OF PETROLEUM PROPERTY RIGHTS.

In the history of oil and gas development in the United States there 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

[6] While it is sometimes possible for private parties to ward off damage stemming from regulatory actions via the takings clause, this is an unlikely remedy for the cases we consider where there are differential holdings of oil and gas and the prices of the two substances are not highly correlated, frustrating voluntary trades. Forced exchanges through mandated unitization typically involve a perceived increase in the risk of future loss, rather than immediate harm to tangible property.

[7] Demsetz, *supra* note 1, at 348.

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 shares of a single, commonly managed enterprise that encompasses the entire pool. The first two categories characterized early U.S. production, while the later, especially unitization, characterizes the more recent period.

Beginning in 1859, adjacent producers separately extracted oil from the same reservoir with no coordinated production plans. The nature and extent of the externalities involved were not well understood. Knowledge and vision of the subterranean reservoir and related principles of fluid extraction were rudimentary with little appreciation of common pools or the geophysical mechanisms that propelled oil to the surface through a well bore.[8] Because of the fugitive nature of subterranean oil and gas, *in situ* property rights were not assigned to surface land owners as was done with fixed subsurface mineral resources, but rather granted only upon extraction or capture as was done with wild animals (minerals *ferae naturae*).[9] Every surface owner had the right to vigorously extract oil and gas to reduce it to his possession without violating the rights of neighboring surface owners.

[8] DeGolyer's conclusion: "A study of oil production in Pennsylvania suggests the industry had to reach its majority before, out of the welter of misunderstood and neglected observations, there began to emerge a rational understanding of the occurrence of oil and gas." See E. DeGolyer, Concepts of Occurrence of Oil and Gas, in History of Petroleum Engineering 17 (1961). Baker and Hardwicke expressed the same view in characterizing the judicial outcome of an oil field dispute: "The Pennsylvania court as late as 1907, being 46 years after the completion of the Drake Well, declared that meager information existed as to oil and gas pools, as to reactions following production, and as to the extent and direction of migration of oil or gas." See Rex G. Baker and Robert E. Hardwicke, Conservation, in History of Petroleum Engineering 1120 (1961).

[9] Donahue, Kauper, and Martin, *supra* note 3 at 326.

This practice led to extractive anarchy. Anarchy prevailed initially not because the resource value was low relative to the cost of alternative arrangements, but because there was insufficient technological basis and understanding for identifying what a coordinated solution might be.

Indeed, by the late nineteenth and early twentieth centuries the economic value of petroleum was high enough to raise concern about apparent wastage and damage to adjacent property. In 1910 up to 11 percent of California's (a major producing state) annual oil output was lost due to fire while in surface storage. In 1914 the Director of the Bureau of Mines estimated that the costs of excessive wells equaled about a quarter of the value of total annual U.S. oil production.[10] As early as 1893, state legislation was enacted in Indiana to limit the unconfined venting of oil or gas into the air. In *Ohio Oil Co. v. Indiana* (177 U.S. 190, 1899), the Supreme Court upheld this regulation as proper legislative authority to "prevent the waste of the common property of the surface owners."[11]

This waste stimulated research into the nature of reservoir mechanics and more efficient resource recovery. Many of the ideas that emerged were slow to gain

[10] George Stocking, The Oil Industry and the Competitive System (1925), and John Ise, The United States Oil Policy (1926) at 141; and American Petroleum Institute, Petroleum Facts and Figures 166 (1951). See also Gary D. Libecap and Steven N. Wiggins, Contractual Responses to the Common Pool: Prorationing of Crude Oil Production, 74 Amer. Econ. Rev. 88 (1984) for estimates of the rental losses involved.

[11] 177 U.S. 210. On the face of it, the ruling in Ohio Oil Co. primarily advances state regulation to restrain private extraction from the common pool, for the common good. As it turns out, however, the effect of the Indiana regulation was somewhat more complex. At least in part, it advantaged Indiana-based natural gas producers who sought to limit the venting of natural gas by the oil producing, Ohio Oil Company. See Richard A. Epstein, "The Modern Uses of Ancient Law," 48 S.C.L. Rev. 243 (1997). The asymmetrical distribution of gains and losses from regulation was a harbinger of problems to come. As emphasized in this paper, differential production incentives between oil and gas producers who have skewed holdings of the two substances have been a major source of regulatory conflict. Compensating reciprocal exchanges often have not been possible because the prices of the two substances are not highly correlated, leading to disputes over the terms of trade. These issues are developed more thoroughly below.

acceptance.[12] Nevertheless, by the time the first petroleum engineering degree was formally awarded at the University of Pittsburgh in 1915 there was a technical understanding of the impact of "overdrilling" on the hydrodynamic reservoir system.[13] It was known, for example, that drilling a second well in close proximity to the first would interfere with the first well's ability to draw fluids up through the well bore (and vice versa) and that the extent of such interference could be anticipated according to the laws of physics. Perhaps more significantly, it became known that drilling too many wells in particular parts of a reservoir could cause reservoir water or gas to break through the producing column of oil, thus trapping significant volumes of unrecoverable oil.[14]

With this scientific knowledge there was a basis for negotiations among private parties to mitigate the effects of the externality. Whether in the form of buy-outs that would have placed the reservoir under single ownership or other private negotiations leading to cooperative restraints on individual drilling programs, one might have expected the rapid development of either of these arrangements to address the common pool.[15] In fact, neither tended to be selected because of high transaction costs in reaching a negotiated settlement. The typical number of stakeholders on a single reservoir was sufficient to hinder multilateral negotiations and raise bargaining costs to prohibitive

[12] F. A. Johnson, who received his petroleum engineering degree in 1915, described his early experience as follows: "The road of the petroleum engineer like that of the geologist was not easy in the early days when both, practicing in the same field of geology, endeavored to convince the hard headed operator that he was a useful asset in his business." Quoted by C. A. Warner, Sources of Men, in History of Petroleum Engineering 48 (1961).

[13] C. A. Warner, *supra* note 11, at 47.

