Effects of Environmental and Land Use Regulation in the Oil and Gas Industry Using the Wyoming Checkerboard as an Experimental Design

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This paper estimates the extra costs of drilling for oil and gas on federal land as compared to private land in the Wyoming Checkerboard. The Checkerboard, an important site of recent oil and gas activity, is a 40-mile-wide strip of land, 20 miles on each side of the Union Pacific Railroad right-of-way, extending westward approximately 200 miles from Rawlins in south central Wyoming to the Utah state line. The Pacific Railway Acts of 1862 and 1864 conveyed to the railroad both surface and mineral rights to the odd-numbered (square-mile) sections of land in this area, while retaining the even-numbered sections as federal property.[1] Thus, four private (railroad) sections surrounded each federal section and four federal sections surrounded each private section, giving land ownership maps of this area the appearance of a checkerboard.[2] Since the 1860's, some of the land has changed hands; however, the alternating ownership pattern is remarkably persistent to the present day and serves as an experimental control that may be used to identify differences in drilling cost on federal and private property. Estimates presented suggest that average drilling costs per well are about $200,000 higher on federal property than on private property. This difference is attributed to more stringent enforcement of environmental and land use regulations on federal land.

I. Checkerboard Drilling Costs

Environmental aspects of oil and gas field work in the United States are subject to numerous federal statutes such as the National Environmental Policy Act, the Toxic Substances Control Act, the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, the Antiquities Act, and the Threatened and Endangered Species Act. These statutes apply to industry activities on all types of land, although an engineering study (B. Harder et al., 1995), a survey of operators, landowners, and federal land managers (Kunce et al., 2001), and congressional testimony (James T. Hackett, 2001) suggest that enforcement is more stringent on federal land than on private land. In particular, cultural resources (i.e., Native American artifacts and historical sites) and biological resources (i.e., wildlife habitat) appear to be given greater protection on federal property as compared with private property.

This paper focuses on costs arising from environmental and land use regulations pertaining to drilling. Drilling, rather than production, is analyzed for three reasons. First, although environmental contamination can occur at any stage in the life cycle of oil and gas wells, drilling is thought to be the activity of greatest risk because of the large volumes of potentially hazardous gases and fluids brought to the sur-

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[1] For a colorful account of this land transaction and other inducements granted by the federal government to support construction of the transcontinental railroad through Wyoming, see Taft A. Larson (1965).

[2] Detailed maps showing the current ownership pattern of land around the Union Pacific railway line in southwestern Wyoming are available from the Wyoming Spatial Data and Visualization Center (http://www.wims.uwyo.edu).

face (E. G. Carls et al., 1994). Second, data on drilling costs, collected by the American Petroleum Institute (various years), are much richer than the highly aggregated data on production costs reported by the U.S. Department of Energy, Energy Information Administration (various years). Third, drilling is a one-time activity, whereas production from a given well may last for many years. Production cost conditions can change over time as subsurface pressure declines causing wells to lose their natural drive. Thus, it would be easier to analyze drilling costs than production costs even if the quality of data on both activities were the same.

Are drilling costs higher on federal property than on private property in the Wyoming Checkerboard? The American Petroleum Institute (various years) collects drilling cost data from operators on completed wells drilled in the United States, including dry holes. Types of costs reported include variable cost items such as labor, materials, supplies, machinery and tools, water, transportation, fuel, and power. Also, information about costs of direct overhead such as for permitting and site preparation, road building, drilling pit construction, erecting and dismantling derricks/drilling rigs, hauling and disposal of waste materials, and site restoration is obtained. The survey, however, does not request information about lease acquisition costs. Thus, while the survey data include major elements of drilling cost associated with environmental and land use regulation, they do not reflect the way in which such regulations may have been capitalized in the value of a lease. Also, I.H.S. Energy Group, Inc. compiles data on additional characteristics of completed wells and merges this information with the drilling cost data. Supplementary characteristics measured include depth (in feet), surface land ownership (private, federal, state, or tribal), well type (oil, gas, or dry), and well location in latitude and longitude coordinates.[3] Data available from I.H.S. contain information on about 325,000 completed onshore wells drilled between 1987–1999.[4]

