NATIONAL ACCOUNTING FOR NON-RENEWABLE NATURAL RESOURCES IN THE MINING INDUSTRIES*

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This paper discusses alternatives to current national accounting procedures for non-renewable natural resources in the mining industries. Three alternative approaches to valuing the discovery and use of these resources are compared and alternative estimates for U.S. oil and gas for the period 1948–79 are presented. The focus is on the conceptual and empirical difficulties associated with valuing non-renewable natural resources.

INTRODUCTION

Natural resources are treated in the national income and product accounts quite differently from physical capital. For example, in the U.S. national income and product accounts (NIPA's), no entries for the discovery and use of natural resources are included similar to those for investment and depreciation of physical capital. This difference in treatment of natural resources has two important implications. First, since the value of discoveries is excluded, no accounting parallel to investment is made for the addition to the nation's stock of natural resources. Second, since the value of what is used up is excluded, no accounting parallel to depreciation is made for the reduction in the nation's stock of natural resources.

This paper examines the issues associated with valuing the discovery and use or depletion of natural resources in the mining industries. Section I presents definitions and classifications of physical quantities of natural resources as well as related economic measures. Section II describes various aspects of the accounting treatment of natural resources: the current treatment of the NIPA's is discussed, difficulties with that treatment are examined, and an alternative treatment is proposed. Section III then details three valuation methods for implementing the accounting treatment proposed in Section II. The first method is based on calculations of the present value of the natural resource, the second uses data on resource land prices to value the natural resource, and the third values the resource by multiplying the net price per unit of the resource (defined below) times proved reserves of the resource (also defined below). Section IV then compares the three methods in terms of illustrative estimates for U.S. domestic oil and gas, 1948–79. The main conclusions and recommendations of the paper

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are:

- Because of uncertainties in natural resource markets for minerals, preliminary estimates should be restricted to the value of proved reserves and changes in proved reserves, including the value of new discoveries, the value of depletion, and the effects of price changes. Proved reserves are the quantities of a resource that with reasonable certainty are known to be recoverable under existing economic and operating conditions.
- Although conceptually appealing, the uncertainty inherent in the present value method hinders its use in generating consistent estimates of the value of natural resources.
- The land price method, while attractive in terms of simplicity, consistency, and objectivity, results in current-dollar estimates that are unrealistically low in earlier periods and in constant-dollar estimates that are not proportional to changes in physical reserves.
- The net price method, which shares many of the advantages of the land price method, has an added advantage in that constant-dollar estimates of discovery value and depletion are always proportional to changes in physical reserves. However, the assumption of long-run equilibrium in natural resources markets that underlies this method is unfounded, particularly in the 1950's and 1960's; hence, the estimates during these periods are unrealistically high.
- Given the problems and uncertainties of all three methods, although alternative estimates of the depletion, discovery value, and value of natural resources may be a useful supplement to information included in the NIPA's, one would not want to include such volatile estimates in the NIPA's.

I. Definitions and Economic Measures of Natural Resources

The scope of this inquiry is limited to the valuation of non-renewable natural resources in the mining industries. Within those categories, natural resource stocks are further limited to proved and probable reserves (see below). This section defines the classifications and physical quantities of the basic natural resource categories to be examined, and the corresponding economic values for these natural resource categories.

A. *Definitions and Classifications of Physical Quantities of Natural Resources*

Natural resources. The focus here is on natural resources regularly bought and sold as commodities, either as final products or as intermediate goods. Within the general category of such commodity resources, the study is further restricted to non-renewable natural resources in the mining industries because of the economic importance of this group, especially oil and gas resources. Although in some sense all resources can be replaced by natural processes, for practical purposes non-renewable resources, such as coal, are exhaustible, one-time gifts of nature. Unlike renewable resources, which through conservation and replanting provide an inexhaustible continuing source of consumption, non-renewable resources once consumed are gone forever. Conservation and sound management practices only extend, rather than perpetuate, consumption of these materials.

Stocks of natural resources. The focus in this paper is on proved and probable reserves, rather than on the more inclusive category "resource base." Resource base estimates include not only reserves capable of being extracted under today's economic conditions and technology, but also reserves capable of being extracted under future conditions. Because of rising prices and improved technology over time, the resource base is usually much larger than the stock of proved reserves. However, estimates of the resource base are very uncertain.[1] They rely on forecasts of prices, demand, and technology 50 to 75 years into the future. In addition, they are subject to geological uncertainty since they include undiscovered reserves inferred from geological information.

Changes in stocks of natural resources. Since natural resource stocks have been restricted to proved and probable reserves, changes in stocks are limited to additions to and reductions in such reserves. In mining industries other than oil and gas, additions are generally equal to new discoveries, and reductions are usually equal to extractions. In the oil and gas industries, however, the picture is more complicated. Additions to oil and gas reserves include extensions of, and revisions to, estimates of proved reserves in old fields and reservoirs as well as new discoveries. These extentions and revisions are usually significantly larger than new discoveries.

Since exploration and development are costly, firms "prove" only enough reserves to meet short- and intermediate-run demand. As with physical capital, there is no point in carrying a large inventory of unused excess capacity. Thus, estimates of proved reserves in new fields (and reservoirs within such fields) are usually only a small part of the total extractions from those fields (and reservoirs). The ultimate size of new fields and new reservoirs is usually determined by wells drilled in years subsequent to the original discovery (extentions). The size of a new field is also revised as oil and gas are extracted since geological and engineering information are obtained, thereby providing the basis for more accurate revisions of reserves. Finally, price increases and improved technology also affect estimates of what can be economically extracted from both old and new fields. The result of all these factors is that reserve statistics produce very conservative estimates of the total resource stocks that will ultimately enter the economic system.[2]

B. *Economic Measures of Natural Resources*

Like capital, mineral reserves are in some sense produced by the economic system as inputs to current and future production. Although they are provided

[1]For a discussion of the reliability of reserve statistics, see Landefeld and Hines (1982), pp. 166–168.