[14] Contemporary estimates from the early part of the twentieth century place the average recovery of oil at only 10-20% of the total resource in place, but in many cases it would have been much less than this overall average. Joseph E. Pogue, Economics of Petroleum 343 (1921).

[15] As Demsetz (*supra* note 1, at 357) observed in a different context: "Two market options are open to the negotiators. The first is simply to try to reach a contractual agreement among owners that directly deals with the external effects at issue. The second option is for some owners to buy out others, thus changing the parcel size owned. Which option is selected will depend on which is cheaper."

levels. Some representative figures illustrate the problem. On the Yates, Hendrick, and Seminole fields of Texas and Oklahoma, all discovered in the 1920s, there were respectively, 16, 18, and 40 different firms with extraction leases. And on the huge East Texas field, because of many small surface landowners, over 1,000 firms were competing for its oil by 1933.[16] Other fields, such as Long Beach and Oklahoma City, were fragmented by production from town lots. The conflicting strategic bargaining positions of so many independent agents, compounded by the problem of holdouts, posed insurmountable difficulties in designing coordinated production programs that would have involved the assignment of some type of property right to subsurface petroleum.[17] Moreover, incomplete and asymmetric information regarding the potential value of respective tracts constrained the assembling of leases into a single tract through purchase.[18] As a result, early efforts to address the common pool externality through property rights definition turned from private solutions to state regulation.

State regulation to limit the drilling of wells and the extraction of oil and gas first developed with the advent of major new discoveries in Oklahoma and Texas during the 1920s and 1930s. These regulations necessarily restricted the rights of producers to extract from the common pool, and importantly, they also limited the scope for negotiating private contracts. By stipulating the number of wells to be sunk, well spacing, pooling, and production quotas, state regulation affected lease values and the range of exchanges possible in private negotiations. These regulations were supported by some

[16] Libecap and Wiggins, *supra* note 9, at 89-94.
[17] "Indeed, an increase in the number of owners is an increase in the communality of property and leads, generally, to an increase in the cost of internalizing," from Demsetz, *supra* note 1, at 357.
[18] Some of the problems of asymmetric information in valuing leases are addressed in Steven N. Wiggins and Gary D. Libecap, Oil Field Unitization: Contractual Failure in the Presence of Imperfect Information, 75 Amer. Econ. Rev. 368 (1985).

producers, resisted by others, and the property rights that emerged were molded by political factors. The compromises necessary to build a political consensus for regulation ultimately weakened its ability to address the common pool externality.

The Texas Railroad Commission and other state regulatory agencies set monthly statewide production levels and allocated the total among regulated wells. The total volume of "allowable" production was determined in accordance with estimates of supply and demand consistent with a targeted oil price. Prorationing rules were issued, setting total field production levels, which were then allocated among individual wells according to their quotas. The production rules were applied uniformly to all fields, even though each oil field had a unique physical configuration and optimum production potential. The structure of property rights induced by this regulation raised production costs relative to what might have occurred with alternative designs. In Texas, the numerous, very high-cost wells (stripper wells) were exempted from production controls altogether. Among regulated wells, per-well quotas were based on acreage and depth, but the Commission gave more weight to depth, encouraging firms with limited leased acreage to drill deeper. Minimum spacing rules were adopted to limit overall drilling, but the Commission routinely granted exemptions to small firms. Indeed, in 1946, a Texas court ruled that small leaseholders had the right to drill at least one well on their land with sufficient monthly quota to cover drilling and operating costs.[19]

These per-well quotas (allowables) were property rights, and while encouraging

[19] *Railroad Commission v. Humble Oil and Refining Co.* (193 S.W. 2nd 824, March 1946). For discussion of the political pressures in Texas to protect high-cost producers, see Gary D. Libecap, The Political Economy of Crude Oil Cartelization in the United States, 1933-1972, 49 J. Econ. Hist. 851 (1989, 850-54). State regulation of oil is discussed by Robert Bradley, Oil, Gas, and Government: The U.S. Experience 851 (1996).

waste, they became a common feature of state regulation. They reflected the political influence in Texas of the numerous very small producers that had limited leased acreage and many wells. Without concessions, the producers of small, high-cost, and marginal wells refused to agree to state controls. Absent their participation, state regulation would have brought little improvement over anarchy in the fields. The opportunity cost of resulting imperfections in the design of the prorationing scheme has been examined by Adelman (1964), among others, and found to have been substantial, probably exceeding $2 billion per year by the early 1960s.[20] Despite all this, state regulation of minimum well spacing and maximum rates of production from individual wells was effective in reducing the cost of the production externality relative to competitive extraction.

III. Unitization and the Trading of *In-Situ* Property Rights

Unitization became an increasingly popular alternative response to the common pool by the late 1940s and early 1950s, as reliance on secondary recovery techniques grew.[21] By that time, new discoveries had diminished, and the industry was turning more to extracting additional oil from mature reservoirs through secondary recovery. Injecting water, gas, or other fluids into particular zones of a partially depleted reservoir can rebuild subsurface pressures and push oil to the surface. The process requires that selected producing wells (where selection is dictated by the configuration of the reservoir) be converted to injection wells, and that additional injection (non-producing) wells be drilled at certain locations—all this for the benefit of increased production that

[20] M. A. Adelman, Efficiency of Resource Use in Crude Petroleum, 31 South. Econ. J. 101 (1964). See also G. Campbell Watkins, Conservation and Economic Efficiency: Alberta Oil Proration, 4 J. Envr. Econ. & Mgmt. 40 (1977).
[21] Herman H. Kaveler, Unitization, in History of Petroleum Engineering 1182 (1961).

will materialize from wells located in other, possibly distant, parts of the formation. To ensure success, this scheme requires private owners to negotiate contracts for cooperative exploitation of the reservoir. Importantly, existing conservation regulation that mainly circumscribed the rights of individual producers did little to facilitate such cooperation. Unitization contracts, in contrast, linked the entire formation and placed it under the management of a single firm, which promoted primary and secondary recovery. These contracts were difficult to write due to disagreements over the shares or property rights to be assigned to the various firms that would give up the right to independently produce under the rule of capture. Accordingly, state governments began to intervene with new laws and regulations designed to promote unitization.

