New Estimates of the Value of Federal Mineral Rights and Land

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The federal government owns a large fraction of the mineral rights and land in the United States. The value of these resources varies substantially over time, both with acquisitions and sales of these assets and with changes in the prices of the minerals and land involved. Whether one is interested in measures of national wealth, land management policy as part of efficient government operations, or (long-run) macroeconomic fiscal policy issues, time-series estimates of the value of federal mineral rights and land are potentially valuable information.

At one extreme, consider a country or state that owns substantial mineral rights when the price of those minerals skyrockets. The additional revenues potentially available either for use in the public sector, or to allow tax cuts to provide greater private income, may alter the course of the economy. There are historical precedents. Saudi Arabia was able virtually to abolish taxation due to revenues from the sale of mineral rights, and Alaska used oil-based revenues to provide cash grants on a per capita basis to its citizens, thereby increasing their private wealth and consumption opportunities.

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The microeconomics of sensible resource allocation, within the public sector and between the public and private sector, relies on careful cost-benefit evaluations of the value of public services and the opportunity costs of providing them. These in turn are only possible with accurate information on actual *and* potential revenue sources, including the opportunity costs of purchases and sales of assets, as well as traditional flows of income into and out of the public sector. Therefore, the value of federal mineral rights and land is potentially an important piece of information for a host of public policy questions.

This paper provides, we believe for the first time, estimates of the value of federal mineral rights in the postwar period in the United States. It also presents a new time-series for the value of federal land and compares the results with previous estimates. We find that the values of federal mineral rights and land are enormous and fluctuate by tens of billions of dollars annually.

In Section I, we consider the valuation of federal mineral rights; in particular, the revenue which the government is able to obtain from onshore and offshore leases for the extraction of oil and natural gas. We review some recent studies of resource accounting (none of which focuses on the government sector) and present a new methodology for valuing mineral rights. We estimate the value of federal oil and gas mineral rights to be $819 billion in 1981, a number higher than the privately held federal debt in that year.[1] Our estimates consider economically recover-

[1] The total national debt in 1981 was $1,004 billion. Of this, $210 billion was held by government agencies and the Federal Reserve, leaving $794 billion held by private individuals and institutions.

able undiscovered reserves,[2] and therefore would substantially exceed estimates that used the methods of previous studies.

Section II is devoted to the valuation of federal land. We review the work of Raymond Goldsmith (1962), Grace Milgram (1973), and Robert Eisner and Paul Pieper (1984) on this subject, and we present new updated estimates of the value of federal land, taking into account the changing composition of federal land. Our estimate for 1981 is $175 billion, composed of $112 billion for urban land and $63 billion for rural land.

Section III provides a summary and agenda for research, and the Appendix provides details of Milgram's methodology for estimating government land value and our extension of her estimates.

I. The Value of Federal Mineral Rights

A. *Previous Studies of Resource Accounting*

Although no previous study attempts to value federal mineral rights specifically, a number of recent studies of income accounting for exhaustible resources, such as oil and natural gas,, support the inclusion of estimates of the underground reserves of these resources in measures of national income and wealth.[3] The current accounting practice is to exclude such estimates. The National Income and Product Accounts of the Bureau of Economic Analysis consider only production of mineral resources, ignoring the level of reserves. The studies argue for the inclusion of the net value of *proven* reserves in estimates of national wealth.[4] This value could change through discovery, depletion, and changes in the price of the resource.

The perpetual inventory method provides a means of building on an estimate of the value of proven minerals for a particular year. Determining the annual changes in value is fairly straightforward; the major difficulty arises in determining a base year estimate for the value of proven resources. In an important study, J. Steven Landefeld and James Hines discuss three methods for estimation: the present value method, the land price method, and the net price method.

The present value method requires forecasting prices, operating costs, production and interest rates over the life of the field after its discovery. The present value of the stream of net revenues is determined. John Soladay extends this method by attempting to take into account the upward revisions in estimates of reserves that typically occur after the discovery; the total quantity produced from a field is greater than the initial discovery. Several ways of guessing future trends in net revenues have been used. Soladay extrapolates future net revenues based on the weighted average of net revenues over the period 1948–74 and chooses a particular interest rate. Landefeld and Hines report results for three arbitrary choices of growth rate in net revenue and interest rates. The Securities and Exchange Commission (SEC)[5] proposed that companies be required to assume no growth in net revenue and a 10 percent discount rate.

The net price method assumes that net revenues increase at the rate of interest. According to economic theory, this is necessary for equilibrium if the cost of exploration and extraction is the same for all of the exhaustible resource.[6] The advantage of this method is that it does not require any assumptions regarding the time path of production, since any pattern has the same present value.

[2] Those resources estimated to be recoverable and profitable to extract at current prices and technology.

[3] See the U.S. Securities and Exchange Commission (1979), UN Economic and Social Council (1979; 1980), Financial Accounting Standards Board (1980), John Soladay (1980), and J. Steven Landefeld and James R. Hines (1982).

[4] They also favor the incorporation of this value in accounting measures of firm wealth.