[2]Over the period 1946 to 1974, Soloday (1980) estimated that actual production from new fields and reservoirs in the U.S. was over seven times the amount initially reported as discovered in new fields. In 1979, new discoveries of oil and gas accounted for only 1.2 billion barrels or 23 percent of the 5.2 billion barrels added to proved reserves. If actual production were seven times the amount of oil initially reported, then ultimately it would be 8.3 billion barrels rather than the 1.2 billion barrels, and total additions to proved reserves would total 12.3 billion barrels rather than 5.2 billion barrels.

by nature in their raw undiscovered state, investments in exploration and development are necessary before these resources enter the economic system. Exploration and development expenditures in the extractive industries are investments that "produce" a large and significant net addition to the stock of future productive worth. Mineral reserves are also similar to physical capital in terms of response to economic changes. For example, an increase in the cost of physical capital may result in modifications to existing capital to make it more efficient, use of existing capital beyond its normal economic service life, and increased use of rebuilt capital. Analogously, increased oil prices have led to improved recovery techniques, pumping from wells beyond the point at which they would normally be capped, and reopening of old fields.

Although natural resource stocks are in many ways similar to physical capital stocks, in one important respect they are dissimilar—they are not *fully* produced by the economic system. While it is true that significant expenditures on exploration, development, and necessary capital may be required to deliver a usable product such as natural gas, the value added from a gas well includes a return to the gas field as well as a return to the associated physical capital. Since the gas pool itself is a free gift of nature and is not produced by the economic system, the return to the gas field is "captured" by the fortunate owner of the property or the developer of the field (if different).

In accounting for non-renewable resources in the mining industries it is important to identify the net value added from the resource itself. In the economic literature, the return to this type of fixed factor of production is usually called a rent. To distinguish the value added associated with the resource from that associated with related physical capital, the former will be termed the net revenue from the resource, where this is equal to total revenue from the resource less all factor payments, including a normal return to physical capital. The corresponding value of the net stock of a natural resource is the discounted present value of the net revenue. Annual changes in the value of the net stock are attributable to the current year's additions to the stock, less depletion—the decrease in the value of the net stock attributable to the current year's extractions—plus any increase in the value of the net stock due to price changes of the resource.

II. Accounting Treatment for Natural Resources

At present, the NIPA's include only a partial accounting for the value of natural resources. There are no entries in investment or depreciation for discovery value or depletion. In national income, the value added by the natural resource itself is partially accounted for as rental payments, and the residual is accounted for as profits. This accounting treatment, associated difficulties with it, and a proposed alternative are discussed, in turn, below.

A. *Current Treatment in the NIPA's*

Before discussing the current accounting treatment in the NIPA's for the mining industries, it is useful to describe the nature of land transactions in mining. Although some mining land is sold outright, much, especially oil and gas land, is leased. In such cases, public or private landowners who grant leases receive: (1) bonuses—one-time payments at the beginning of the lease that are not affected by subsequent success or failure in extraction; (2) rents—annual payments independent of extraction; and (3) royalties—annual payments typically equal to one-eighth to one-sixth of the value of annual extraction.

On the product side of the NIPA's, gross private domestic investment (GPDI) in the mining industries consists of fixed investment in both producers' durable equipment and structures.[3] Investment in structures includes not only the types of construction expenditures typical of other industries, but also expenditures on exploration, mine shafts, and wells.[4] The product side also includes in final sales to consumers and governments value added that is attributed to natural resources.

On the income side of the NIPA's, the value added from resource extraction in years subsequent to the year of discovery is included in depreciation, in wages and salaries, in the rental income of persons, and in mining company profits.[5] Rents and royalties associated with leases are included as rental incomes of persons owning the leased land; the residual value added is included as mining company profits.[6]

B. *Difficulties with the Current Treatment*

The U.S. Bureau of Economic Analysis (BEA) recognizes that there are difficulties with the current treatment of natural resources in the NIPA's. First, if there is a positive and depletable value added associated with the resource itself, it is somewhat inconsistent to include annual payments to landowners (rents and royalties) as factor payments but to exclude one-time payments (bonuses) for the initial right to mine a resource. Both types of payments are for resource use, and while bonus payments are not affected by actual extraction, mining firms presumably take the expected potential of the land into account in their bonus offers.[7]

[3]Gross and net stocks of mining equipment and structures are calculated using the perpetual inventory method. Gross stocks are estimated by cumulating past investments and deducting discards. Net stocks are equal to gross stocks less cumulated depreciation. Gross and net stock estimates are made in historical, constant 1972, and current dollars.

[4]All exploration expenditures reported by mining firms (whether capitalized or not) are included in the structures component. For example, wages and geologic testing costs associated with exploration are included. As noted below this capitalization of exploration expenditures in the NIPA's differs from the treatment in the United Nations System of National Accounts.

[5]Depreciation of equipment and structures in the mining industries is measured by the methods used elsewhere in the NIPA's. Specifically, depreciation is measured using straight-line schedules with uniform service lives. Discards are calculated by a distribution of retirements around an average service life of 16 years.

[6]If the land is publicly owned, rents and royalties are classified as indirect business non-taxes. Bonuses are not included in rental incomes of persons where the recipient is a private individual or in indirect business non-taxes where the recipient is the government. Instead, bonuses are treated as the purchase of an asset or an asset transfer (specifically as a sale/purchase of land). As such, they are included in the sector saving and investment accounts.

[7]It is not unreasonable to assume that firms base their bonus payment offers on some measure of the value of an oil or gas field. The Federal Government, in determining whether to accept competitive oil and gas leases in the outer continental shelf, calculates the expected value of the field in determining the adequacy of bonus offers and accepts offers equal to or greater than 83 percent of the value of the field. [Smiley (1979), p. 15.]