The first step was to adopt so-called "unitization assistance" laws. These measures provided anti-trust exemptions and conferred certain rights on majority owners to impose cooperative oil field development programs on minority holdouts. The right to impose unitized operations on dissenting minorities became known as compulsory or statutory unitization, and approximately half of the states with unitization assistance statutes awarded this right of compulsion to majority owners.[22]

In Oklahoma compulsory unitization legislation was enacted in 1945. It stated that once 85 percent of the leases approved unitization, the remainder could be forced to join.[23] Small firms resisted the new law, challenged it in court, and attempted repeal in 1947. By 1951, however, opposition to compulsory unitization in Oklahoma was largely

[22] State surveys of compulsory unitization provisions are presented in James E. Russell, Forrest E. Hoglund, and Granville Dutton, Statutory Unitization: The Engineering Aspects of an Energy Recovery Measure (Society of Petroleum Engineers Paper #3965, 1972), and Dean Lueck, Petroleum Conservation and the Statutory Overthrow of the Common Law (unpublished working paper, 1997).
[23] 1945 Oklahoma Session Laws at 162.

spent, and the original law was amended with little controversy to lower the required majority from 85 to 63 percent.[24] In Texas, however, small firms resisted the loss of the regulatory advantages afforded them through the state's prorationing regulation, and because of their large number and political influence, Texas was never able to adopt a compulsory unitization law.[25]

If unit contracts are to succeed at internalizing the common pool externality, they must award to each owner a fixed share of all production *and* costs associated with the reservoir. Such an arrangement makes each party a residual claimant to reservoir-wide rents, and reconciles individual incentives with those of the group to maximize the value of the reservoir as a whole. Under these circumstances, unit shareholders hold property rights to an undivided share of the petroleum *in situ*, thereby negating the impact of the rule-of-capture.

This fundamental principle of unitized development breaks down when any shareowner is allocated different portions of unit costs and revenues, and intense conflict may result. Consider in the extreme, the position of an owner who is allocated 100 percent of all production, but 0 percent of the costs. That owner would then champion any incremental investment that increases production from the reservoir, no matter how small and regardless of cost or the impact on the profits of other owners. Below we examine why these unbalanced allocations were agreed to in some unit contracts. This type of dispute within the unit is not unlike the conflict that arises between royalty interest owners (typically surface property owners), who bear no costs of production, and

[24] 1951 Oklahoma Session Laws at 136.
[25] Gary D. Libecap and Steven N. Wiggins, The Influence of Private Contractual Failure on Regulation: The Case of Oil Field Unitization, 93 J. Polit. Econ. 708 (1985).

working interest owners (producing firms), who do. For example, in *Kingwood Oil Company v. Kenneth C. Bell* (244 F.2d 115; 1957 U.S. App. LEXIS 4828; 7 Oil & Gas Rep. 779) an economically sound secondary recovery operation was blocked by the working interest owner's obligation to carry *all* costs for a 50 percent royalty owner. This stipulation effectively doubled the cost per barrel on the working interest owner's share of the proposed enhanced recovery, making it much less financially attractive.[26]

Many unit contracts that emerged after 1950 deviated from the ideal form of fixed, reservoir-wide cost and revenue shares. This was especially the case for units covering reservoirs containing both oil and natural gas.[27] Such reservoirs were frequent since 63 percent of the largest U.S. oil fields contained significant volumes of natural gas along with oil.[28] In reservoirs with both oil and gas the parties typically first partitioned the reservoir into separate participating areas or PAs, such as the "gas cap" and "oil rim" and then negotiated distinct shares for themselves within each PA. In these "dual PA units" each owner was granted a fixed share in costs and benefits, but a share in the gas cap often deviated significantly from the share in the oil rim. Unit contracts also commonly assigned different cost and revenue allocations during primary and secondary phases of production, leading to "multi-phase units." Table 1 reveals that of 60 sampled unit agreements written in the U.S. and Canada, 33 (or 55 percent) were partitioned in either of these two ways.[29]

[26]Although renegotiating problematic lease terms may allow field development to proceed, the need for such re-negotiation itself represents an incremental cost of development that in some cases may be sufficient to discourage the undertaking. The main difference between the situation described in the text and unitization is that royalty owners typically have no direct authority over operating decisions. They can influence them, however, through royalty requirements.
[27] Libecap and Smith, Self-Enforcing Provisions, *supra* note 5.
[28] See Richard Nehring, The Discovery of Significant Oil and Gas Fields in the United States (1981).
[29] Libecap and Smith, Self-Enforcing Provisions, *supra* note 5 at 526.

Share partitions in dual PA units fail to completely internalize the production externality.[30] A firm with a 100 percent share of the oil rim and another with 100 percent of the gas cap have different development incentives for the entire reservoir, and conflicts result. Whatever gas remains in the reservoir at a given time can be used to force oil through porous rock to the well bore. Hence, oil rim owners prefer to delay production of gas and reinject it into the reservoir as an oil drive. Gas cap owners, who have no share in the enhanced production of oil, prefer immediate production of the gas. Only if an owner's share were constant across both partitions would he favor the course of action that maximizes the value of the *combined* production of oil and gas.

Despite this potential for conflict, dual PA unit contracts were written because of inherent difficulty in trading the newly created unit property rights to *in situ* oil and gas. Because future *relative* prices were uncertain, the respective owners held disparate expectations about lease values and often were unable to reach agreement on overall unit shares.[31]

To see the problem suppose the leases of the "gas cap owner" covered 80 percent of the total gas resource within the reservoir, but only 40 percent of the oil, whereas the "oil rim owner" held the remaining 20 percent of the gas and 60 percent of the oil.[32] There are many possible agreements between the two that would unitize the reservoir (for example, a 50/50 allocation of all costs and benefits between them, or 55/45 in favor of

[30] Multi-phase units typically do not involve the same problems. See Libecap and Smith, Self-Enforcing Provisions, *supra* note 5.

[31] Although oil and natural gas compete to a limited degree in some uses, their prices are not highly correlated, as shown below in Figure 3. For further discussion, see Libecap and Smith, Regulatory Remedies, *supra* note 5.

