Accounting for Subsoil Mineral Resources

LAST SUMMER, A blue-ribbon panel of the National Academy of Sciences' National Research Council completed a congressionally mandated review of the work that the Bureau of Economic Analysis (BEA) had published on integrated economic and environmental accounts. The panel's final report commended BEA for its initial work in producing a set of sound and objective prototype accounts. The November 1999 issue of the SURVEY OF CURRENT BUSINESS *contained an article by William D. Nordhaus, the Chair of the Panel, that presented an overview of the major issues and findings and a reprint of chapter 5, "Overall Appraisal of Environmental Accounting in the United States," from the final report. As part of its promise to inform users of the results of this evaluation, BEA is reprinting additional chapters from the panel's report; below is a reprint of chapter 3, which reviews BEA's development of a set of subsoil mineral accounts.*

INTRODUCTION

SUBSOIL minerals—particularly petroleum, natural gas, and coal—have played a key role in the American economy over the last century. They are important industries in themselves, but they also are crucial inputs into every sector of the economy, from the family automobile to military jets. In recent years, the energy sector has been an important contributor to many environmental problems, and the use of fossil fuels is high on the list of concerns about greenhouse warming.

The National Income and Product Accounts (NIPA) currently contain estimates of the production of mineral products and their flows through the economy. But the values of and changes in the stocks of subsoil assets are currently omitted from the NIPA. The current treatment of these resources leads to major anomalies and inaccuracies in the accounts. For example, both exploration and research and development generate new subsoil mineral assets just as investment creates new produced capital assets. Similarly, the extraction of mineral deposits results in the depletion of subsoil assets just as use and time cause produced capital assets to depreciate. The NIPA include the accumulation and depreciation of capital assets, but they do not consider the generation and depletion of subsoil assets.

The omission is troubling. Mineral resources, like labor, capital, and intermediate goods, are basic inputs in the production of many goods and services. The production of mineral resources is no different from the production of consumer goods and capital goods. Therefore, economic accounts that fail to include mineral assets may seriously misrepresent trends in national income and wealth over time.

Omission of minerals is just one of the issues addressed in the construction of environmental accounts. Still, extending the NIPA to include minerals is a natural starting point for the project of environmental accounting. These assets—which include notably petroleum, natural gas, coal, and nonfuel minerals—are already part of the market economy and have important links to environmental policy. Indeed, production from these assets is already included in the nation's gross domestic product (GDP). Mining is a significant segment of the nation's output; gross output originating in mining totaled $90 billion, or 1.3 percent of GDP, in 1994. This figure masks the importance of production of subsoil minerals in certain respects, however, for they are intimately linked to many serious environmental problems. Much air pollution and the preponderance of emissions of greenhouse gases are derived directly or indirectly from the combustion of fossil fuels—a linkage that is explored further in the next chapter. Moreover, while the value of mineral assets may be a small fraction of the nation's total assets, subsoil assets account for a large proportion of the assets of certain regions of the country.

Current treatment of subsoil assets in the U.S. national economic accounts has three major limitations. First, there is no entry for additions to the stock of subsoil assets in the production or asset accounts. This omission is anomalous because businesses expend significant amounts of resources on discovering or proving reserves for future use. Second, there is no entry for the using up of the stock of subsoil assets in the production or asset accounts. When the stock of a valuable resource declines over time through intensive exploitation, this trend should be recognized in the economic accounts: if it is becoming increasingly expensive to extract the subsoil minerals necessary for economic production, the nation's sustainable production will be lowered. Third, there is no entry for the contribution of subsoil assets to current production in the production accounts. The contribution of subsoil assets is currently recorded as a return to other assets, primarily as a return to capital.

There is a well-developed literature in economics and accounting with regard to the appropriate treatment of mineral resources. The major difficulty for the national accounts has been the lack of adequate data on the quantities and transaction prices of mineral resources. Unlike new capital goods such as houses or computers, additions to mineral reserves are not generally reflected in market transactions, but are determined from internal and often proprietary data on mineral resources. Moreover, there are insufficient data on the transactions of mineral resources, and because these resources are quite heterogenous, extrapolating from existing transactions to the universe of reserves or resources is questionable.