Second, the current treatment fails to account for the depletion of nonrenewable natural resources in a manner consistent with depreciation. To rectify this omission and maintain consistency with the rest of the accounts would require not only an entry for depletion, but also an entry for discovery value in order to produce an accurate net investment estimate. However, the uncertain value of mineral resources at the time of their discovery has led BEA to conclude that such an entry would be too tenuous to include. Thus, both depletion and discovery value are ignored.

Third, the value added from natural resources subsequent to the year of discovery are included in the market value of GNP, even though it is assumed that no production has occurred. Although rents and royalties are counted as costs of production in years subsequent to discovery, there are no factor payments for the initial "production" of the natural resource.[8]

Difficulties with the current accounting treatment for natural resources were also recognized by the United Nations Statistical Office in their report, *Future Directions for Work on the System of National Accounts.* No specific methodological solutions are proposed since the intent of the report was "to stress the importance of future work on these topics, and the need to design the accounts in a way that will accommodate them, when (and if) it is considered desirable to do so."[9] Many of the issues raised above are discussed in the report. The report also presents the views of an expert group convened in April of 1980.[10]

The expert group generally agreed that in estimating the value of natural resources: 1) only proved reserves should be considered; 2) calculations should be made of the changes in the value of proved reserves resulting from discoveries, depletion, and the effects of price changes; 3) increases in the value of proved reserves resulting from changes in relative prices are no different from capital gains on other capital assets, and further work should be devoted to incorporating such effects into GNP; 4) the conceptual and empirical problems involved suggest that entries should appear in the System of National Accounts (SNA) balance sheet and reconciliation accounts rather than the current flow accounts; and 5) associated exploration costs are intrinsically no different from other research costs; hence, they should not be capitalized since other research costs are not capitalized.[11]

C. *An Alternative Treatment*

The following T-accounts illustrate a proposed accounting treatment of the discovery value and depletion of natural resources.[12] Specifically, they are based on a simple example of a leased oil well for which a bonus payment of $1,600

[8]Although factor costs are incurred in proving reserves, there are no costs incurred for the production of the resource itself equal to the present value of future net revenues. For a discussion of these issues see Jaszi (1958), p. 94.

[9]United Nations (1979), p. 15.

[10]United Nations (1980).

[11]There was a difference in opinion on this last point among the expert group, but the majority favored retaining the current treatment in the SNA.

[12]It is assumed, for the moment, that the conceptual problems and measurement difficulties noted above have been overcome. These are dealt with below in section IV.

by an oil company to a private landlord captures the full discovery value of the asset, and rent and royalty payments as presently measured in the NIPA's fully account for any residual value added. It is also assumed that the bonus payment is made in the year of discovery (when the reserves were proved) and that the well will be depreciated according to a straight-line schedule (constant depletion/constant extraction) over a 16-year service life.[13]

The T-accounts in the upper half of Table 1 depict the proposed treatment of discovery value in the year hypothetical oil reserves are proved (here assumed to be the year in which the bonus payment is paid). No changes are made in the oil company's production account. In the private landlord's production account the lease of the land causes rental income to rise by $1,600. Nationally, gross private domestic investment will rise by $1,600, rental income of persons will rise by $1,600, and GNP will rise by $1,600.

TABLE 1

PROPOSED T-ACCOUNTS

1. T-Accounts for Discovery Value

Oil Company		Private Landlord		Nation	
	Rental income of persons +1600	Sale (Bonus) +1600	Rental income of persons +1600	Gross private domestic investment +1600	

Note: Bonus treated as investment by oil company in the year bonus is paid.

2. T-Accounts for Depletion

Oil Company		Nation	
Capital consumption allowance (Depletion)	+100	Capital consumption allowance (Depletion)	+100
Profit	−100	Profit	−100
	0		0

Note: Bonus treated as investment by oil company in the year the bonus is depreciated.

The T-accounts in the lower half of Table 1 show the proposed treatment of depletion in subsequent years when extraction occurs (here the years in which the bonus payment is depreciated). Since it is assumed that the oil well's value added is already fully accounted for in rents, royalties, and oil company profits, no changes are made in these items for the value added by the oil well. However, since the discovery value (the bonus payment) has now been treated as an investment, changes must be made to account for depletion of the oil well (that

[13]Although these assumptions, especially with respect to bonus payments, are unrealistic, they facilitate the presentation. For example, as discussed below (see section III.B.), it is unlikely that bonus payments would account for more than a portion of total discovery value; also rent and royalty payments may be more akin to deferred purchase payments than annual payments for current value added.

is, depreciation of the bonus payment). Specifically, the oil company's capital consumption allowance would rise by $100 ($1,600 over a 16-year life) and the oil company's profits would fall by $100. Thus, in subsequent years GNP would remain constant, but net national product would fall by the $100 corresponding to the capital consumption allowance.

III. Three Alternative Valuation Methods

Three alternatives for valuing non-renewable natural resources are presented in this section. The bases for the three alternatives are as follows: (1) the present value of future net revenues associated with developing the natural resource, (2) the price of land associated with the natural resource, and (3) the net price (defined below) per unit of the resource multiplied by the reserves of the resource (or changes in those reserves). The specifics of each of these approaches—the present value method, the land price method, and the net price method—are discussed, in turn, below.

An alternative valuation method, which is not presented here, is to use natural resource firms' stock prices to impute a reserve value. Although appealing, the method has several serious methodological and conceptual problems. First, it is difficult—perhaps impossible—to disentangle the value of an international oil company's domestic operations from its overseas operations; or to disentangle the value of reserves from the value of other assets. Second, how does one obtain a current value for that portion of a firm's value financed by debt denominated in historical dollars? Finally, stock prices often reflect the overall investment outlook rather than the value of a particular company. It is not at all unusual, despite inflation, for the value of a share of stock for a large company to be less than even the historical book value for that share.