[32] Unbalanced holdings of this type, which are common in practice, result from a skewed distribution of leases relative to the underlying deposit and the non-homogeneous placement of oil and gas accumulations within the geological structure.

the gas cap owner, and so on), but each of these alternatives requires that the gas cap owner exchange gas for a greater portion of oil. In the end, the gas cap owner must hold a uniform share in both oil and gas, or else the reservoir will not be effectively unitized. Uniform shares in both resources align the interests of the owners in the maximization of the economic value of the reservoir, rather than to maximize the separate value of oil or gas.

The terms of trade governing this exchange are subject to bargaining, but because the gas cap owner started with proportionately more gas than oil, the direction of trade is determined by the initial allocation. If the parties hold divergent views regarding relative prices of the oil and gas, however, it is possible that no terms of trade can achieve mutual approval. For example, if the gas cap owner believes that the relative value of each unit of gas is 3 (in terms of oil), while the oil rim owner believes the relative value is 2, the former would demand *at least* 3 units of oil in exchange for each unit of gas, but the latter would willingly provide *at most* 2 units of oil in exchange. An impasse can result, blocking complete unitization.

Figure 1 describes the initial holdings and price expectations of the two parties and delineates the set of feasible trades under these circumstances. The gas gap owner, starting at point E with 80 percent of the gas resource, would be willing to exchange at the rate of 1 unit of gas for 3 in oil, moving up the steeper of the two trading lines shown in the figure. He would refuse worse offers, which lie to the left and are shaded horizontally. He would accept offers to exchange at rates better than 3:1, which lie to the right of the trading line and are free of horizontal shading. The goal of the trade is to reach the diagonal line where oil and gas shares are equalized. The oil rim owner, also

starting at point E, but with just 20 percent of the gas, would be willing to acquire gas at the rate of 1 gas for 2 oil, moving up the flatter of the two trading lines. He would refuse worse offers (shown by vertical shading) and welcome better. As indicated, the only *feasible* trades are those in the unshaded portion of Figure 1, below and to the right of point E. These trades, however, have the gas cap owner *expanding* his interest in gas and reducing his interest in oil, a process that carries the parties away from unitized shares in the reservoir. In the limit, the final outcome might place all the gas with the gas cap owner and all the oil with the oil rim owner. Thus, divergent beliefs regarding relative prices could foreclose the possibility of unitizing the reservoir and lead instead to separate partitioned ownership of the two resources.[33]

This adverse result can only arise when there are two or more reservoir substances that differ in kind and value. If there is only oil in the reservoir and the parties disagree on its value, there is no similar obstacle to a complete buyout by the party holding the higher expectation of value, and thereby achieving unitization by default.[34] Accordingly, uncertain relative prices of oil and natural gas *from the same reservoir* led firms to create separate bundles of property rights within the reservoir, rather than a single right to all *in situ* resources.

[33] Some dual-resource common pool problems may be susceptible to partitioning for technological reasons, as well. For example, fisheries that consist of mixed species (for example, shrimp and red snapper) tend to be exploited simultaneously by competing technologies that attract different groups of fishermen with little in common. We suspect that dissimilarities and/or unfamiliarities that stem from these technological differences would raise further hurdles to effective unitization of the common pool.

[34] When a subjective difference in valuation applies to a single asset, as in Buchanan and Faith's extension of Coase's rancher/farmer example, either buyouts by the more optimistic party, or the operation of a liability rule in place of property rights, may resolve the externality without stifling investment. When the valuation of two assets are at issue, as in our case, and a system of strict property rights exists in the form of the rule of capture, buyouts and liability rules do not suffice. See James M. Buchanan and Roger L. Faith, Entrepreneurship and the Internalization of Externalities, 24 J. Law & Econ. 95 (1981).

Separate partitions also can occur even when the respective owners hold identical expectations regarding the relative values of oil and gas. So long as relative values are volatile and uncertain, attaching financial risk to each party's holding, and the parties are risk-averse, then there is no assurance that any of the feasible trades available to the parties will lead to unitization, with the gas cap owner having an equal interest in both gas and oil. The problem is that, while the parties value the efficiency of unitized management obtained through equal shares, they also value the efficient distribution of risk among owners obtained through diversified holdings. These two goals could conflict as illustrated in Figure 2, and only by coincidence would the efficient allocation of risk between the two parties coincide with a unitized apportionment of equity in the reservoir.

To see the problem, start again from the initial endowment point E in Figure 2, where the gas cap owner holds 80 percent of the gas. He would be willing to exchange gas for oil, but only at an ever-increasing price as his gas holding diminishes. The upward-curved line represents these trades. All trades to the left of this line marked by horizontal shading make the gas cap owner worse off relative to the initial endowment and would be refused. The oil rim owner is in a similar position, willing to trade to acquire gas, but only at an ever decreasing price as his holding of gas grows, as reflected by the downward-curved line. All trades to the right of this line shown by vertical shading would be judged inferior to point E and therefore refused by the oil rim owner. The only mutually agreeable trades are confined to the small, unshaded disc, which does carry the parties in the direction of unitized holdings indicated by the diagonal line, but stops short of reaching it. Any feasible trade has the gas cap owner retaining a higher interest in gas than oil, again resulting in dual participating areas. The distinct resources

simply could not be pooled. But this arrangement with separate partitions and different allocations of costs and revenues within each partition fails to completely internalize the production externality.[35]

To address the "non-internalized" portion of the production externality, partitioned unitization agreements typically included other contractual provisions that committed the parties to actions designed to balance the interests of the owners and circumvent potential conflicts. For example, many dual PA units included some agreed-to provisions for reinjecting produced gas back into the reservoir and delimiting the timing of major gas sales. In multi-phase units, there were provisions that delineated the timing of transition from primary recovery to secondary recovery and the revised allocations that went with them.[36]

Indeed, as envisioned by Demsetz, by the time a unitization agreement had been signed, the owners had already engaged in many exchanges or "Coasian trades." If the oil rim owners really believed, for example, that the gas was more valuable if left in the reservoir to boost recovery of oil, then they had incentives to win this concession from the gas-cap owners, and the expected extra profits financed the trade. One typical concession was to offer the gas-cap owners a reduced share in oil rim development costs. Unfortunately, this negotiating process was vulnerable to break down, especially in cases where the parties held disparate expectations regarding the relative values of reservoir

[35] Since the main impediments to unitization appear to result from asymmetries in resource holdings and information, it is reasonable to ask (as Dean Lueck has done) whether it would not be more effective to unitize the many small holdings into one consolidated tract prior to exploration. Certainly there is less asymmetry among the parties at that point. However, there remains the problem of holdouts and bargaining over shares. Given that only about one in ten exploration wells results in discovery of a commercial reservoir, one may doubt whether it would be worthwhile to incur the transactions costs of forming a unit before the need for it has been clearly established.