[5] Securities and Exchange Commission (p. 503) quoted in Landefeld and Hines, p. 150.

[6] If the resource has an increasing cost of extraction, net price should increase at less than the rate of interest in equilibrium. Landefeld and Hines neglect to note this in their defense of the net price method.

The third method discussed by Landefeld and Hines, the land price method, assumes that the entire value of the proven reserves is paid to the landowner in the form of bonus payments and royalties.[7] They also assume that royalties are a constant fraction of the net value of the resource, so that annual data on bonuses can be used to estimate the net value of the oil and gas prospects leased that year. One problem with this method is that the value of oil and gas prospects leased in a particular year bears no particular relationship, even in expected value terms, to new proven reserves in that year, because of decision and drilling lags. This is therefore fundamentally different from either the present value or net price methods. A second difficulty lies in Landefeld and Hines' estimates, since they use 12.5 percent as the fraction of net price which is paid in the form of royalties. Since royalties are at least 12.5 percent of the *gross* price of oil and gas, this significantly understates the importance of royalties, and their estimates for the value of oil and gas prospects leased are too low. This is confirmed by noting that the estimates using the land price are much smaller than their estimates using other methods. (See Landefeld-Hines, p. 159.)

Each of these methods is inadequate for creating *government* wealth and capital formation accounts. The most important problem is the neglect of the value of economically recoverable undiscovered reserves. This neglect, as argued below, causes an understatement of wealth and capital gains and a misstatement of government investment.

Earlier studies argued against including economically recoverable undiscovered resources in either national or firm accounts on the grounds that estimates were too uncertain. This problem is much less severe for the United States as a whole than for the individual firm, since the sample of prospects is far larger and, therefore, the distribution is tighter (the coefficient of variation is smaller). While the range of estimates of undiscovered resources may be wide, there is no a priori reason for believing an estimate to be biased. By contrast, assuming that undiscovered resources have no value is surely biased and, therefore, estimates of wealth and income will be biased.

[7]Payments to landowners are only relevant to calculations concerning firms, and not to calculations of national wealth.

B. *Methodology for Valuing Mineral Rights*

When the government leases the mineral rights in a particular area—rights essentially to as yet undiscovered resources—it has reduced its mineral wealth by transferring claims to part of it to the private sector. In return, the government receives some payment immediately in the form of a bonus, with the rest of the payments deferred as royalties or rental payments. Bonuses are cash payments that are not conditional on the existence or size of the resource, and are typically the variable subject to bidding. Royalty payments are fractions, usually fixed in advance, of the gross revenue of the produced output, if any. By the time reserves are proven, their only value to the government is the present value of the royalties they represent.

The base-year value to the government of federal mineral rights is the sum of three components: future royalties on proven reserves; future royalties on estimated undiscovered reserves; and future bonuses on unleased land.[8] This may be written (choosing 1981 as the base year) as follows:

$$(1) \qquad V_{1981} = PVR_p + PVR_u + PVB,$$

where PVR_p = present value of future royalties on proven reserves, both onshore and offshore; PVR_u = present value of future

[8]This is obviously not the total value of the minerals on federal land, nor is it even necessarily the remaining scarcity rent on the minerals (since bonuses and royalties may not capture the full rent). We ignore rental payments, that are quite small compared to bonuses and royalties, as well as additional taxes that might be generated from the production. The extra taxes should only arise from special taxes on the resource (for example, crude oil windfall profits tax) or the economic surplus captured by the producer rather than the government.

royalties on undiscovered reserves, again both onshore and offshore; and PVB = present value of bonuses on mineral leases.

To obtain the value for any future year, we take the value for the previous year, add capital gains or losses, and subtract bonus and royalty payments received. Capital gains and losses are calculated by assuming that the current price is the base from which future prices grow at the interest rate.[9] Since all three components of the base-year value are proportional to the current price, the capital gain is just the change in price times the previous year's value. Using this method, the base-year value can be projected backwards as well.

Ignoring undiscovered reserves can cause several problems in the wealth and income accounts of the government. For example, the sale of leases would be treated as an increase in government receipts and wealth rather than an asset sale, and future royalty rights would not appear in the accounts until drilling was successful. Further, capital gains and losses associated with price changes would only be counted on proven reserves. Government capital formation, defined as the change in government wealth, would be overstated, since the sale of assets in the form of possible reserves would be ignored.[10]

For all of these reasons, we believe accurate resource accounting for the government sector requires estimating a value for the undiscovered reserves on government land. This need only be done for a base year; the perpetual inventory method may then be applied to calculate other years.[11] For the base-year calculation, we use U.S. Department of the Interior estimates for the expected undiscovered reserves for onshore and offshore federal land.[12] To value the royalties on these undiscovered reserves, an assumption regarding future prices needs to be made. We choose the strong and convenient assumption that future prices are expected to increase at the rate of interest.[13] This assumption means that the time path of production is irrelevant; all production patterns yield the same present value of royalties. Such time independence is especially useful for undiscovered reserves, since there is a substantial and uncertain time until the resource will be extracted. The assumption can be justified by noting that the Long-Term Pricing Committee of the Organization of Petroleum Exporting Countries (OPEC) has recommended a 3 percent real annual increase in oil prices that, given its low cost of production, would be close to that suggested by economic theory. The average annual rise in real oil prices received by U.S. producers was 3.5 percent over the period 1950–82.[14]