While the complete data set has a large number of observations with details about each well drilled, a disadvantage is that components of total cost are not itemized. This means that the environmental compliance component of drilling cost cannot be directly identified and standard methods cannot be used to estimate a drilling cost function. An estimate of the desired cost differential, however, can be obtained by limiting attention to a comparison of drilling costs on federal and private land in the Wyoming Checkerboard. The land ownership pattern there provides an experimental control for five factors that would otherwise contaminate the resulting estimates: (1) remoteness, (2) characteristics of reserves, (3) environmental resources, (4) regional differences in attitudes toward resource development, and (5) management. In general, federal land tends to be located at greater distances from cities and towns than rural private land and many tracts of federal land have been set aside for specific purposes (e.g., parks, forests, recreational areas) that rule out use for permanent settlements. Thus, drilling costs may be higher on federal land because it is less accessible. Also, it may happen that characteristics of hydrocarbon reserves on federal land differ from those on private land. For example, reserves could be deeper on federal land than on private land, or private land could be relatively richer in oil reserves than gas reserves. Moreover, there may be differences in the quantity of environmental resources to protect on federal versus private land. Differences between scenic attributes of national park and national forest lands and rural private land may be most obvious, but less immediately noticeable ecological differences may be important as well. In fact, some federal lands have been set aside to protect specific, unique or diverse environmental resources. Regarding management, the U.S. Department of Interior [National Park Service and Bureau of Land Management (BLM)] manages some federal lands, while the U.S. Department of Agriculture (National Forest Service) manages others so it is useful to control for possible policy differences between agencies. Finally, regional differences in attitudes toward resource development may affect decision-making on both federal and private lands. J. Vernon Henderson (1996) discusses the possible importance of this aspect in a manufacturing context.

[3] Longitude and latitude coordinates provided are accurate to five decimal places and place each well to within one meter of its exact location.

[4] Data for earlier years also are available, but measures of cost are less accurate and location of wells are missing or at least appear to be less precise than for 1987–1999.