[36] Libecap and Smith, Self-Enforcing Provisions, *supra* note 5.

fluids. Any side agreement formulated to balance the interests of the owners was precarious because the process of unitization was itself incomplete. The deal could unravel if there were any significant economic shocks to prices or costs that altered the net values of the two fluids.

Suppose the owners agreed that gas sales would not begin until 30 percent of the oil had been recovered from the reservoir, and as compensation the gas-cap owners were granted a disproportionately low cost-sharing obligation in the oil rim. This exchange was based on expectations regarding the cost to gas-cap owners of delaying gas sales. If those expectations subsequently changed, the basis for the exchange would be lost. For instance, if there were an unexpected, post-agreement surge in natural gas prices or a geological reassessment that subsequently increased the estimated volume of the gas deposit, then the provisions of the original contract would appear to the gas-cap owners as inadequate compensation for their sacrifice.

In *Union Pacific Resources Company v. Texaco, Inc.* (882 P.2d 212; 1994 Wyo. LEXIS 111) the reassessment of reserves in two distinct participating areas had just this effect, triggering demands by some owners that their contractual shares in the respective participating areas be renegotiated. This conflict stemmed from the fact, as recognized by the Court, that "the allocation of profit varies depending upon the geologic formation from which production is achieved." Although the partitioned unit agreement achieved an *initial balancing* of interests, it failed to *permanently align* the interests of all owners, as a complete unitization agreement would do. The words of the Court are instructive:

> However, even plainly stated terms may be the subject of significant disputes. The parties to the Operating Agreement are sophisticated corporate entities with considerable experience in forming these types of agreements. The parties also understand that their business involves a

> highly regulated industry. Despite these skills, the parties failed to anticipate the likelihood that a basic fact on which their agreement was premised might change.

The potential for such conflicts of interest, opportunism, re-contracting, and outright abrogation were the prices paid for the creation of separate competing property rights within the same reservoir. The benefit of partitioned units was to enable some kind of cooperative agreement, albeit incomplete, in lieu of extractive anarchy (as moderated by state conservation regulations).[37]

The recent increase in volatility of relative oil and natural gas prices, as indicated in Figure 3, suggests that it is now more difficult for owners to maintain balance between the bundles of competing property rights that have traditionally been created within partitioned units.[38] With wider and more frequent swings in relative prices, the scope for opportunistic behavior and the reward for abrogation of agreements increase. At some point, the cost of bundling property rights into separate partitions within the reservoir may exceed the benefit. As that becomes the case, either complete unitization or reliance on less effective state regulation, if no unit agreement can be reached, will become a more common industry practice.

The Prudhoe Bay oil and gas field in Alaska is a case in point, and notable for being the largest petroleum reservoir ever discovered in North America. At the time of discovery (1968), and due to the field's remote location and lack of transport facilities, it was debatable whether or when the huge gas reserve could be developed for commercial

[37] For a more sympathetic view of rule-of-capture competition and less favorable interpretation of regulatory intervention as a source of overproduction and overdrilling, see Bradley, *supra* note 18, at chapter 3.

[38] The rise of OPEC and deregulation have combined to make oil and gas prices the least predictable of any major commodity.

sale, instead of remaining in the ground to maintain pressure and assist in the production of oil. Because the gas was distributed unevenly beneath the various leases and its value was highly speculative, the owners negotiated in vain over eight years to find terms of trade that would give to each party a fixed share of the aggregate resources in the reservoir. The oil rim owner (BP) was unwilling to accept any of the risky gas resource in exchange for the oil lying beneath its leases. Terms of the agreement finally reached in 1977 called for the field to be partitioned into separate oil rim and gas cap participating areas, with varying shares allocated to each owner. BP, for example, was allocated 51 percent of the oil rim, but only 14 percent of the gas cap. For their part, the principal gas cap owners (ARCO and Exxon) obtained BP's agreement to a series of trades regarding field operations that involved, among other things, the timing of gas sales from the reservoir.[39] At that point, the field was declared by the owners and the Alaska Oil and Gas Conservation Commission to have been "unitized."

Neither gas nor oil prices behaved after 1977 in the manner anticipated by the parties, and the unanticipated swings brought economic pressures that caused the initial balance between competing interests to fail. Because the separate reservoir fluids had not been pooled, the field had been unitized in name only. Although the gas cap owners became residual claimants to gas cap profits and oil rim owners became residual claimants to oil rim profits, none of the parties had been made a residual claimant to a fixed share in unit-wide profits. Thus, the creation of competing participating areas within the same field brought conflicts of interest, opportunistic behavior, arbitration, and litigation over how the reserve would be developed. The original unit operating

[39] Alaska Oil and Gas Conservation Commission, Transcript of Public Hearing Re: Prudhoe Bay Unit—Liquid/Miscible Natural Gas Injectant, April 12, pp. 238, 289, 951-956 (1996).

agreement was significantly amended on at least seven occasions during the 1980s and 1990s as individual conflicts were settled on a piecemeal basis.