A. *Present Value Method*

A common method for valuing physical capital is to estimate the expected present value of future net revenues that would be attributed to the particular asset in question. Recently, this technique has been extended to the valuation of natural resources. The U.S. Securities & Exchange Commission (SEC) currently requires use of the present value technique for valuing oil and gas reserves in supplemental disclosures on company 10K forms.[14] The United Nations Statistical Office has suggested use of present values when market prices of resources are not readily available.[15] Japan and Hungary have recently made estimates of the present value of their energy and other mineral assets.[16] Finally, the Financial Accounting Standards Board (FASB) in the United States has suggested that mining, oil, and gas firms present the necessary information for investors to compute net present values.[17] Below, the basic method for calculating the present

[14]Securities and Exchange Commission (1979); for a more complete discussion of this technique, see Bernardo Ferran (1981).

[15]United Nations (1979), Annex A, pp. 19-21 and p. 24.

[16]See Derek Blades (1980).

[17]Financial Accounting Standards Board (1980).

value of natural resource reserves is presented and the informational uncertainty associated with this type of calculation is discussed. Then, various ways of dealing with this uncertainty are reviewed.

1. *Basic calculation and uncertainties.* The multiperiod nature of resource extraction complicates calculation of the present value of reserves. Most of a given year's discoveries will be extracted in subsequent years and, at the same time, extraction in a given year will result in reduced extraction from proved reserves in future years. Thus, the benefits of discovery (discovery value) and the costs of extraction (depletion) occur over time and should be derived by discounting using the rate of return—or the opportunity cost—associated with alternative investments. This in turn, means that present value estimates of discovery value, depletion, and net stocks depend upon the path of future (1) resource prices, (2) costs of extraction, development, and exploration and (3) rates of return on alternative investments.

The relationship between prices, costs, and rates of return can be seen by examining the formula for the present discounted value of natural resource reserves shown in equation (1).

(1)
$$PV_0 = \sum_{t=0}^{T} \frac{N_t Q_t}{\prod_{i=0}^{t} (1+r_i)}$$

where PV_0 represents the present value of the reserves, N_t represents the average net price per unit of the resource (total price per unit less unit costs of extraction, development, and exploration) over period t,[18] Q_t represents the quantity (in units) of resource extracted during period t, and r_i represents the average rate of return on alternative investments over the period i. The implication of the expression is that the future path of the net price of the natural resource relative to the future path of the rates of return on alternative investments will be critical in determining the present value of the reserves.

The value of a net change in reserves is equal to the change in the present value of the reserves from one period to the next; it can be decomposed into discovery value, depletion, and price change, as shown in equation (2):

(2)
$$PV_1 - PV_0 = \sum_{t=1}^{T} \frac{N_t D_t}{\prod_{i=0}^{t} (1+r_i)} + \sum_{t=1}^{T} \frac{N_t E_t}{\prod_{i=0}^{t} (1+r_i)} + (N_1 - N_0) Q_0$$

where PV_t, N_t, Q_t, and r_i are defined similarly to their counterparts in the previous expression, D_t represents the increase in extraction in period t resulting from discoveries in period 1, E_t represents the decrease in extraction in period t resulting from extraction in period 1. The first term on the right-hand side of equation (2) is equal to discovery value—the present value of the increase in future extractions resulting from period 1 discoveries. The second term is equal to depletion—the present value of the reduction in future extraction resulting from period 1 extraction. The last term is equal to price change—the increase (decrease) in the present value of the resource due to increases (decreases) in prices; it corresponds to capital gains (losses).

[18] In theory, the net price should be net of all costs including capital costs so that it can accurately represent only the value added associated with the natural resource.

2. *Dealing with informational uncertainty.* Three general ways have been proposed for dealing with the uncertainty surrounding implementation of the present value method. In order of increasing informational requirements and difficulty of implementation the three are based on: economic theory, administrative fiat, and empirical estimation.

The first of the proposals is an appeal to economic theory as described in the natural resource literature.[19] The fundamental notion that underlies most of the literature is attributed to Hotelling (1931) and concerns his theoretical finding that in equilibrium the scarcity rent (net price) of untapped resources should rise at the rate of interest (rate of return on alternative investments). At any rate of increase in the net price above (below) the rate of return on alternative investments, entry (exit) and increases (decreases) in the rate of extraction will combine to reestablish the equilibrium rate of price increase. More recently, researchers have extended Hotelling's analysis by considering alternative market structures and demand conditions for natural resources. Virtually all of these authors conclude that even under widely different market structures (monopoly or perfect competition), the price of the resource (before deduction of costs) will rise at a rate somewhat lower than the rate of return on alternative investments.[20]

The above result is important, since if the net price rises at a rate equal to the rate of return on alternative investments, the current net price, N_0, can be used in valuing natural resource stocks and changes in natural resource stocks. Thus, in theory, the uncertainty associated with forecasting net price and the rate of return on alternative investments can be finessed. However, in practice some of the necessary assumptions (for example, perfect foresight) are not fulfilled in natural resource markets. Hence, even if over long periods of time the average rate of increase equals the average rate of return on alternative investments, periods of disequilibrium are likely to occur, and during these periods present value estimates of the value of natural resource reserves will either understate or overstate the "true" value of the reserves.

The second proposal "resolves" the uncertainty by administrative fiat. For example, the SEC currently requires oil and gas producers to estimate the present value of future net reserves on company 10K forms. In doing so, the SEC specifies current prices, costs, and a 10 percent discount rate to be used in the computation of present value, "in order to achieve uniformity in assumptions and to provide for the use of reasonably objective data in making the valuations."[21]

The SEC requirements have met with considerable opposition from oil and gas producers. As Exxon (1979) points out, "The 'Future Net Revenues' and present value of such revenues, as computed under the (SEC) Regulations, present neither a true 'future value' nor 'present value'... the arbitrary ten percent discount rate used in the determination of the present value of estimated future net revenues represents neither a cost of capital nor a borrowing rate, and, additionally, does not necessarily reflect political risks."