Notwithstanding the difficulties that arise in constructing mineral accounts, the Bureau of Economic Analysis (BEA) decided this was the best place to begin development of its Integrated Environmental and Economic Satellite Accounts (IEESA). BEA in the United States and comparable agencies in other countries have in recent years developed satellite accounts that explicitly identify mineral assets, along with the changes in these assets over assets, along with the changes in these assets over time. This chapter analyzes general issues involved in minerals accounting and assesses the approach taken by BEA (as described in Bureau of Economic Analysis [1994b]). The first section provides an overview of the nature of subsoil mineral resources and describes the basic techniques for valuing subsoil assets. The second section describes BEA's approach to valuation, including the five different methods it uses to value subsoil mineral assets. The third section highlights the specific strengths and weaknesses of BEA's approach, while the fourth considers other possible approaches. The chapter ends with conclusions and recommendations regarding future efforts to incorporate subsoil mineral assets into the national economic accounts.

GENERAL ISSUES IN ACCOUNTING FOR MINERAL RESOURCES

Basics of Minerals Economics

A mineral resource is "a concentration of naturally occurring solid, liquid, or gaseous material, in or on the earth's crust, in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible" (Craig et al., 1998:20). The size and nature of many mineral resources are well known, whereas others are undiscovered and totally unknown. Figure 3–1 shows a spectrum of resources that differ in their degree of certainty, commonly described as measured, indicated, inferred, hypothetical, and speculative. Another important dimension is the economic feasibility or cost of extracting and using the resources. Some resources are currently profitable to exploit; others may be economical in the future, but currently are not. Along this dimension, mineral resources are conventionally described as economic (profitable today), marginally economic, subeconomic, and other.

Resources that are both currently profitable to exploit (economic) and known with considerable certainty (measured or indicated) are called reserves (or ores when referring to metal deposits). This means reserves are always resources, though not all resources are reserves.[1]

Over time, reserves may increase. Exploration may result in the discovery of previously unknown deposits or demonstrate that a known deposit is larger than formerly indicated. Research and development may produce new techniques that allow previously known but uneconomic resources to be profitably extracted. A rise in a mineral commodity's price may also increase reserves by making previously unprofitable resources economic.

The exploration required to convert resources into reserves entails a cost. As a result, companies have an incentive to invest in the generation of new reserves only up to the point at which reserves are adequate for current production plans. For many mineral commodities, therefore, reserves as a multiple of current extraction tend to remain fairly stable over time.

1. Two additional categories of mineral endowment are worth noting since they are commonly encountered. The reserve base encompasses the categories of reserves and marginal reserves, as well as part of the category of demonstrated subeconomic resources shown in Figure 3–1. While reserves and the reserve base are typically a small subset of resources, resources in turn are a small subset of the resource base. The resource base, not illustrated in Figure 3–1, encompasses all of a mineral commodity found in the earth's crust.

While by definition all reserves can be exploited profitably, the costs of extraction, processing, and marketing, even for reserves of the same mineral commodity, may vary greatly as a result of the reserves' heterogenous nature. Deposit depth, presence of valuable byproducts or costly impurities, mineralogical characteristics, and access to markets and infrastructure (such as deepwater ports) are some of the more important factors that give rise to cost differences among reserves.

Figure 3–2 reflects the heterogenous nature of mineral resources by separating the reserves and other known resources for a particular mineral commodity according to their exploitation costs.[2] The lowest-cost reserves are in class A; their quantity is indicated in the figure as $0A$ and their exploitation costs as $0C_1$. The next least costly reserves are found in class B, with a quantity of AB and a cost of $0C_2$. The most expensive reserves are found in class M. These reserves are marginally profitable. The market price $0P$ just covers the extraction cost of class M ($0C_m$) plus the opportunity cost ($C_m P$) of using these reserves now rather than saving them for future use. This opportunity cost, which economists refer to as *Hotelling rent* (or sometimes scarcity rent or user cost) is the present value of the additional profit that would be earned by exploiting these reserves at the most profitable time in the future rather than now.[3]

Known resources in Figure 3–2 with costs above those of class M, such as those in classes N, O, and P, are by convention not reserves. In this case, mineral producers, like other competitive firms, will have an incentive to produce up to the point where the current production costs of the next unit of output, inclusive of rents, just equals the market price. When Hotelling rents exist,

2. Similar comparative cost curves are used to illustrate the relative costs of mineral production for major producing countries or companies. See, for example, Bureau of Mines (1987) and Torries (1988, 1995).