Most of the disputed issues pertained to the disposition of produced gas and the allocation of costs between participating areas. ARCO and Exxon, for example, favored processing any gas that was produced in association with oil to extract as much natural gas liquids (NGL) as could be blended with crude oil for shipment and sale down the Trans-Alaska Pipeline. BP favored instead converting the NGLs into a miscible fluid that could be reinjected into the reservoir to enhance the recovery of remaining oil.[40] Oil production from this massive field actually began to decline in 1988. This was not due to physical depletion of the underlying oil deposit, but to a lack of agreement on which parties would pay for facilities required to handle the rising volume of gas that was produced along with oil as the field matured.[41]

Disputes regarding the management of this "unitized" field came repeatedly before State officials, including the Alaska Oil and Gas Conservation Commission (AOGCC), the Alaska Public Utilities Commission, and the Alaska Superior Court. Despite a series of adjustments to the unit operating agreement and a re-balancing of interests that each adjustment produced, conflicts continued. Finally, in 1995 the AOGCC opened public hearings on the underlying causes and deleterious effects of the partition between gas cap and oil rim interests, and on possible courses of corrective

[40] Alaska Oil and Gas Conservation Commission, Conservation Order No. 360, paragraphs 73-74, Aug. 9, 1995.
[41] D. J. Szabo and K. O. Myers, Prudhoe Bay: Development History and Future Potential, Paper No. 26053, Society of Petroleum Engineers (1993).

action, including compulsory re-unitization of the field by the State of Alaska, if necessary.[42]

The owners strongly resisted this attempt at compulsory unitization and finally succeeded in winning a ruling from the State Attorney General that denied jurisdiction to the AOGCC on grounds that the agency had already recognized the oil field as having been unitized in 1977. Thus, although the partitions were the source of underlying economic conflicts, they were declared legally irrelevant. Even so, the owners needed to more effectively unitize the field to deal with their overlapping claims and conflicting bundles of property rights. This course was seen as more durable and less costly than a continuing series of lawsuits and regulatory filings. The first public indication of their efforts came in 1999 when BP effected a buy-out of ARCO's interest in the Prudhoe Bay field by agreeing to purchase the entire company.[43] The Federal Trade Commission temporarily blocked this transaction on anti-trust grounds, but an even more comprehensive alternative was found. Phillips Petroleum purchased the ARCO stake in the Prudhoe Bay field and a new exchange of interests between all remaining owners dissolved the partition between the oil rim and gas cap and created for each owner a fixed share in the operations of the entire field. This action completely unitized Prudhoe Bay, internalizing the common pool externality.

[42] Alaska Oil and Gas Conservation Commission, Conservation Order No. 360, *supra* note 39.
[43] According to the Atlantic Richfield Co. 10-K filing with the U.S. Securities and Exchange Commission, Alaska accounted for 51% of ARCO's worldwide petroleum production in 1999, the last full year prior to the sale.

IV. THE PROBLEM OF COMPULSORY UNITIZATION.

As we have noted, because of the problems encountered in negotiating private unitization agreements, state governments often resorted to compulsory unitization as a remedy for the common pool externality. Depending on the standards by which compulsory unitization is implemented, the procedure can restrict the owners' rights to voluntarily negotiate and adopt operating agreements that fall short of the state's criteria. As Demsetz argued, restricting the range of private negotiations in this fashion imposes infinite transaction costs on certain trades and is likely to create inefficiency.[44]

Compulsory unitization can have this effect if it overrides a voluntary agreement that has been crafted on the basis of the anticipated costs and benefits of its various provisions. The state may impose a unit in cases where voluntary agreements appear to fall short of complete unitization. But welfare can be reduced by such action. Above we noted that when it is difficult for the parties to trade the rights to the resources *in situ* and completely unitize, less complete separate participating areas and related Coasian trades may still move the parties away from extractive anarchy. In situations where complete unitization of the reservoir would not satisfy the criterion of Pareto efficiency, due to either disparate expectations or constraints on the distribution of risk among the owners, any state imposed unitization necessarily results in efficiency losses on at least some of the owners. Accordingly, the welfare effects of compulsory unitization are not unambiguous.

There is a paradox, however. While actually invoking the power of compulsory unitization can lead to inefficiency, the *threat* of invoking that power may reduce

[44] Demsetz, *supra* note 1, at 348-49.

bargaining costs if it mitigates the holdout problem. But, for the threat to be effective, it has to be credible, which requires the state to follow through with compulsory unitization at least in some cases. Indeed, the value of the threat stems at least in part because it imposes an inefficient outcome on the owners, which they wish to avoid. It would be a mistake, then, for the state to automatically reject a voluntary agreement made by the owners, regardless of its apparent limitations.[45] To do so ignores the full costs of making the transaction, all of which fall on the owners of the reservoir. It is at least as much in their interests as it is in the state's to craft an agreement that will maximize the value of the reservoir. The state can perhaps contribute to their success by adopting measures (including compulsory unitization) that reduce the power of holdouts, but not by requiring perfection of the agreement that results.

There are indications, beyond Alaska, that the regulatory agencies and courts might ignore, or fail to recognize, the burden that compulsory unitization can impose on the owners. The overriding principle of conservation and avoidance of waste has been used to impose mandatory unitization plans on unwilling parties. In *Clark Oil Producing Co. v. Donald P. Hodel, Etc., et. al.* (667 F. Supp. 281; 1987 U.S. Dist. LEXIS 7694; 97 Oil & Gas Rep. 291) for example, the Court found that under federal law governing oil and gas leases on the outer continental shelf, a mandatory plan could be imposed over the opposition of any owner if the regulation avoided the drilling of "unnecessary" wells. This ruling begs the question of which wells should be deemed unnecessary, particularly if the owners themselves could not reach agreement on an issue that would directly reduce costs and increase their profits. Under federal law, however, there is apparently

[45] Compulsory unitization is a measure to be invoked only if the private negotiations fail to produce a voluntary agreement within a reasonable time.

no requirement that the mandated plan have a favorable, or at least neutral, impact on the welfare of each affected owner. This position is consistent with the traditional view that unitization has the potential to increase overall reservoir rents, and therefore could enhance the welfare of each individual owner. The arguments made here, however, suggest unitization may not be welfare enhancing, at least when set against other voluntary alternatives available to the owners. Accordingly, proper public policy is not so obvious. Kansas is one state that does look to the welfare implications, requiring that mandated unitization provide "fair and equitable" treatment of all interest owners, and accepting the partial unitization of a common pool if there will be no material adverse effect upon other parts of the pool.[46] More than anything else, this stance reflects the fact that, with or without unitization, imperfections in the definition and trading of property rights to oil and gas exist. It is therefore important for regulators to recognize that an apparent second best solution, voluntarily reached, may be preferable to mandated unitization.