[19]The long history of mathematical analysis of equilibrium and optimal depletion patterns for natural resources is described in articles by Peterson and Fisher (1977) and by Pindyck (1978).

[20]See, for example, Weinstein and Zeckhauser (1975).

[21]Securities and Exchange Commission (1979), p. 5703.

Partly as the result of the reactions of oil and gas producers, the SEC has revised its thinking. In its initial ruling the SEC had planned on requiring such information on primary financial statements (reports to the stockholders). Although the SEC will continue to call for such information in supplemental disclosures (on 10K forms), it has now concluded that present value estimates based on proved reserves do not presently possess the degree of certainty required of primary financial statements.

The third way in which the uncertainty of data is handled is by means of empirical estimation. Many alternative methods for estimating future prices (and revenues), costs, and rates of return have been proposed. These methods may be categorized as: simple extrapolation, econometric extrapolation, and large-scale model simulation.

Simple extrapolations or projections based on current data may be appropriate over short periods of time when little changes in the market. However, oil and gas wells have service lives as long as 25 years.[22] Hence, present value calculations require forecasts of market conditions 25 years into the future. Such long-term extrapolations of today's market conditions are of questionable value since today's energy markets are changing so rapidly.

Econometric extrapolation using techniques such as regression analysis attempts to improve upon simple extrapolation by estimating the relationships between many of the important factors affecting natural resource markets. For example, Soloday (1980) estimated the present value and depreciation of oil and gas stocks by forecasting the future oil market. However, the data available at the time of his study were for 1948 to 1974; hence, it is doubtful that the resulting forecast based on the pre-and early-OPEC era has much relevance for the period 1975 to 1999. Thus, if the underlying relationships between the factors affecting resource output and prices change, econometric extrapolation may be as misleading as simple extrapolation.

Large-scale model simulation combines econometric and simulation techniques. By using simulation where the historical relationships are no longer relevent, attempts are made to solve the forecasting problems associated with rapidly changing market relationships. For example, various assumptions may be made about decision makers' reactions under different scenarios, such as how OPEC would react to a change in the world demand for oil. Improvement in the predictive power of such models depends critically on the assumptions and data that underlie them.[23]

In reviewing these problems in dealing with the informational uncertainty associated with the present value approach, The Financial Accounting Standards Board (FASB) concluded that "... the reliability of measurements of fair value (estimated present value) of mineral assets was inadequate for disclosure to be

[22]In the NIPA's service lives for oil and gas wells vary from 7.2 to 24.8 years with an average service life of 16 years.

[23]The U.S. Department of Energy (DOE) found its Long Range Energy Analysis Package (LEAP) model's forecasts to be extremely sensitive to structural specification. In addition, there are problems in obtaining accurate data to provide as input. See DOE (1980). In another report, DOE (1979) discussed the widely different predictions of energy/GNP ratios generated by five long-run energy models.

required at the present time."[24] The FASB therefore decided to require disclosure on the basis of current cost where current cost of an asset may be measured by (a) the estimated buying price for an asset having the same characteristics as the asset owned, or (b) the estimated cost of some other method of acquisition, for example, exploration and development. Both of these methods recommended by FASB would be based on buying prices of developed and undeveloped land. A method of valuing natural resources based on land prices is discussed in the next section.

B. *Land Price Method*

This section considers a second method for valuing natural resources, one that uses land purchase data to infer levels of firms' investments in resource-bearing land. First, the basic method will be presented. Then, the model will be extended and adapted to the special circumstances of the oil and natural gas industries and the data requirements will be discussed.

1. *Basic method.* If land purchases by resource-extracting firms are similar to their purchases of fixed physical capital and other assets, then it may be possible to use data on land purchases to construct an investment series for valuing natural resources. In theory, under conditions of long-run equilibrium in perfect competition the purchase price for a piece of physical capital or land should be equal to the present value of that asset.[25] Thus, if one assumes the market for resource land roughly approximates perfect competition, one may simply use land purchase prices to produce an investment series.

Once investment series are derived from land prices, estimates of natural resource stocks and their depletion can be constructed. For example, if the series are treated similarly to other BEA investment series, straight-line depreciation/depletion schedules over the expected lifetimes of wells and mines can be used to calculate the corresponding depletion series in historical, constant, and current dollars.

2. *The method extended.* It is necessary to extend the method just presented in order to apply it to cases in which land is leased rather than purchased. As noted earlier, many mining firms, especially those in the oil and gas industries, purchase resource land very infrequently; instead, their preferred method of paying for the use of resource land is by means of bonus payments, rentals, and royalties, as described in section II.A. Through these payments, firms acquire the mineral rights to land without obtaining title to the land itself. The distinction between these leasing payments and money spent on actual land purchases is unimportant. However, the extent to which the ultimate payments for use of the land are unknown at the time the firm purchases the mineral rights to the land is a serious difficulty.[26]

[24]Financial Accounting Standards Board (1979), p. 20.

[25]Under conditions of perfect competition the total purchase price of an asset will be equal to the present value of the asset since at any purchase price above (below) the present value the rate of return on the asset will be below (above) the rate of return on alternative investments.

[26]The reader will recall that bonus payments and rental payments are specified at the outset, but royalties depend on annual extraction.

To overcome this, it seems reasonable to assume that a firm estimates future royalty payments and includes them as implicit costs of investing in land. Thus, for the oil and gas industries, and other mining industries that have such leasing arrangements, investment, I, would be:

$$I = PV \geq B + L + R \tag{3}$$

where PV is the present value of expected future net revenues associated with extraction of the resource, B is the bonus payment, L is the sum of future rental payments discounted to the present, and R is the sum of future royalty payments discounted to the present.