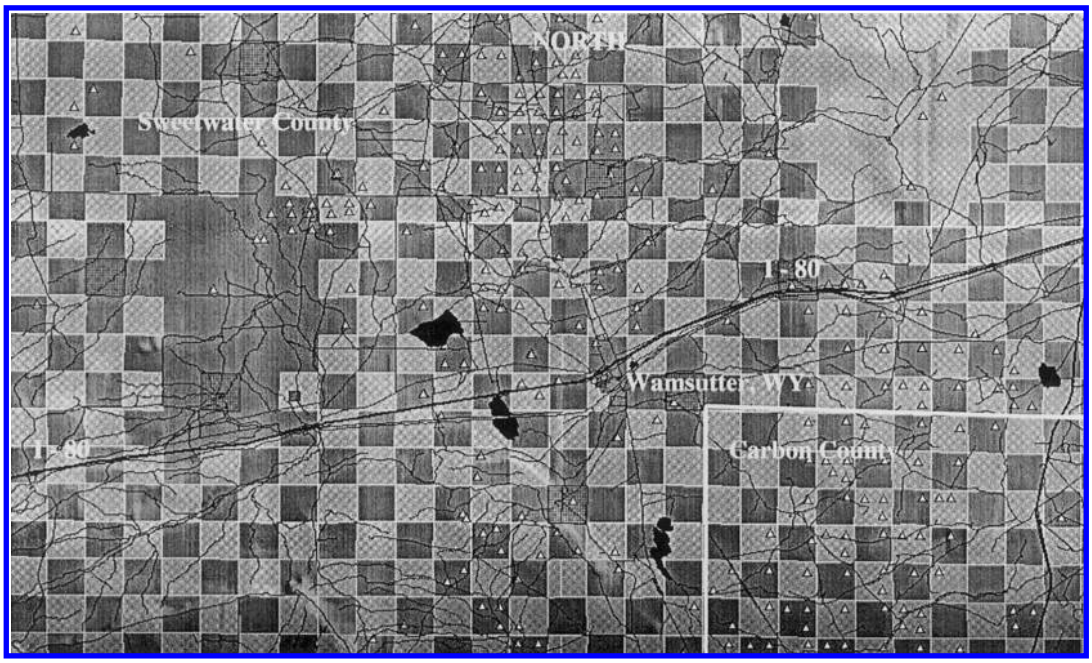

FIGURE 1. CHECKERBOARD MAP

Note: Light gray—BLM land; dark gray—private land; dotted squares—state land.

In the Checkerboard, the pattern of current land ownership is almost entirely determined by the land grant provided by the Pacific Railway Acts of 1862 and 1864. These acts predate broad-scale environmental concern in the United States by as much as a century and predate even the first U.S. national park (Yellowstone), which was established in 1872. Since that time, certain sections have changed hands; for example, federal sections have been sold or traded for private sections to accommodate expansion of towns, to permit better access to water for agriculture, as well as for other purposes. In a few cases, the state of Wyoming traded land owned in other locations for federal sections in the Checkerboard. Also, the Union Pacific Railroad has sold all of the sections it originally owned to other private owners, mainly for use in agriculture. These land transactions, however, have not greatly disturbed the original alternating federal–private ownership pattern established by the Pacific Railway Acts. Figure 1 shows a portion of the Checkerboard near the town of Wamsutter, Wyoming. BLM land is shown in light gray, private land is shown in dark gray, and state land is shown in dotted squares. Locations of wells drilled between 1987–1999 are shown using white triangles. Figure 1 also identifies two areas where federal and private ownership of land has been consolidated. These consolidations, which are two of the largest in the entire Checkerboard, are excluded from the analysis below. Also, climate and topography of the Checkerboard are relatively homogeneous (high altitude desert). This feature, together with the prevailing land ownership pattern, means that remoteness, reserve characteristics, and the quantity of surface environmental resources on each type of land in the Checkerboard should be roughly equal. Moreover, BLM is responsible for all federal land there and the area is small enough that public attitudes toward development are unlikely to vary between locations.

If the Checkerboard is a valid experimental control, then only characteristics of wells that are related to environmental and land use regulations should differ between federal land and private land. To test this, data were obtained for 1,463 wells drilled in the Checkerboard over the

TABLE 1—DIFFERENCE IN MEANS FOR DEPTH, WELL TYPE, AND BLM DISTRICT

Variable		Private	Federal	Test statistic (private–federal)
Depth	Mean	10,433	10,706	−1.79
(in feet)	s.e.	102.25	112.58	
Oil wells	Mean	0.066	0.054	0.93
(fraction of total)	s.e.	0.0088	0.0090	
Gas wells	Mean	0.818	0.855	−1.78
(fraction of total)	s.e.	0.0142	0.0141	
Dry wells	Mean	0.116	0.091	1.44
(fraction of total)	s.e.	0.0120	0.0110	
Rawlins district	Mean	0.486	0.422	2.39
(fraction of total)	s.e.	0.0178	0.0199	
Rock Springs district	Mean	0.277	0.318	−1.67
(fraction of total)	s.e.	0.0159	0.0188	
Kemmerer district	Mean	0.237	0.260	−0.99
(fraction of total)	s.e.	0.0152	0.0177	
Observations		789	615	

Note: s.e. denotes standard error.

period 1987–1999. The 59 wells drilled on state land were excluded from the analysis because of their relatively small number and because the state did not acquire sections at random. Of the remaining 1,404 wells, 44 percent were drilled on federal land, and 56 percent were drilled on private land. Using a *t*-test, the null hypothesis of equality of these proportions is rejected at the 1-percent level (David J. Sheskin, 1997). A higher proportion of drilling on private land would be expected if drilling costs on federal property are higher, or if delays in obtaining needed permits are longer.