V. CONCLUDING REMARKS.

In this paper, we have followed the gradual development of property rights to subsurface oil and gas deposits in the United States through private and political negotiations. The pattern has been influenced by technological change, shifts in relative prices, information asymmetries, and political factors. The process generally has followed the process suggested by Harold Demsetz in 1967. We show, however, that the unpredictability of relative oil and gas prices limited the arrangements that could be voluntarily adopted to address the common pool externality. In cases where there were

[46] See, for example, *Cleon Parkin, et. al., v. The State Corporation Commission of Kansas, et. al.* (234 Kan. 994; 677 P.2d 991; 1984 Kan. LEXIS 276; 80 Oil & Gas Rep. 39).

both oil and gas in large quantities in a reservoir negotiations were especially difficult because of volatile prices, disparate expectations, and the owners' need to manage financial risk as well as reservoir behavior. Units often could not be completed, or when they were, unit agreements often did not completely align incentives. To address differences in perceived values for natural gas and oil, units were partitioned into different participating areas or PA s with the majority of oil owners in one PA and the majority of natural gas owners in another. Once again, these units were an improvement over competitive extraction, but conflicting incentives led to production disagreements and coordination problems. The history of the Prudhoe Bay Unit illustrates the problems that can be encountered when there are gas cap and oil rim partitions.

Partitioned units are associated with litigation and other forms of waste, and states have used coercive unitization statutes to force a unit agreement once a fixed majority agreed to the action. As we have argued, although forced unitization has been viewed positively as a means of addressing the common pool externality, it can reduce the welfare of parties relative to private agreements. The policy implication is that coercive unitization should be used sparingly, perhaps in cases when no private agreements are forthcoming after lengthy negotiations.

Table 1: The Frequency of Partitioned Units

Total Observations = 60	With Multi-Phase Partition	No Multi-Phase Partition
With Dual PA partition	3	11
No Dual PA partition	19	27

Source: Gary D. Libecap and James L. Smith, The Self-Enforcing Provisions of Oil and Gas Unit Operating Agreements: Theory and Evidence, 15 J. Law, Econ. & Org., 526 (1999).

Figure Legends

Figure 1: Divergent Expectations Block Unitization

Figure 2: Risk Aversion Blocks Unitization

Figure 3: Increasing Volatility of Relative Prices (Oil/Gas)