3. Where the relevant market for a mineral commodity is global and transportation costs are negligible, Figure 3–2 reflects cost classes for reserves and other known resources throughout the world. Where a mineral commodity is sold in regional markets, a separate figure would be required for each regional market, and the cost classes shown in any particular figure are only for the reserves and other known resources in the regional market portrayed.

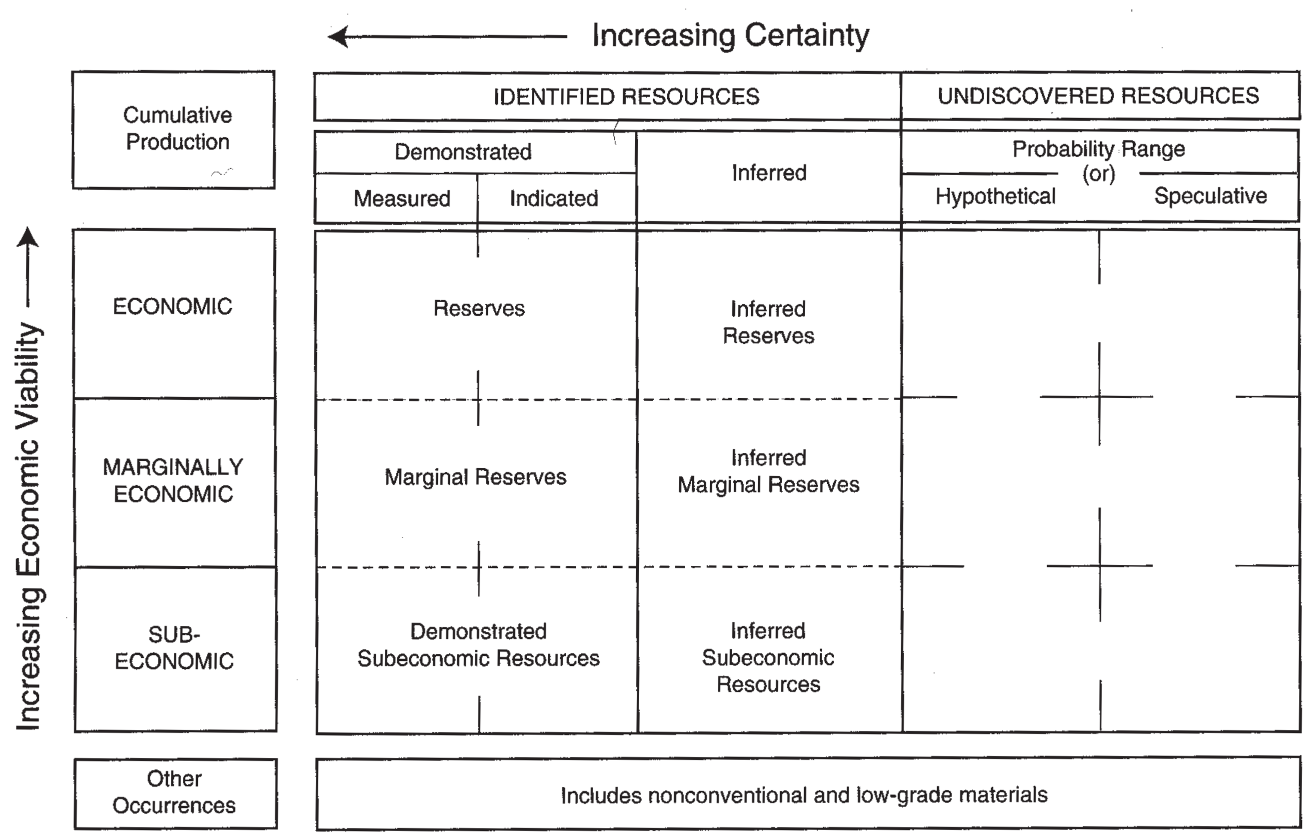


FIGURE 3-1 Classification of Mineral Resources. Source: Mineral Commodities Summaries, U.S. Geological Survey (1992:203)

they are the same for all classes of reserves for a particular mineral commodity market. Thus, the total Hotelling rent shown in Figure 3–2 is simply the Hotelling rent earned on marginal reserves ($C_m P$) times total reserves ($0M$).