Table 1 presents tests for differences between means for all other available variables. As shown, mean well depth on federal land is 10,706 feet while mean well depth on private land is 10,433 feet, a difference of 273 feet, or about 2.6 percent.[5] The null hypothesis of no difference between mean well depth on the two types of property is not rejected at the 5-percent level using a *t*-test assuming independent samples with equal variances. This version of the test was applied because the null hypothesis of equal variances was not rejected at the 1-percent level using an *F*-test. Similar distributions of well depth on federal and private property would be expected if the checkerboard land ownership pattern controls for reserve depth.

Table 1 also shows that roughly the same fractions of oil and gas wells are drilled on federal and private land, testing at the 5-percent level for equality of proportions using a *t*-test. This outcome suggests that reserve characteristics other than depth are similar on the two types of land. Also, the smaller percentage of dry holes on federal property (0.091) versus private property (0.116) might suggest that greater precautions are taken there to avoid such an outcome, but the difference in these two proportions is not significantly different from zero at the 5-percent level.[6] Finally, the proportion of wells drilled on federal and private land in two of the three BLM districts is about the same. In the Rawlins BLM district, however, the percentage of wells drilled on private land is disproportionately greater than the percentage of wells drilled on federal land. An increase in drilling on private land in this area in 1999 appears to be responsible for this outcome.[7]

Table 2 shows that mean real drilling costs are higher on federal land than on private land.[8] Real drilling costs are computed from nominal drilling costs using the 1995 U.S. GDP deflator for the years 1987–1999. The top portion of Table 2 shows that for all wells, average real drilling costs on federal land are higher by $201,000 than on private land. This difference

[5] Wells drilled in the Checkerboard are relatively deeper than those drilled elsewhere. In Wyoming average well depth over the 1987–1999 period was 6,586 feet, and the average depth of onshore U.S. wells during this time was 4,904 feet.

[6] The relatively low percentage of dry wells (12 percent) suggests that development wells may outnumber exploratory wells and perhaps reflects application of recent technological advances such as three-dimensional seismic reservoir identification methods.

[7] If the 1999 data are disregarded, then the null hypothesis of equality between the percentage of federal land wells drilled in the Rawlins district and the corresponding percentage of private land wells drilled in that district would not be rejected at 5 percent using a two-tail test. The recent increase in drilling on private land in this area may reflect higher costs of drilling on federal property.

[8] A regression estimated using all 1,463 observations of real drilling cost on dummy variables for land ownership indicates that the null hypothesis of no difference in drilling cost between private land and state land would not be rejected at conventional significance levels. Thus, the comparison of drilling costs on federal vs. private land would appear to be of greatest interest.

TABLE 2—DIFFERENCE IN MEANS FOR REAL DRILLING COST

Variable		Private	Federal	Test statistic (private–federal)
Real drilling cost (in thousands of $1995)	Mean	885	1,086	−4.03
	s.e.	25.28	43.06	
Observations		789	615	
Real drilling cost (well depth < 9,600 feet)	Mean	500	553	−2.63
	s.e.	12.43	15.84	
Observations		280	181	
Real drilling cost (well depth > 9,600 feet and < 12,300 feet)	Mean	783	879	−4.92
	s.e.	11.43	15.82	
Observations	259		204	
Real drilling cost (well depth > 12,300 feet)	Mean	1,421	1,689	−2.23
	s.e.	64.70	101.08	
Observations		250	230	

Note: s.e. denotes standard error.

is significant at less than the 1-percent level using a *t*-test for equality of means assuming independent samples with unequal variances. An *F*-test of the null hypothesis of equal variances also is rejected at the 1-percent level in this case. In light of effects controlled by restricting attention to the Wyoming Checkerboard, the drilling cost premium identified on federal land is cautiously interpreted as the result of increased stringency of application of environmental and land use regulations. Evaluated at mean real drilling costs for the Checkerboard between 1987–1999 ($965,000/well), this premium represents a cost increase of about 21.7 percent.