Figure 1: Divergent Expectations Block Unitization

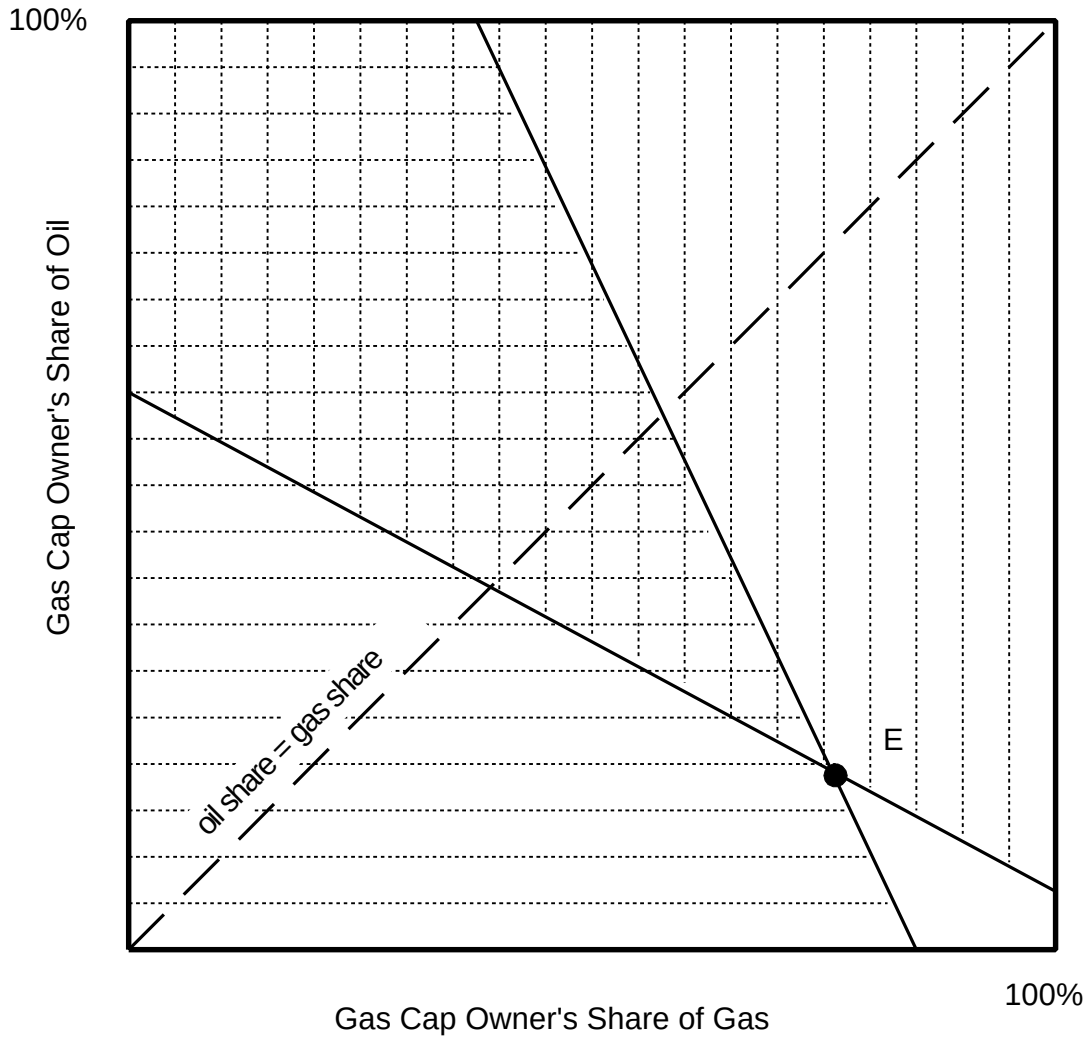


Figure 2: Risk Aversion Blocks Unitization

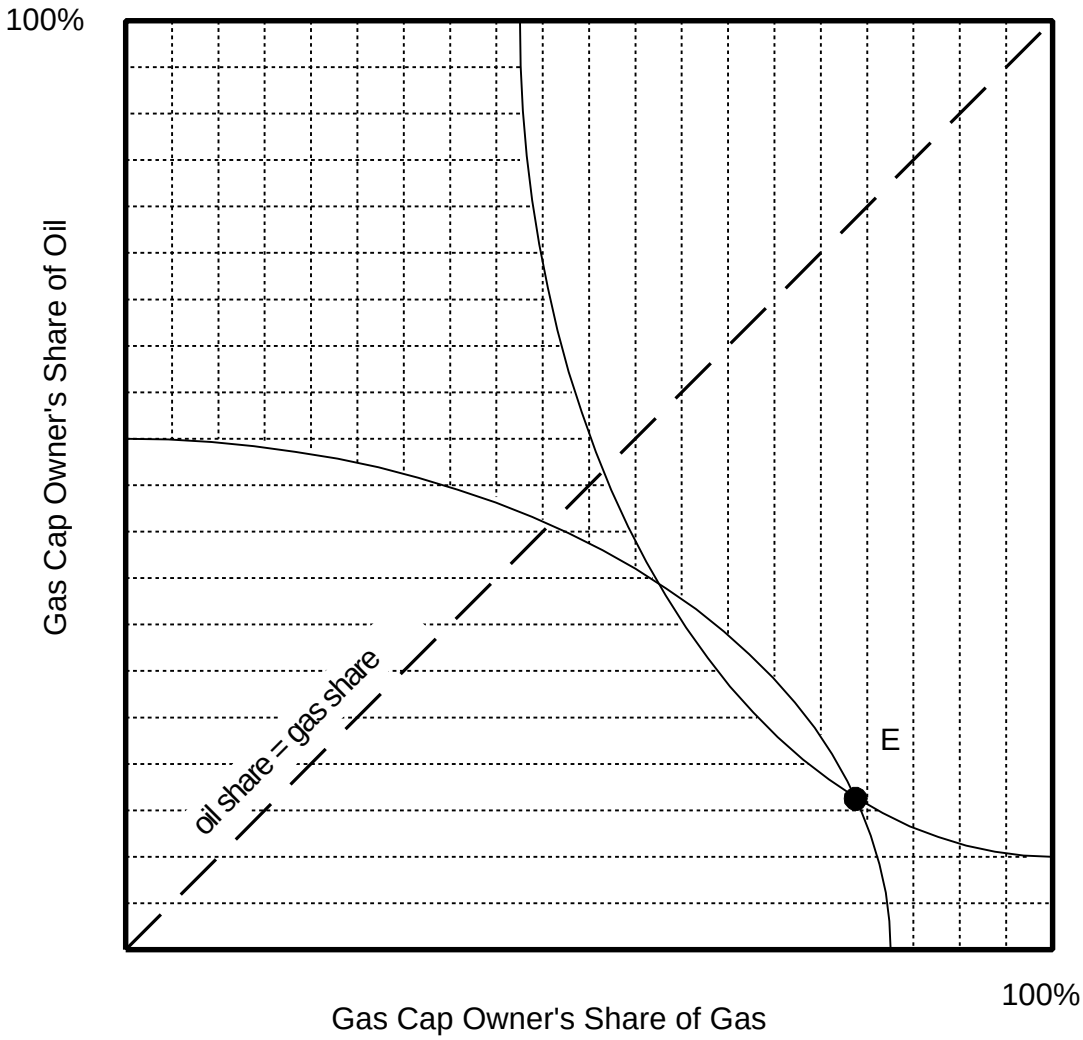
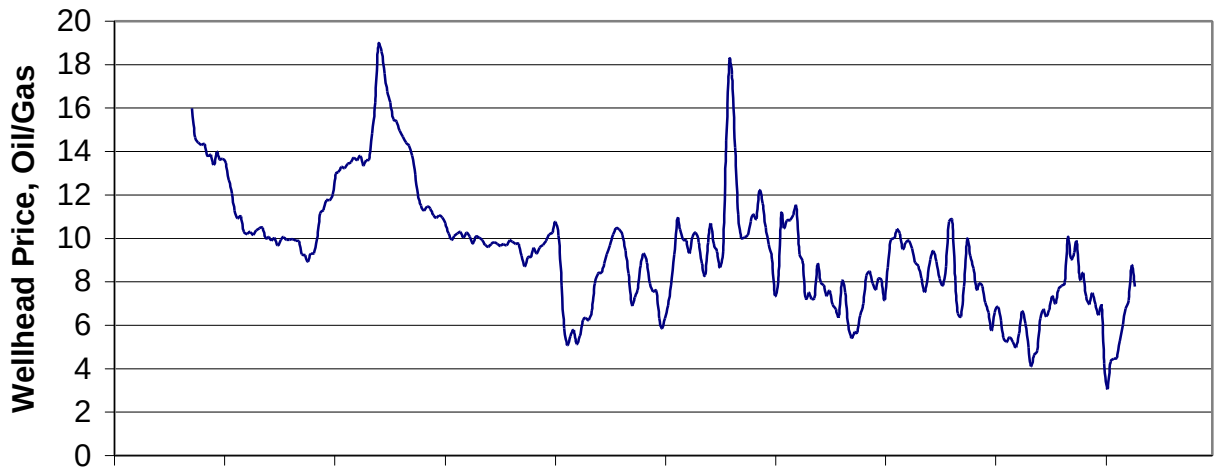


Figure 3: Increasing Volatility of Relative Prices (Oil/Gas)



Source: U.S. Energy Information Administration