This assumption implies that the value of future royalties on both undiscovered and proven reserves on federal land is the royalty rate times the quantity of reserves times the current price for the relevant resource. Thus,

$$(2)\quad PVR_p = \sum_k P_k \times \left(r^f \times R_p^{kf} + r^o \times R_p^{ko} \right),$$

where k indexes the mineral, f indexes offshore reserves, o indexes onshore reserves, R is the quantity of reserves, and r is the relevant royalty rate.[15]

[9] Capital gains are in current dollars; they occur even when the prices increase as predicted. We consider alternative price increase assumptions below.

[10] All of these distortions occur in the accounts of any landowner if only proven reserves are taken into consideration. The earlier studies, discussed in the previous section, were concerned with valuing the assets and depletion of a producer; they were not concerned as much with the landowner from whom the lease was obtained. In this paper, of course, the government is the focus; however, in the United States, the government generally is not a producer of minerals.

[11] This does not take into account changes in the estimated recoverable undiscovered reserves. These would be paper gains and losses. We examine alternative estimates of undiscovered resources below.

[12] The estimates of offshore undiscovered reserves were obtained from the *Federal Offshore Statistics* (1983). The corresponding onshore estimates were obtained by personal correspondence with D. Zimmerman of the Department of Interior. We discuss the methods used by the department below.

[13] We consider alternative assumptions later.

[14] Calculated using price data from the American Petroleum Institute (1984).

[15] The royalty rate is assumed to be 12.5 percent for onshore federal land and 16.67 percent for offshore reserves in the case of oil and natural gas. It is calculated using the ratio of minerals produced to royalty payment received from U.S. Department of the Interior, *Mineral Revenues* (1983). This source also permits the

Similarly,

$$(3)\quad PVR_u = \sum_k P_k \times \left(r^f \times R_u^{kf} + r^o \times R_u^{ko}\right).$$

The present value of future bonus payments on unleased land also needs to be included to obtain the base-year estimate for the value of federal mineral rights. To do this, we first find the present value of bonuses paid to the federal government over the period 1954–79.[16] We divide this by the present value of royalties paid over the period 1956–81. The difference in the periods covered is designed to account for discovery and production lags. We assume that the present value of future bonuses on undiscovered resources will be the same fraction of estimated future royalties on these undiscovered resources as occurred in this period.[17]

Thus, we assume,

$$(4)\quad \frac{PVB^{1981}_{1954-79}}{PVR_p + PVR^{1981}_{1956-81}} = \frac{PVB}{PVR_u},$$

where $PVB^{1981}_{1954-79}$ = 1981 present value of bonuses paid to the government on leased land from 1954 to 1979, in 1981 prices, and $PVR^{1981}_{1956-81}$ = 1981 present value of royalties paid to the government from 1956 to 1981, in 1981 prices.

Since PVR_p and PVR_u are calculated as in (2) and (3) above, we only need to convert bonuses and royalties actually paid in the period to present value dollars. To do this, we assume an annual real rate of discount of 2 percent and compute

$$(5)\quad PVB^{1981}_{1954-79} = \sum_{\tau=1954}^{1979} B_\tau (1.02)^{(1981-\tau)} \cdot \frac{Q_{1981}}{Q_\tau},$$

where B_τ = bonuses paid to the government for year τ, Q_{1981} = *GNP* deflator for 1981, and Q_τ = *GNP* deflator for year τ.

Similarly,

$$(6)\quad PVR^{1981}_{1956-81} = \sum_{\tau=1956}^{1981} R_\tau (1+0.2)^{(1981-\tau)} \cdot \frac{Q_{1981}}{Q_\tau},$$

where R_τ = royalties received by the government in year τ.

C. *Estimates of the Value of Federal Oil and Gas Mineral Rights*

Our estimates for the value of federal oil and gas mineral rights in 1981 are presented in Table 1. Two striking facts are apparent. First, the present value of bonuses from offshore mineral leases far exceeds the corresponding figure for onshore leases. The reason for this is that offshore bonuses were much greater than onshore bonuses in the period 1954 to 1979. For example, since 1971, offshore bonuses have annually exceeded $1 billion whereas onshore bonuses did not reach $20 million (see *Mineral Revenues*). This difference is reflected in our estimate of the present value of bonuses through equation (4).

Second, the present value of future royal-

TABLE 1—CALCULATION OF THE 1981 VALUE OF FEDERAL MINERAL RIGHTS FOR OIL AND NATURAL GAS (V_{1981})
(Billions of 1981 Dollars)

Component	Total	Onshore	Offshore
PVB	221.1	0.9[a]	220.1
PVR_p	88.4	34.5	53.9
PVR_u	509.8	111.0[b]	398.8
total: V_{1981}[c]	819.3	146.4	672.8

[a] This figure is calculated assuming that the future ratio of onshore and offshore bonuses will remain the same as in the historical period.