In estimates based on this equation, rental payments can be safely ignored since they are very small compared to bonus payments and royalty payments.[27] If one also assumes that the firm expects to make zero profit on resource land—that is, that the present value of future net revenues (PV) just equals the sum of the bonus payment and the present value of future royalty payments—then equation (3) becomes:

$$PV = B + R. \tag{4}$$

Finally, if one assumes that royalty payments are a fixed percentage, n, of future net revenues ($R = nPV$), then equation (4) becomes:[28]

$$\begin{aligned} PV &= B + nPV \\ PV(1-n) &= B \\ PV &= B/(1-n) \end{aligned} \tag{5}$$

Thus, it is possible to estimate the present value of future royalty payments and thus the total value of the investment from current bonus payments without knowing the paths of future prices, costs, production, and rates of return on alternative investments.

The major difficulty with this technique is that it assumes that the data on bonus payments capture the full value of the resource. There are at least two reasons why it is likely that the technique will produce artificially low estimates. First, bonus payments are extremely speculative investments. Given the structure of petroleum markets it is likely that large integrated oil and gas companies have an advantage in dealing with individual landowners and even in competitive bidding for Federal lands.[29] Second, the available data are incomplete. Firms do not always pay bonuses for their land. Oil and gas firms own some of the land on which they drill, though no good data exist on the extent of production from

[27] In 1979, for example, rental payments for outer continental shelf oil leases in the United States amounted to \$0.02 billion while bonus payments for such leases were \$4.6 billion. Although published data on private bonus and rental payments are not available, according to industry sources private rental payments are also small relative to bonus payments.

[28] Alternatively, it would be possible to estimate future royalty payments by forecasting future production quantities and prices and applying a fixed royalty percentage to the forecasted future revenues; however, such calculations would be subject to large errors.

[29] Smiley (1979), in his study of the Federal Government's competitive auctions for outer continental shelf oil leases, found that dynamic aspects of bidding strategies produced winning bids that averaged only 80 percent of the present value of the leases.

firm-owned land. Also, approximately 77 percent of oil and gas production from Federal onshore land comes from noncompetitively leased land, for which firms pay no bonuses.

In addition to less than complete capture of the full value of the resource, the land price technique has two other difficulties. First, using BEA depreciation methods, depletion is assumed to follow a distribution of discards around the average service life of a mine or well and a straight-line schedule is applied. Such estimates of depletion may, or may not, be proportional to existing physical measures of extraction. Second, an assumption implicit in the method is that extraction begins immediately after the bonus payment is made (or land is purchased). Although this assumption is similar to situations involving investment in plant and equipment, it is more likely to present a problem with natural resources, given the amount of exploration and development that is necessary before extraction from a field can begin.

C. *Net Price Method*

A third method for valuing natural resources is to apply the average net price per unit of the resource to changes in reserves. A similar approach is practiced by mining firms in valuing depletion. Also, as was noted above, equilibrium in natural resource markets (where the net price rises at a rate equal to the rate of return on alternative investments) produces the interesting result that depletion as measured by changes in the present value of the resource equals depletion as measured by the net price method. In this section the basic technique for estimating the value of natural resources using the net price method is presented and discussed.

With this method estimates of the economic value of reserves and the value of changes in reserves are derived by multiplying the net price per unit of the resource times the physical quantities of proved reserves, Q_t, and changes in proved reserves. As noted above, net price, N_t, is the average price per unit less costs of extraction, development, and exploration (including physical capital costs). The value of total proved reserves at the end of period t, V_t, is simply N_tQ_t, while the value of changes in reserves (discovery value, depletion and price change) is given by the expression in equation (6):

$$V_t = N_{t-1}Q_{t-1} + N_{t-1}D_t - N_{t-1}E_t + (N_t - N_{t-1})Q_t \tag{6}$$

where N_{t-1} and N_t represent end-of-period net prices, Q_{t-1} and Q_t represent end-of-period proved reserves, and D_t and E_t represent discoveries and extractions during the period.[30]

Net price per unit of oil and gas can be estimated from the data by means of a four-step procedure:

(1) Net rent per unit (including the value added from physical capital associated with oil and gas extraction) is calculated by taking total

[30]For expression (6) to be correct, prices must be constant throughout period t at end of period $t-1$ prices and rise instantaneously at end of period t. In a more realistic example where prices vary over the period the appropriate expression is:

$$V_t = N_{t-1}Q_{t-1} + N_t^aD_t - N_t^aE_t + (N_t - N_{t-1})Q_t + (N_t^a - N_{t-1})(E_t - D_t)$$

revenue from extraction, subtracting total variable cost, and dividing the remainder by the total quantity extracted.

(2) Net rent per unit is then multiplied by quantities of total reserves to obtain an estimate of the total value of oil and gas reserves.

(3) The natural resource component of the total value of oil and gas reserves is obtained by subtracting the current replacement cost value of oil and gas producers' net stock of physical capital from the total value of oil and gas reserves.

(4) The net price per unit of the resource is calculated by dividing the natural resource value obtained in step (3) by total reserves.

Once net price per unit of oil and gas is estimated, it can be applied to data on reserves presented in order to produce a detailed breakdown of the components of changes in the value of resources. Such a detailed breakdown would also be possible with the present value method but not with the land price method.

While the net price method does not require specific assumptions about the future patterns of prices, costs, and rates of return, it does require one critical either/or assumption. Either one must assume that in the face of uncertainty in energy and minerals markets, mining firms actually use the *ad hoc* procedure of multiplying net price by reserves (or extraction) to determine the market value of reserves (or depletion); or one must assume that the present value method is used to determine the market value and that on average long-run market equilibrium will prevail (that is, the net price will rise at a rate equal to the rate of return on alternative investments). At the same time, an important advantage of the net price method is the absence of any assumptions concerning depletion. Since the net price calculation of depletion is based on an annual estimate of physical changes in reserves, it does not require any assumptions regarding service lives or patterns of depletion over time. Thus, net price estimates of the real value of changes in reserves will always be proportional to physical changes in reserves; in contrast, land price estimates based on bonus payments may bear little relationship to physical changes.