Those reserves whose marginal extraction costs are below those of the marginal reserves in class M are called inframarginal reserves. As a result of their relatively low costs, they yield additional profits when they are exploited. Mineral economists refer to these additional profits as Ricardian rents. In Figure 3–2, the *Ricardian rents* per unit of output equal C_1C_m for reserves in class A, C_2C_m for reserves in class B, and so on.

Unless technical or other considerations intervene, mineral producers will generally exploit first those reserves that have relatively low production costs and thus high Ricardian rents (like classes A and B). This implies that the reserves currently being extracted have lower costs than the average of all reserves and that their Ricardian rents are likely to be above average.

Since reserves by definition are known and profitable to exploit, they are assets in the sense that they have value in the marketplace. Although mineral resources other than those classified as reserves might have in-completely defined characteristics (in terms of costs and quantities) or be currently unprofitable to exploit, they still may command a positive price in the marketplace. Petroleum companies, for example, pay millions of dollars for offshore leases to explore for oil deposits that are not yet proved reserves. Mining companies pay for and retain subeconomic deposits. The option of developing such deposits in the future has a positive value because the price may rise, or some other developments may make the deposits economic.

Thus, a full accounting of subsoil assets should consider not only reserves, but also other mineral resources with positive market value. In the case of reserves, market value may reflect Hotelling rent, Ricardian rent, and option value.[4] In the case of mineral resources other than reserves, a positive market value is due solely to their option value.

Key Definitions in Mineral Accounting

Changes in the value of the mineral stock come about through additions, depletions, and revaluations of reserves.

4. The total value of reserves is $V = \sum_i v_i R_i$, where v_i is the unit value of reserves in class i ($i = A, B, \ldots, M$), and R_i is the quantity of reserves of class i