[b] This figure is derived assuming that the ratio of offshore undiscovered gas reserves in Alaska is the same as in the 48 states.

[c] The present value of bonuses for the period 1954–79 for offshore and onshore were $50.9 and $0.2 billion, respectively. The corresponding figures for the value of royalties for the period 1956–81 were $20.81 and $8.70 billion, respectively.

calculation of royalty rates for other minerals. If the federal government is forced to share royalties with the states, the value of the mineral rights developed later would be divided with them.

[16] See *Mineral Revenues* (Tables 10 and 13).

[17] Changes in development lags would not substantially alter the results. The assumption that the ratio of bonuses to royalties remained constant seems reasonable given that real prices are expected to increase; it is not founded in any particular model.

TABLE 2—VALUE OF FEDERAL OIL AND NATURAL GAS RIGHTS AND CHANGES IN VALUE, 1954–82
(Billions of Current Dollars)

Year	Value			Change in Value
	Total[a]	Oil	Gas	
1954	80.6	62.3	18.3	–
1955	80.8	62.0	18.8	0.2
1956	81.9	62.4	19.5	1.1
1957	89.4	69.0	20.4	7.5
1958	88.7	67.2	21.5	−1.7
1959	87.8	64.6	23.2	−0.9
1960	90.0	63.9	25.1	2.2
1961	91.1	64.0	27.1	1.1
1962	91.3	63.7	27.6	0.2
1963	91.5	63.4	28.1	0.2
1964	90.4	63.0	27.4	−1.1
1965	90.1	62.4	27.7	−0.3
1966	90.2	62.5	27.7	0.1
1967	90.9	62.8	28.1	0.7
1968	90.4	62.1	28.3	−0.5
1969	93.6	64.9	28.7	3.2
1970	94.9	65.9	28.7	3.2
1971	100.6	69.8	30.8	5.7
1972	101.5	67.9	30.6	0.9
1973	109.9	75.4	34.5	8.4
1974	176.0	129.2	46.8	66.1
1975	210.8	142.9	67.9	34.8
1976	238.0	150.5	87.5	27.2
1977	273.9	155.8	118.1	35.9
1978	295.7	161.7	134.0	21.8
1979	389.5	222.8	166.7	93.8
1980	598.3	376.4	221.9	208.8
1981	819.3	547.1	272.2	221.0
1982	817.2	486.8	330.4	−2.1

[a]We have assumed that the present values of gas and oil bonuses are proportional to the present values of gas and oil royalties on undiscovered reserves; i.e, $PVB^{gas}/PVB^{oil} = PVR_u^{gas}/PVR_u^{oil}$.

ties from economically recoverable undiscovered reserves similarly dominates the corresponding figure for proven reserves. The explanation for this is straightforward: estimates of undiscovered resources are much larger than currently proven reserves.

The detailed time-series of the total value of federal oil and gas mineral rights from 1954 to 1982, presented in Table 2, are extremely interesting. The aggregate series began a very rapid growth in 1974, and jumped again in 1979–80. The current value of over $800 billion is the single largest asset in the complete balance sheet of the federal government. It is substantially larger than the value of federal land. In fact, it is approximately the combined value of *all* federal tangible assets or *all* federal financial assets (see Eisner and Pieper). Prior to 1974, the total series was quite stable in nominal dollars, and therefore it exhibited a slight downward decline in real terms. While the dollar value has increased sharply recently, even prior to the increases in energy prices the value for oil and gas were substantial. For example, in 1971 the value was $100 billion (in 1971 dollars) which was much more than the value of federal land. It also was twice as large as the value of federal government gold holdings.

The relative value of oil and gas in the total has changed somewhat over the period. While oil is still the largest component, the share of oil has fallen from over three-fourths in the late 1950's, to two-thirds or less in the last few years. While oil typically receives more attention than natural gas, these figures reveal the importance of natural gas.

TABLE 3—COMPONENTS OF THE CHANGE IN VALUE OF FEDERAL OIL AND GAS RIGHTS, 1954–82
(Billions of Current Dollars)

Year	Change in Value	Components		
		Revaluations	Bonuses	Royalties
1954	–	–	0.1	0.0
1955	0.2	0.3	0.1	0.1
1956	1.1	1.2	0.0	0.1
1957	7.5	7.6	0.0	0.1
1958	−1.7	−1.6	0.0	0.1
1959	−0.9	−0.7	0.1	0.1
1960	2.2	2.6	0.3	0.1
1961	1.1	1.2	0.0	0.1
1962	0.2	0.8	0.5	0.1
1963	0.2	0.4	0.0	0.2
1964	−1.1	−0.8	0.1	0.2
1965	−0.3	−0.1	0.0	0.2
1966	0.1	0.5	0.2	0.2
1967	0.7	1.4	0.5	0.2
1968	−0.5	1.1	1.3	0.3
1969	3.2	3.6	0.1	0.3
1970	1.3	2.6	0.9	0.4
1971	5.7	6.2	0.1	0.4
1972	0.9	3.7	2.3	0.5
1973	8.4	12.0	3.1	0.5
1974	66.1	71.8	5.0	0.7
1975	34.8	36.7	1.1	0.8
1976	27.2	30.3	2.2	0.9
1977	35.9	38.7	1.6	1.2
1978	21.8	25.0	1.8	1.4
1979	93.8	100.8	5.1	1.9
1980	208.8	215.8	4.2	2.8
1981	221.0	231.9	6.7	4.2
1982	−2.1	6.8	4.1	4.8