IV. Illustrative Estimates for U.S. Oil and Gas, 1948–79

This section presents illustrative estimates of the economic value of oil and gas reserves and the value of changes in reserves. Sets of estimates corresponding to the present value method, the land price method, and the net price method are presented. Each set of estimates is derived using the formulas and techniques discussed above.

This section begins by comparing the alternative estimates to one another. Next, the alternative estimates are reviewed in relation to the NIPA's. Finally, the rates of return implicit in the alternative estimates are discussed and compared to the rate of return for all nonfinancial corporations.

Table 2 presents estimates of oil and gas reserves for 1948–79 using each of the three methods; one set of estimates is presented for each method except the present value method, where three sets of estimates are shown. Among the present value estimates, the first set corresponds to assumptions used by the SEC

TABLE 2

ALTERNATIVE ESTIMATES OF THE ECONOMIC VALUE OF OIL AND GAS RESERVES, SELECTED YEARS, 1948–79
(BILLIONS OF DOLLARS)

	Present value				
Year	I SEC	II Long Run Equilibrium	III Empirical Extrapolation	Land Price	Net Price
1979	123.3	272.0	416.4	62.5	272.0
1978	61.9	136.5	196.1	52.7	136.5
1975	63.3	139.5	364.3	33.6	139.5
1973	50.5	111.4	87.1	18.9	111.4
1970	34.8	76.6	41.7	9.9	76.6
1968	33.8	74.6	46.8	8.5	74.6
1963	32.5	71.7	32.3	5.6	71.7
1958	36.5	80.6	64.6	5.2	80.6
1953	32.7	72.2	47.0	3.1	72.2
1948	29.4	64.9	N.A.	1.9	64.9

(1979) and employs a constant real 10 percent rate of discount and no real increase in net price.[31] The second set corresponds to an assumption of long-run equilibrium in the relevant resource market, implying that the rate of return is equal to the rate of increase in the net price; for consistency, a constant real 10 percent rate of return and a constant real 10 percent increase in net price are used.[32] The third set of present value estimates is intended as a rough estimate of future market conditions; future prices will increase or decrease at a rate equal to the average annual change in prices over the last five years.

As Table 2 indicates, the present value estimates vary by over fivefold. For example, depending on the assumptions made about rates of return and future prices, the value of 1975 oil and gas reserves ranged from a low estimate of $63.3 billion to a high estimate of $364.3 billion. This large range in the present value estimates is particularly troublesome given the fact that there is little basis for choosing between the alternative assumptions underlying the estimates. If one uses the very rapid increases in oil prices over the last five years to calculate present value estimates, the results are markedly different than if one assumes that in the future either a competitive equilibrium will be established with energy prices in real terms rising at a rate closer to the real rate of return on alternative investments, or that energy prices will stabilize as was the case in the 1950's and 1960's. The practical difficulty lies in determining what assumptions should be adopted and which set of estimates is most reliable.

Although the land price method has the advantage over the present value estimates of producing only one set of estimates, until the 1970's the land price

[31]A 10 percent rate is suggested by the U.S. Office of Management and Budget (OMB) for use in the evaluation of government programs and projects. According to OMB, "the prescribed rate of 10 percent represents an estimate of the average rate of return on private investment before taxes and after inflation." [George P. Schultz (1972), p. 3.] Furthermore, Feldstein and Poterba (1980) estimated the 1979 real rate of return to nonfinancial corporate capital as 9.6 percent.

[32]The specific numbers chosen for this case are irrelevant since as long as the rate of return is equal to the increase in net price, the two offset each other.

estimates appear to be unrealistically low. This is not surprising since although the land price estimates may be accurate indicators of resource land acquisition costs (as noted above), they are unlikely to capture fully the investment value of the resource. A second difficulty is that land price values based on estimated service lives and straight-line depletion patterns may or may not be proportional to actual reserve changes. For many years, illustrative land price depletion estimates of changes in the value of reserves are roughly proportional to physical reserve changes. For other years, however, the uneven pattern of bonus payments, extractions, and discoveries produces significant differences between changes in reserves and changes in the value of reserves.

Although they are identical to the first set of present value estimates (which assumed price increases equal to the rate of return on alternative investments), the net price method has a distinct advantage over the present value method. Since the net price method produces one set of estimates, once the method is chosen there is no need to choose from among a range of results. There is no need to make forecasts or assumptions about future interest rates, prices, or extraction. Net price estimates also have the advantage over land price estimates that constant-dollar depletion, discovery value, and changes in reserves are proportional to physical changes in reserves.

The difficulty with the net price method is in determining whether current net price is appropriate for valuing the future production. From 1948 to 1972 when wellhead price was constant or declining (while variable costs, capital costs, and interest rates were rising), the net price method seems to overvalue future production. More recently, since 1972, given the rapid increases in net price it may be that the net price method undervalues future production.

2. *Relation of the alternative estimates to the NIPA'S.* Table 3 illustrates how the alternative measures of discovery value and depletion for proved reserves compare to NIPA measures of investment and depreciation for physical capital. The estimates of oil and gas investment (GPDI) and depreciation (CCA) are calculated in a manner consistent with the NIPA's. The total U.S. investment (GPDI) and depreciation (CCA) estimates are taken directly from the NIPA's.

The present value estimates of discovery value and depletion are far more volatile than total GPDI or CCA or than oil and gas GPDI or CCA. For example, in 1970, Alaskan oil discoveries caused discovery values to increase by a factor of 3, while expected price increases estimated by empirical extrapolation caused depletion to increase rapidly in the 1970's. This volatility is important since discovery value and depletion can be quite large. For example, some of the more extreme estimates of discovery value and depletion would add as much as 27 and 23 percent to NIPA measures of GPDI and CCA, respectively.