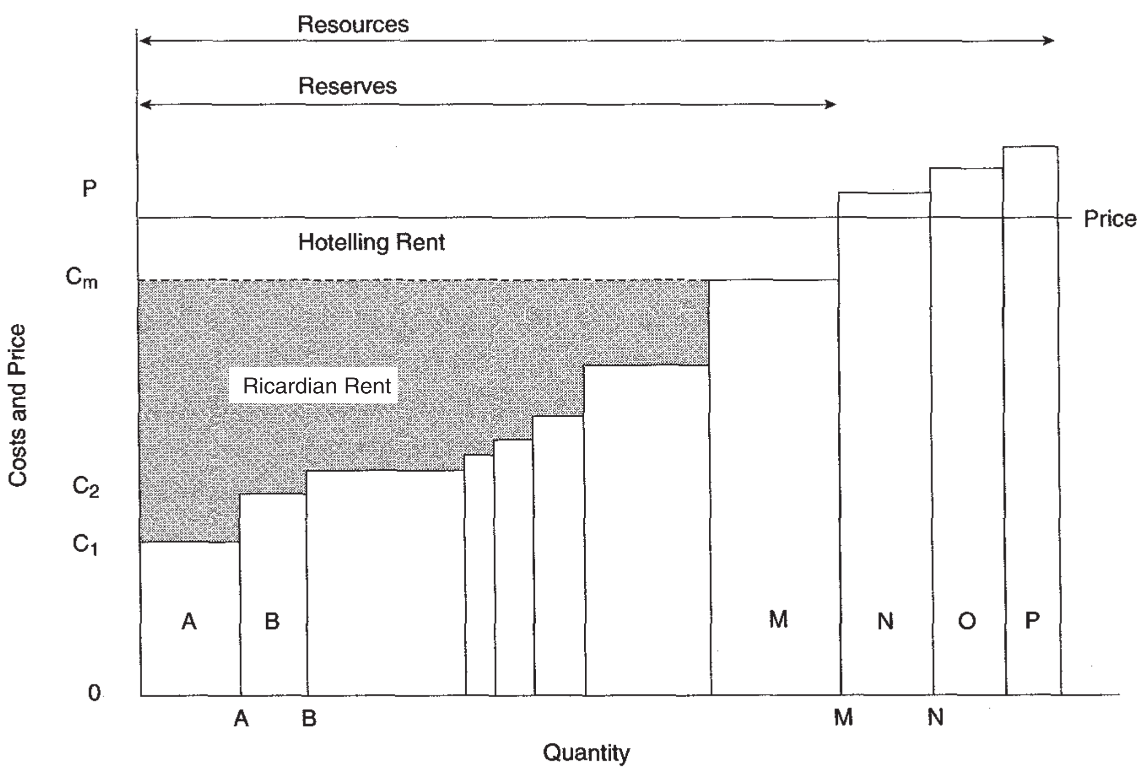


FIGURE 3-2 Mineral Reserves and Other Known Resources by Cost Class.

- *Additions* are the increases in the value of reserves over time due to reserve augmentations. They are calculated as the sum of the price of new reserves times the quantity of new reserves for each reserve class.
- *Depletions* are the decreases in the value of reserves over time due to extraction. They are similar to capital consumption (depreciation) and parallel the concept of additions.
- *Revaluations* are changes in the value of reserves due to price changes. They measure the residual change in the value of reserves after correcting for additions and depletions.

Techniques for Valuing Mineral Assets

As noted in the last section, the major challenge in extending the national accounts to include subsoil minerals is to broaden the treatment of mineral assets to include additions and depletions and to incorporate depletion in the production accounts. This task involves estimating the value of the subsoil assets. A specific subsoil asset consists of a quantity of a mineral resource and the invested capital associated with finding and developing that resource. Invested capital includes physical structures such as roads and shafts, as well as capitalized exploration and drilling expenses. The total value of the subsoil assets equals the sum of the value of the mineral and the value of the associated capital (see Figure 3–3). Currently, U.S. national economic accounts include the value of the associated capital, but exclude the value of the mineral resource. One of the goals of natural-resource accounting is to estimate the total value of subsoil assets and to separate this estimate into the value of the mineral and the value of the associated capital. An additional goal is to track over time changes in the value of the stock that result from additions, depletions, and revaluations.

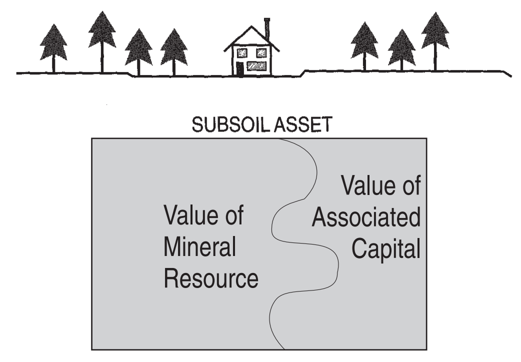


FIGURE 3-3 The Two Components of Subsoil Assets.

Three alternative methodologies are used in valuing mineral resources: (1) transaction prices, (2) replacement value, and (3) net present value. In developing its mineral accounts, BEA used one version of the first method and four versions of the third. This section explains the basic elements of each approach.

Transaction Prices

The most straightforward approach to valuing mineral resources relies on market transaction prices. This is the standard approach used across the national economic accounts for capital assets. When resources of petroleum, copper, gold, and other minerals are sold, the value of the transaction provides a basis for calculating the market value of the mineral component of the asset.

A close look at the transaction-prices approach reveals, however, a number of difficulties that need to be resolved. The major difficulty is that a market transaction usually encompasses a number of assets and liabilities, such as the associated capital (e.g., surface roads, shafts, and refining operations), taxes, royalty obligations, and environmental liabilities. Because the transaction usually includes not only the mineral resources, but also associated capital, the value of the capital must be subtracted to obtain the mineral value. In addition, the property is usually encumbered with royalty obligations to prior owners or to owners of the land. Many mineral properties also have associated environmental problems, such as contaminated soils and water, and they may even be involved in complicated legal disputes, such as connection to a Superfund site with joint and several liability. Some of these associated assets and liabilities (such as mining structures) are true social costs or assets, while others (such as royalty obligations) are factor payments.