Also included in Table 2 is the change in value from year to year. These changes tended to be small until the total value became large subsequent to the substantial increases in energy prices in 1973–74. The change in the value of these mineral rights in many years in the 1970's and early 1980's exceeded the nominal federal government budget deficit (see Boskin, 1982).

Table 3 breaks the change in the value of federal oil and natural gas mineral rights through time into three components: revaluation; bonuses; and royalties. While bonuses and royalties became large in the early 1970's, they are still relatively minor compared with the enormous revaluations of this period. The bulk of the change in the value in most years is the revaluation of the rights. The revaluations largely reflect the energy price shocks, but once the total value of oil and gas becomes large, even small price changes can lead to large revaluations. It should be stressed that revaluations would occur even if the price followed the assumed pattern of growing at the interest rate. In recent years, these revaluations are substantial relative to the capital gains on assets held by the household sector of the United States (see Eisner, 1980).

The figures in Tables 2 and 3 reveal how important the value of federal government mineral rights can be to measures of national wealth, to measures of changes in that wealth, to mineral leasing policy, and to sensible government budget reporting and policy. The total value of these mineral rights is enormous ($819 billion). To place this in perspective, in 1981, this value exceeded the value of the privately held national debt ($794 billion). Obviously, the value of other minerals

TABLE 4—PROVEN AND UNPROVEN OIL AND GAS RESERVES (1981)
(Oil in Billion Barrels/Gas in Trillion Cubic Feet)

	95% Confidence Level[a]		Mean		5% Confidence Level[a]	
	Oil	Gas	Oil	Gas	Oil	Gas
Offshore[b]						
Proven	3.8	41.6	3.8	41.6	3.8	41.6
Undiscovered, Economically recoverable	15.5	82.9	25.5	140.2	39.9	216.25
Onshore[c]						
Proven	4.6	24.9	4.6	24.9	4.6	24.9
Undiscovered, Economically recoverable	24.3	61.3	41.61	112.1	66.6	170.1

[a] Ratios to mean values for onshore reserves are assumed to be the same on federal land as total land. Also, it was assumed that the ratio of unproven offshore and onshore reserves in Alaska is the same as in the 48 states.

[b] Offshore figures are from Tables 53 and 54 of *Federal Offshore Statistics*, December 1983.

[c] Onshore figures were published only through 1980. The updated *USGS* mean figures for 1981, which are somewhat *lower* than the published 1980 figures, were kindly provided by Dale Zimmerman, U.S. Department of the Interior.

would add to this total. Clearly, ignoring the value of resources in government budgets and in national income and wealth accounts can be quite misleading.

The critical estimates of undiscovered economically recoverable resources of conventional oil and gas on federal land in 1981 were made by the U.S. Department of the Interior.[18] These are presented in Table 4. Estimating proven reserves in a field where hydrocarbons have been discovered is difficult and results in frequent revisions; the task of estimating undiscovered recoverable resources is much more complex, as the number of dry holes attests. Using a point estimate, however well-founded in expert geological opinion, perhaps suggests more certainty than actually exists. We have therefore calculated the value of federal oil and gas mineral rights for 1981 using the high (5 percent) and low (95 percent) bounds calculated by the U.S. Geological Survey (*USGS*).[19] The high estimate is $1134.9 billion, while the low estimate is $582.1 billion. While the range of these estimates is clearly large, even the low estimate shows that federal oil and gas mineral rights have considerable value. Independent studies by other groups have come up with different ranges for the quantities of undiscovered re-

[18] The U.S. Geological Survey (*USGS*) divided the U.S. onshore and offshore areas into 137 provinces. Individual appraisals were made for each of the provinces using geological data and exploration histories as the basis for separate subjective assessments by six geologists. The subjective assessments of high, modal, and low probabilities for undiscovered recoverable resources of oil and gas are averaged, then aggregated probabilistically across provinces to obtain estimates for the entire United States. A more complete description of the methodology used by the *USGS* is given in their Circular 860 (1981).

[19] The procedure for deriving the high and the low figures is as follows. The mean PVR_u figures for gas and oil are multiplied by the ratio of the corresponding 5th and 95th fractile figures (separating out the offshore and onshore components) from *USGS* and the PVR_u^{low} and PVR_u^{high} are obtained. Following the methodology for calculation of PVB, PVB^{low}, and PVB^{high} are obtained and the appropriate total values are derived according to equation (1).

coverable oil and gas in the United States, but, at least since 1975, there has been a growing consensus, with overlapping ranges and point estimates for both oil and gas approximately within the range of the *USGS* estimates.[20]

Two additional points should be made about undiscovered resources. First, they do not stay undiscovered forever. Annual additions to proven offshore reserves were about 14 percent of the total stock of proven reserves over the period 1977–81 for both oil and gas (see *Federal Offshore Statistics*). Second, estimates of recoverable undiscovered resources must properly depend upon prices and technology. Technological advances or real price increases should lead to upward revisions in the estimates of undiscovered recoverable resources.