The land price estimates would represent a far smaller addition to total GPDI and total CCA than the alternative estimates of discovery value and depletion. The land price estimates exhibit far less volatility than the alternative estimates. The land price estimates of discovery value and depletion are also more in line with oil and gas GPDI and CCA. The land price estimates of discovery value are smaller than oil and gas physical capital investments, and exhibit a variation of roughly the same magnitude as the physical capital estimates. The land price estimates of depletion are smaller than oil and gas depreciation and physical capital and exhibit a growth path following that of oil and gas prices.

TABLE 3

Gross Private Domestic Investment in Fixed Nonresidential Capital and Alternative Estimates of Oil and Gas Discovery Value, Selected Years, 1948–79 (Billions of Dollars)

	Gross Private Domestic Investment		Discovery Value				
			Present Value				
Year	Total	Oil and Gas	I	II	III	Land Prices	Net Prices
1979	290.20	23.35	6.62	14.60	22.35	12.52	14.60
1978	248.89	17.69	3.05	6.72	9.66	5.14	6.72
1973	143.33	4.53	1.65	3.64	2.85	5.09	3.64
1970	103.91	3.78	6.95	15.32	8.34	1.02	15.33
1968	90.65	4.25	2.04	4.51	2.82	2.17	4.51
1963	54.84	3.17	2.30	5.07	2.36	0.52	5.07
1958	42.03	3.50	3.19	7.03	5.36	0.80	7.03
1953	34.47	2.92	3.39	7.47	4.86	0.62	7.47
1948	26.28	1.90	3.22	7.11	N.A.	0.35	7.11

Capital Consumption Allowances, with Capital Consumption Adjustment, and Alternative Estimates of Oil and Gas Depletion, Selected Years, 1948–79 (Billions of Dollars)

	Capital Consumption Allowance		Depletion				
			Present Value				
Year	Total	Oil and Gas	I	II	III	Land Prices	Net Prices
1979	201.20	16.49	9.13	20.13	30.81	9.84	20.13
1978	175.26	9.14	5.72	12.61	18.12	5.50	12.61
1973	91.41	5.92	3.61	7.96	6.23	1.62	7.96
1970	70.02	4.66	2.77	6.12	3.33	1.11	6.12
1968	57.09	4.20	2.67	5.89	3.69	0.89	5.88
1963	39.51	3.19	2.09	4.61	2.14	0.65	4.61
1958	33.89	2.92	2.23	4.92	3.95	0.53	4.92
1953	23.67	2.11	1.86	4.11	2.68	0.26	4.11
1948	15.01	1.41	1.56	3.44	N.A.	0.22	3.44

The net price estimates, while perhaps reasonable for the 1970's, appear to vastly overvalue future production in earlier periods resulting in discovery value and depletion estimates as high as 27 and 23 percent of total GPDI and CCA, respectively.

3. *Implicit rates of return relative to alternative rates of return opportunity costs.* What rates of return are implied by the foregoing estimates, and how do they compare to the rate of return to oil and gas without an imputation for depletion and reserve value; and to the rate of return/opportunity costs in other sectors? Table 4 presents estimates of the average rate of return implicit in the alternative estimates of reserve value and depletion along with estimates of the rate of return to oil and gas without an imputation for reserve value, the rate of return to all non-financial corporations and an assumed rate of time preference.

TABLE 4

ALTERNATIVE OPPORTUNITY COST AND IMPLIED RATE OF RETURN ESTIMATES (PERCENT)

	1953-79	1948-79
Total nonfinancial corporate sector	11.4	11.7
Time preference (assumed)	3.0	3.0
Oil and Gas	13.8	15.0

All these rates are real rates of return. The rate of return for oil and gas including an imputation for depletion and reserve value is equal to what we have described as the net return, less depreciation and depletion, divided by the sum of the replacement value of physical capital and reserve value. The rates of return for non-financial corporate capital and for oil and gas are computed in the same way except that no values are included for depletion or reserve value.

The average rate of return for U.S. oil and gas without an imputation for depletion and the value of reserves is higher than the rate of return for all nonfinancial corporate capital—13.8 versus 11.4 percent for the period 1953-79 and 15.0 versus 11.7 percent for the period 1948-79. As can be seen from table 5, the present value imputations for depletion and the value of reserves lowers the rate of return for oil and gas from a range of 13.8 to 15.0 percent to a range of 3.7 to 6.2 percent. Although these rates may be higher than some social discount rate based on time preference these implicit rates of return for oil and gas are well below the average market rate of return for the total nonfarm sector.

TABLE 5

IMPLICIT RATES OF RETURN FOR OIL AND GAS WITH AN IMPUTATION FOR DEPLETION AND RESERVE VALUE (PERCENT)

	1953-79	1948-79
Present Value I	6.2	6.2
Present Value II	3.8	3.7
Present Value III	4.4	N.A.
Land Price	10.1	11.4
Net Price	3.8	3.7

The implicit rates of return from the present value and net price imputations are low relative to the market rates of return to other industries in part because the imputations for reserve value and depletion attempt to account for the *full social* costs of oil and gas production, and in part because the various assumptions in the present value and net price estimates on average overvalued future production relative to the actual market value of production, 1948-79; for example, until the 1970's oil and gas prices were quite low and the net price failed to rise at a rate equal to the rate of return on alternative investments.

The land price estimates produce an implicit rate of return for oil and gas of 10.1 percent over the period 1953-79, and 11.4 percent over the period 1948-79.

These rates, which are based on actual market payments, are roughly comparable to the estimated rate of return for all non-financial corporate capital, 11.4 percent for the period 1953–79 and 11.7 percent for the period 1948–79.

Among the imputations for depletion and value of reserves over the whole period 1948–79 the land price estimates seem the most reasonable as measured by average market rate of return. The land price imputations bring the oil and gas average rate of return into line with the average rate of return in the total nonfinancial corporate sector. Although the rates of return produced by the present value imputations may be appropriate for social valuations, implicitly embodying such rates in NIPA estimates for oil and gas makes comparisons with other industries difficult.

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