Another difficulty with using transaction prices is the sporadic nature of the transactions. The infrequency of the transactions, coupled with the heterogeneity of the grade of the resource, makes it difficult to apply the transaction price for one grade or location of the resource to other grades in other locations.

Because of the complex assortment of assets and liabilities associated with transactions of mineral resources, the price must be adjusted to obtain the value of a resource. As noted above, the working capital and the associated capital must be subtracted from the transaction price, while any extrinsic environmental liabilities should be added, as should any factor payments, such as royalties or taxes, to obtain the value of the underlying resource.

Box 3–1 provides an example of how to adjust the transaction price to obtain the market value of a mineral resource for a hypothetical sale involving the purchase of 500,000 barrels of oil. In this example, the buyer pays $2 million for a property containing 500,000 barrels of oil, and this is recorded as the transaction value. Attached to those reserves is a long-term debt of $1.0 million; this liability must be added to the purchase price. If the acquired reserves also include associated working capital of $0.2 million, this amount must be deducted from the purchase price. Correcting for these two items creates an effective purchase price or market value of the asset of $2.8 million.

An additional issue arises because of payments such as future taxes and royalties. In acquiring the above property, the new owner must, for example, pay a 10 percent overriding royalty to the landowner. Such payments should be included in the value of the resource even though they do not accrue to the seller of the property. In the example shown in Box 3–1, future royalties and taxes are assumed to have a present value of $0.6 million. These payments introduce a major new complication because taxes and royalties depend on future production. Not only are they uncertain, but they also cannot be easily estimated from market or transaction data. One approach is to adjust the transaction price by marking up the value of the transaction by a certain amount. Adelman and Watkins (1996:4), for example, suggest that 27 percent be added to the "effective purchase price" to account for transfers. After adjusting for royalties, this yields a social asset value for the above property of $3.4 million. The final adjustment is for associated capital, which is assumed to have a value of $0.8 million. After this amount is subtracted, the estimated social value of the underlying petroleum reserve is calculated to be $2.6 million.

Replacement Value

A second approach uses the costs of replacing mineral assets to determine their value. Under this approach, it is assumed that firms have an incentive to undertake investments to find new resources up to the point where the additional cost of finding one more unit just equals the price

Box 3–1: Transaction Price Method[a]

Recorded Dollar Transaction (500,000 barrels)		$2.0 million
Adjustments		
Add: assumed liabilities	$1.0 million	
Subtract: working capital	$0.2 million	
Effective Purchase Price of Asset		$2.8 million
Add: present value of taxes, royalty transfers	$0.6 million	
Value of Assets		$3.4 million
Subtract: value of associated capital	$0.8 million	
Value of Petroleum Reserve		$2.6 million

[a] This methodology is not followed in the conventional accounts. For instance, in valuing the stock of cars, we do not subtract tax credits, nor do we add in future liabilities such as property taxes. Similarly, to the extent that royalties are regarded as a sharing of profits (like dividends), they should not affect the value of an asset; to the extent that royalties are actually a deferred part of the purchase price, they can be capitalized to increase the value of an asset.

Box 3–2: Definitions of Symbols and Basic Concepts in Minerals Accounting

For this discussion, assume that there is only one class of a mineral reserve, that extraction costs are constant, and that the unit value of the reserve rises at the social rate of discount. Variables are:

R_t = total quantity of reserves of the mineral commodity at year end
H_t = unit value of the reserves (say, petroleum reserves), which equals Hotelling rent under the above assumptions
A_t = quantity of new reserves discovered during the year
q_t = quantity of extraction or production during the year
V_t = total value of the reserves at year end