We also tested the sensitivity of our results to alternative assumptions about the rate of price increases. Two considerations suggest that price may not grow at the rate of interest. If costs are nontrivial (as on the outer continental shelf), the scarcity rent, rather than price, should grow at the rate of interest. If the relevant costs at the margin are those of major OPEC producers, say Saudi Arabia, costs are indeed trivial, but if monopoly power is continuously exercised, marginal revenue, not price, will grow at the rate of interest. While we believe that for long-run considerations, the competitive, trivial costs result may be most appropriate, we present below estimates of the relative value of mineral rights if price grows less rapidly than the interest rate.

The net present value of proven (R_t) and undiscovered (U_t) reserves at t are given by

$$(7)\quad NPVR_t = R_t P_t \sum_{i=0}^{\infty} (1-y)(ydq)^i = R_t P_t \frac{(1-y)}{1-ydq},$$

$$(8)\quad NPVU_t = U_t P_t \sum_{j=0}^{\infty} (1-c)(cdq)^j \cdot \sum_{i=0}^{\infty} (1-y)(ydq)^i = \frac{U_t P_t (1-y)(1-c)}{(1-cdq)(1-ydq)},$$

where R_t = proved reserves at t; U_t = undiscovered (economically recoverable at current cost) reserves at t; $(1-y)$ = fraction of R_t produced during t (assumed constant); $(1-c)$ = fraction of U_t converted to R_t during t (assumed constant); P_t = real price per unit at date t; t = valuation date; d = discount factor $= 1/1+r$, where r is real interest rate; and q = price growth factor.

Some sample calculations indicate the potential difference under alternative price path assumptions when price grows at less than the interest rate. Calculations assume $r = 0.03$; $y = 0.10$; $c = 0.03$. For example, the present value of royalties with a price increase two-thirds of the assumed real interest rate is \$470 billion in 1981 as opposed to our estimate of \$598 billion. The present value of bonuses likewise would be somewhat smaller. Our point, however, that the value of federal mineral rights is large relative to other federal assets and liabilities remains unaltered. Further, virtually all of our other assumptions tend to bias the estimated value downward. (See Table 5.)

II. The Value of Federal Land

A. *Previous Studies of the Value of Federal Land*

A time-series for the value of federal land in the postwar period (1945–81) is provided by the estimates of Goldsmith (1962), and the follow-up studies by Milgram and by Eisner and Pieper. These studies, as well as the current one, demonstrate how successive refinements of basic data often hang from a very slender thread.

Goldsmith bases his postwar time-series on an estimate of the value of government land on December 31, 1946 in the study by

[20] See *USGS* for a survey of other studies.

TABLE 5—RATIO OF VALUE FOR $Q < R$

Assumed Rate of Real Price Increase[a]	*NPVR*	*NPVU*
1.0	0.851	0.552
1.5	0.884	0.680
2.0	0.920	0.761
2.5	0.958	0.864
3.0	1.000	1.000

[a] Percent per annum.

J. E. Reeve et al. (1950). The land value estimate of the Reeve et al. study has two main components: military and nonmilitary government land. These estimates are as follows: land, nonmilitary: $4.93 billion; and land, military: (a) market value, $1.07 billion; (b) replacement value, $2.13 billion.

The estimate for nonmilitary land is based upon its original acquisition costs, with (casually justified) adjustments to reflect 1946 market values. Separate adjustments were made for each of five categories of land. For most categories, Reeve et al. do not cite any source as the basis for the adjustment factors employed.

For military land, Goldsmith chooses Reeve et. al.'s replacement value figure, which is an estimate of the cost to the military to replace its holdings with comparable land. For nonmilitary government land, Goldsmith's extension (1962) of the Reeve et al. estimates from 1946 through 1958 is based upon two price indices: forest land: Reeve et al.'s value for forest land in 1946 multiplied by "index of stumpage prices in national forests" (p. 380), and other civilian land: value for 1946 (Reeve et al.'s total minus forest land) multiplied by "index of grazing land prices in western states" (p. 380). Goldsmith describes his extension for military land as a "rough estimate" (p. 380).

Milgram estimates the value of government land over the period 1952 to 1968. Her series is based upon Goldsmith's estimate for 1956. Values for 1952–55 and 1957–68 are extrapolated using the following methodology. Increments to the stock of government land are derived from the change in the General Services Administration's (GSA's) annual estimates of the value of government land, from the change in acreage of government urban land and rural land, and from price series developed by Milgram for rural, nonmetropolitan, and urban land.