The lower portion of Table 2 shows that the cost premium for drilling on federal land is significantly different from zero for each of three ranges of well depth (using *t*-tests at less than the 5-percent level) and, more importantly, that it increases with the depth of wells.[9] For relatively shallow wells (those at a depth of 9,600 feet or less), the average real drilling cost on federal land is about $53,000 higher than on private land. For wells drilled to depths of between 9,600 and 12,300 feet, the cost difference is $96,000, and for the deepest wells, the cost difference is $268,000.[10] The null hypothesis that the private/federal cost differences for the deepest and shallowest wells are the same can be rejected at 1 percent using a *t*-test assuming independent samples and using the pooled variance from the entire sample to approximate the subsample variances. A possible explanation for why the cost premium increases with well depth is that deeper wells require more time to drill and on federal property, drilling is more likely to be interrupted by the more stringent application of environmental and land use regulations prevailing there. These regulations impose seasonal bans on drilling aimed at protecting archeological sites, big game winter range, and habitat for several species of birds and raptors. Thus, particularly on federal property, deep wells must be drilled incrementally in possibly inefficient phases that can stretch over a year or more (Hackett, 2001, p. 7).

These estimates, however, are subject to at least three qualifications. First, when a number of wells are drilled in a particular lease area, operators may have difficulty in allocating fixed costs (including those associated with environmental compliance) between wells. This problem arises on both federal and private property, but is a factor that would reduce the precision of the estimates presented. Second, the estimates presented are averages of cost premiums for drilling on federal property, rather than an extra cost applicable to all drilling sites on this type of land. For example, quantities of environmental resources to protect in the Checkerboard vary greatly over space, so the cost premium may well be higher on some federal sections than on others. Third, estimates of the drilling cost pre-

[9] Further analysis reveals no consistent time trend to report in the cost premium for drilling on federal land.

[10] Data reported in Table 2 show that the proportion of deep wells drilled on federal property (0.48) is significantly greater (at the 1-percent level) than the corresponding proportion of shallow wells (0.39), whereas the opposite outcome might be expected. Operators, however, are constrained by the depth of reserves when choosing the depth of wells. Also, if the expected payoff from relatively deep wells is higher than the expected payoff from relatively shallow wells, then the extra environmental compliance costs on federal property may be less of a deterrent to drilling as depth increases. In this regard, 70 percent of the dry holes in the sample were drilled to depths less than 9,600 feet, while 18 percent of dry holes were drilled deeper than 12,300 feet, so it appears that more information is accumulated about well prospects as expected depth increases.

mium on federal property may be to some extent offset by capitalization of the extra costs into lease values.

II. Implications and Conclusions

These estimates have several implications for both public policy and future research. One policy issue is whether drilling regulations should be more stringently enforced on federal land than on other types of land. If the purpose of the regulations is to internalize negative externalities associated with drilling, then enforcement of regulations should be similar on similar types of land.

A second issue relates to possible reductions in output of oil and gas due to more stringent enforcement of regulations on federal property. Reduced output from currently producing reserves may add to incentives to explore in the most environmentally sensitive areas (i.e., national parks and the Arctic National Wildlife Refuge) sooner than otherwise. Also, the value of reduced future output represents a lower-bound estimate of the opportunity cost of regulation of surface land use. An estimate of this cost for Wyoming, obtained by valuing estimates of lost future output each year using estimates of the discounted shadow price of the resource in the ground, comes to about $1 billion (Kunce et al., 2001). This figure, of course, must be balanced against benefits of increased protection of biological, cultural, and other environmental resources on land where oil and gas exploration and development may occur. Yet, monetary estimates of these benefits are not well established and further research may be warranted to determine whether the current regulatory structure should be made more or less stringent. Checkerboard land in Wyoming and other states may be a useful setting for such studies.

A third issue is concerned with effects on production tax revenue in states that apply these types of taxes. Federal policies that restrict output force such states to cut back on public service expenditures or fund public services from other revenue sources. Thus, it is easy to see why public officials in states such as Wyoming, New Mexico, and Alaska with large amounts of federal property that rely heavily on mineral production tax revenue to finance public services can be vocal opponents of more stringent environmental and land use regulation.

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