In a given year, petroleum firms might discover new reserves totaling A_t. Then the additions are given by:

$$\text{additions}_t = H_t A_t \tag{3.1}$$

During that year, petroleum production, and therefore depletion of existing reserves, is measured by q_t. Depletion is, under the special assumptions listed above, quantity times the value of reserves:

$$\text{depletions}_t = H_t q_t \tag{3.2}$$

The total value of reserves at year end is:

$$\text{value of reserves} = V_t = H_t R_t \tag{3.3}$$

The change in the value from the end of year $t-1$ to the end of year t is given by:

$$\text{change in value of reserves} = V_t - V_{t-1} = H_t R_t - H_{t-1} R_{t-1} \tag{3.4}$$

Revaluations are the change in the value corrected for the value of additions and depletions:

$$\text{revaluation} = H_t R_t - H_{t-1} R_{t-1} - H_t A_t + H_t q_t \tag{3.5}$$

at which firms can buy that unit—that is, up to the market value. Therefore, the additional or marginal cost of finding a mineral resource should be close to its market price. Associated with this approach, however, are many of the same issues discussed above under transaction prices. For example, a particular replacement cost is relevant only for valuing deposits of comparable quality and cannot be used to value resources of another grade. This point can be illustrated using Figure 3–2. Assume that exploration is resulting in the discovery of resources of class M. The market value of this class would be a function of the difference between 0P and production cost $0C_M$. It would be profitable for firms to continue exploring for such deposits until the finding costs (that is, the replacement costs) just reached the value of this class of resource. However, the replacement cost of class M cannot be used to value other classes, such as class A, which have a lower extraction cost and therefore a higher value. Because of cost differences, using class M to value classes A through L would yield an underestimate of the value of these reserves.

Net Present Value

A third valuation technique, the net present value or NPV method, entails forecasting the stream of future net revenues a mineral resource would generate if exploited optimally, and then discounting this revenue stream using an appropriate cost of capital.[5] Under certain conditions—such as no taxes—the sum of the discounted revenue values from each time period will equal the market value of the resource. For example, assume that a 100 million-ounce gold asset generates a stream of net revenues (after accounting for all extraction and processing costs) that, when discounted at a rate of 10 percent per year, has a present value of $1.5 billion. According to this approach, the value of the asset is taken to be $1.5 billion. If the value of the plant, equipment, and other invested capital ultimately associated with the asset is estimated to be $500 million, the current value of the gold reserves is $1 billion, and their unit value is $10 per ounce. Again, as with the previous two methods, each class of resource should be separately valued, since the stream of revenues from a higher class of resource will be greater than that from a lower class.

5. The appropriate discount rate for energy and environmental resources is debatable. See Lind (1990, 1997) , Schelling (1995) , and Portney and Weyant (1999).

A special case of the NPV approach, known as the Hotelling valuation principle (see Miller and Upton, 1985), avoids the difficulties of forecasting future net revenues and then discounting them back to the present. This approach makes the strong and generally unrealistic assumption that the unit value of a resource grows at exactly the same rate as the appropriate discount rate. In the above example, this would imply that the unit value of the gold resource would grow at the discount rate of 10 percent per year; that is, the unit value would be $10 in the first year, $11 in the next year, $12.1 in the following year, and so forth. Under this assumption, the present value of the resource would easily be calculated as the current period's resource price multiplied by the current physical stock of the resource. Under a further set of assumptions, such as homogeneous resources and constant extraction costs, the current period resource price is simply the current net revenue (unit price less unit extraction cost).

For example, assume that in a given year the United States has 100 million ounces of homogeneous gold reserves, that the price of gold in that year is $350 per ounce, and that the average extraction cost is $335 per ounce. Under the Hotelling valuation principle, the price of the gold reserves would be $15 per ounce, and the total value of the gold assets would be calculated as $1.5 billion. Note that it would still be necessary to deduct the value of capital from the $1.5 billion to obtain the value of the mineral reserve. Again, for this approach to be valid, the per unit price of gold reserves ($15 in this example) would need to grow at the discount rate appropriate for these assets.