Milgram derives an independent estimate of the value of rural government land in 1956, using rural government acreage and a price for rural public land. The price is based primarily upon an estimate of the market value of the public domain managed by the Bureau of Land Management (BLM). The value of urban government land in 1956 is determined as the difference of Goldsmith's 1956 estimate for total federal land, and her rural land value estimate.

Increments to the rural land stock are determined by the value of the change in government owned rural acreage, using the rural public land series. Increments to the urban land stock are estimated by subtracting the incremental rural estimates from the change in the annual GSA estimate of the value of total government land. The yearly stock estimates are computed by adding these increments to the previous year's stock, after the rural component for the prior year has been adjusted by a price index for nonmetropolitan land, and the urban component for the prior year has been adjusted by an urban price index.

Eisner and Pieper estimate the value of federal land in 1980 as $119.5 billion. They use Milgram's 1968 figure as a base and assume that annual net investment in land is zero. They infer the change in the market

TABLE 6—VALUE OF FEDERAL LAND IN BILLIONS OF (CURRENT) DOLLARS

Year	Value	Source[a]
1946	7.0	G
1951	13.4	G
1956	13.4	G, M
1961	20.6	M
1966	29.5	M
1971	37.6	E-P
1976	73.3	E-P
1980	119.5	E-P

[a] G = Goldsmith; M = Milgram; and E-P = Eisner and Pieper.

TABLE 7—VALUE OF FEDERAL LAND IN BILLIONS OF (CURRENT) DOLLARS

	New Extended Estimates			Eisner-Pieper Estimates
	Total	Urban	Rural	
1969	37.3	21.9	15.5	34.9
1970	44.8	29.0	15.8	36.4
1971	53.8	36.2	17.6	37.6
1972	63.4	44.3	19.1	42.6
1973	72.8	53.1	19.7	50.4
1974	76.5	49.9	26.6	57.3
1975	80.4	52.9	27.5	63.6
1976	90.5	57.9	32.6	73.3
1977	105.5	67.6	37.9	82.2
1978	120.3	74.7	45.5	96.9
1979	137.5	86.5	51.0	110.4
1980	174.4	118.3	56.1	119.5
1981	175.1	112.4	62.7	128.0[a]

[a]Updated using Eisner and Pieper's methodology.

value of government land from the Federal Reserve Board's estimate of the market value of private land, and from the ratio of Milgram's 1968 estimate to the 1968 Federal Reserve Board's estimate for private land. Thus,

$$GL_t = PL, F_t \cdot (GL, M_{68}/PL, F_{68}),$$

where GL_t is the market value of government land at t, PL, F_t is the Federal Reserve Board's estimate of the market value of private land in year t, and GL, M_{68} is Milgram's estimate of the market value of federal land in 1968. Table 6 reproduces the estimates of these authors for selected years.

Eisner and Pieper's estimates for the value of federal land are consistent with recent work by Goldsmith (1982) on the national balance sheet. Milgram's study provides estimates of the value of land over all sectors, 1952–68. Goldsmith extrapolates these estimates to 1975, arriving at a figure for the aggregate value of land of $1551 billion. He estimates the share of federal land at 4 percent, which would give an estimate of $62 billion for the value of federal land in 1975, compared with Eisner and Pieper's $63.6 billion.[21]

[21]Based on Goldsmith's estimates of total national assets in 1980 of $21,645 billion (1982, Table 89, p. 200), we can derive his estimate of the value of federal government land in that year. According to Goldsmith, land values constituted 13.7 percent of total national assets. Assuming that the federal government still holds 4 percent of total land values, the value of federal government land in 1980 would be $118.6 billion. This is again roughly the same magnitude as Eisner and Pieper's corresponding estimate of $124.9 billion and far smaller than our estimate of $174.4 billion. Goldsmith's estimates suggest that he, like Eisner and Pieper, does not take into account the substantial change in composition of federal government land.

B. *New Estimates of the Value of Federal Land*

We have extended Milgram's estimates of the value of federal land to the period 1969–81, using a variant of her methodology as described in the Appendix. In Table 7, these estimates can be compared with Eisner's extension of the Goldsmith/Milgram estimates.

We estimate the value of federal land to be $175 billion in 1981, composed of $112 billion urban land and $63 billion rural land. Our new estimates substantially exceed those of Eisner and Pieper. The total is larger in every year, and the rate of growth is significantly higher.

Our estimates are higher because we take into account the change in the composition of federal land holdings. Eisner and Pieper

TABLE 8—COMPOSITION OF FEDERAL LAND HOLDINGS SELECTED YEARS
(Millions of Acres)

Year	Urban	Rural	Total
1968	1406.3	753938.5	755344.8
1972	2326.8	758349.6	760676.4
1976	2936.2	759256.2	762192.4
1980	4768.4	714753.4	719521.6

do not consider the composition; their extension simply indexes the value of government land by the change in value of private land in the aggregate. While the total acreage held by the federal government declined by almost 5 percent between 1968 and 1981, its holdings of more valuable urban acreage more than tripled. This is shown in Table 8.

This total value estimate of $175 billion is approximately the value of all of the equipment (such as machines, trucks, typewriters, computers, etc.) owned by the federal government (as estimated by Eisner and Pieper). It is far less than the value of federal mineral rights as estimated in Section I, Part C.

It may be tempting simply to add the value of federal land to mineral rights. However, there are theoretical reasons to suspect that at least some of the value of federal mineral rights is capitalized into the value of the federal land bearing the minerals. In that case, it would be necessary to discount the value of the land before aggregating the land and the mineral rights. Since we are uncertain of the extent of capitalization, we have focused on the disaggregated components rather than their sum.

We have clearly not captured the full value of federal onshore mineral rights in our land value figures. Our estimate of the value of onshore mineral rights in 1981 ($146 billion) greatly exceeds the value of federal rural land ($63 billion). Furthermore, the method of derivation for estimates of federal rural land values makes it unlikely that they will reflect the underlying mineral values.[22] Clearly, to obtain the total value of land and mineral rights, we would have to add some, though not all, of the value of federal land to our estimate of the value of federal mineral rights.

III. Summary and Conclusion

We have presented new and updated estimates of the value of federal land and oil and gas mineral rights. These estimates are $175 billion and $819 billion, respectively, by 1981.[23]

Our results reveal the increasing importance of the value of the federal government's holdings of urban land in the total value of federal land over the period from 1968 to 1981. Over this interval the federal government's holdings of urban land tripled in acreage.

We estimate the value of federal oil and gas mineral rights to be very substantial, particularly following the sharp rise in energy prices in 1974 and 1979. In 1981, for example, the magnitude exceeds the privately held national debt.

This study is unique, as far as we know, in its effort to determine the value of the federal

[22] The magnitude of the rural land value estimates is largely determined by the average estimated price of the public domain managed by the BLM. (See the Appendix.) The BLM price estimates do not appear to take mineral rights into account.

[23] Recently, the Minerals Management Service (MMS) (1985) estimated the value of undiscovered offshore oil and gas to be $95 billion, one-sixth our estimate. The difference is primarily attributable to two sources: 1) lower estimates of quantities due to revision of estimates, leasing, and discoveries between 1981 and 1986; and 2) differences in value per barrel due partly to the recent fall in oil prices and partly to MMS assuming price growth of 1 percent per year, but real interest rates of 8 percent.

government's mineral rights and in the methodology used. We exploit information about undiscovered reserves and royalty and bonus payments to the government. Our methodology can be extended both to other minerals and to the private sector.

There remains room for considerable research on both the value of government land and its mineral rights. A new benchmark estimate for the value of federal land in a particular year is especially important. A more detailed disaggregation of the types of federal land holdings and improved and updated corresponding price information would also be helpful.

Improved estimates of the size of other mineral resources on federal land and estimates of the relationship between the quantity of economically recoverable unproven reserves of oil and gas and their prices would enable us to produce more comprehensive measures of wealth.

Finally, let us reemphasize the potential importance of estimates such as ours to sensible government budgetary decisions. These include land management policy, general cost-benefit analysis incorporating proper measures of the opportunity cost of resources, and perhaps even, in some contexts, fiscal policy.

APPENDIX

Milgram's time-series estimates, z_{56}, for the period 1952–68 rely on Goldsmith's estimate of the value of federal land (1962, p. 188). She uses the following price indexes:

A nonmetropolitan price index, IR_i, based upon the value of farmland per acre, as estimated by the U.S. Department of Agriculture.

An urban price index, IU_i, based upon three component indexes: FHA site prices, of residential land values in Los Angeles and Philadelphia.

Average price per acre of rural land held by the federal government, PR_i. This is a weighted average of two indexes: the value of the public domain in the jurisdiction of the Bureau of Land Management (BLM) (90 percent), and the value of farmland per acre (10 percent).

She uses three additional statistics from the BLM:

An estimate of the value of government land, LC_i.

Acreage held by the federal government, broken down as rural = AR_i, and urban AU_i.

The statistics of the BLM appear in *Summary Report of Real Property Owned by the United States Throughout the World*, General Services Administration.

Milgram computes three series: value of rural land = MR_i; value of urban land = MU_i; total value of federal government land = MA_i.

An algebraic expression of Milgram's procedure is

$$MA_t \equiv MR_t + MU_t$$

$$MR_{52} = (PR_{56} \cdot AR_{56})$$

$$MR_t = MR_{t-1} \cdot \frac{IR_t}{IR_{t-1}} + PR_t \cdot \Delta AR_t$$

$$MU_t = MU_{t-1} \cdot \frac{IU_t}{IU_{t-1}} + \Delta LC_t - PR_t \cdot AR_t,$$

where $\Delta LC_t = LC_t - LC_{t-1}$.

Comments: 1) Milgram's estimates for 1952–55 and 1967–68 are extrapolations of the series determined by the method above. 2) PR_t could not be determined for our extension from Milgram's sources. Our extension from 1969 on uses the published farmland series, but a series on the value of the public domain was not available from the BLM. Therefore, the public domain component of the weighted average is based on an extrapolation of the value of the public domain in 1968. The growth rate for each subsequent year was assumed to equal the average annual growth rate of farmland over the period 1969–81.

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