BEA'S VALUATION OF SUBSOIL MINERALS

This section presents a more detailed description of BEA's valuation methods (as set forth in Bureau of Economic Analysis, 1994b). In the absence of observable market prices for reserves, BEA estimates mineral reserve and flow values using five valuation methods. These calculations are performed for reserves of fuel minerals (petroleum, natural gas, and coal) and other minerals (uranium, iron ore, copper, lead, zinc, gold, silver, molybdenum, phosphate rock, sulfur, boron, diatomite, gypsum, and potash) for each year from 1958 through 1991 (oil and gas figures are calculated from 1947 to 1991). In addition, aggregate stock and flow values for five mineral categories (oil, gas, coal, metals, and other minerals) are entered in the appropriate rows and columns of the IEESA Asset Account for 1987. This section first examines the five methods used by BEA in estimating mineral values, along with the data they require, and then describes BEA's findings. Box 3–2 provides definitions of the symbols used in minerals accounting.

BEA's Five Basic Valuation Methods

Current Rent Method I

Current rent methods I and II are NPV methods based on the Hotelling valuation principle. The attraction of the Hotelling valuation principle is the ease with which the calculation can be performed, avoiding the need to forecast mineral prices and to assume an explicit discount factor. In both methods, the value of the aggregate stock is calculated as the net price times the quantity of reserves, where the net price is as described below. Additions or depletions are similarly calculated as net price times the quantity of additions or depletions. One of the difficulties with this approach is that the Hotelling valuation principle tends to provide a systematic overvaluation of reserves, the reason for which is discussed in a later section.

Current rent methods I and II are quite similar in construction. They differ primarily in the method of adjusting for the value of associated capital. (The algebra of the different formulas is shown in the boxes in this section.) Current rent method I (see Box 3–3) uses the normal rate of return on capital to determine the return on associated capital in the mining industry that should be subtracted from revenues. It then calculates the "resource rent per unit of reserve" by taking the net profits from mining, subtracting the return and depreciation on the associated capital, and dividing that sum (called "resource rent" by BEA) by the quantity of resource extracted during the year. The method thus yields an estimate of the unit value of the reserves currently extracted.

To calculate the total value of the mineral reserve, the current resource rent per unit is multiplied by the total reserves, in the spirit of the Hotelling valuation principle. Additions and depletions are calculated as those quantities times the resource rent per unit. Revaluations are simply the residual of the change in the value of the stocks plus depletions minus additions. It has been observed that the value of the stock can be highly volatile; this volatility is due primarily to the revaluation effect.

Box 3–3: Formulas for Current Rent Method I

$$\text{total mineral reserve value}_t = V_t =$$
$$[p_t - a_t]R_t - rR_tK_t/q_t - R_tD_t/q_t =$$
$$[p_t - a_t - rK_t/q_t - D_t/q_t]\times R_t$$
$$\text{additions}_t = [p_t - a_t - rK_t/q_t - D_t/q_t]\times A_t$$
$$\text{depletions}_t = [p_t - a_t - rK_t/q_t - D_t/q_t]\times q_t$$
$$\text{revaluations}_t = V_t - V_{t-1} + \text{depletions}_t - \text{additions}_t$$

where

V_t = value of mineral reserves
p_t = price of commodity
a_t = average cost of current production
R_t = total quantity of reserves
r = average rate of return on capital
K_t = value of associated capital, valued at current replacement cost
q_t = total quantity extracted
D_t = depreciation of associated capital
A_t = quantity of discoveries of new reserves
additions_t = value of discoveries of new reserves
depletions_t = value of depletions
revaluations_t = change in value of reserves corrected for depletions and additions

The revaluation term is not directly calculated; it will include any errors in calculating additions, depletions, and opening and closing stock values.

Current Rent Method II

Current rent method II is virtually identical to current rent method I. The only difference is in the method of adjusting for associated capital. The value of the associated capital is subtracted from the total value of the mineral asset to obtain mineral-reserve values in current rent method II. Again employing the Hotelling valuation approach, the total value of the mineral asset (including the value of the associated capital) is calculated as the per unit net revenue times the total quantity of reserves. The total value of the mineral reserve is then calculated as the total value of the asset value minus the value of the associated capital. The unit resource value, which is used to price additions and depletions, is just this total reserve value divided by the total quantity of reserves. This approach is defined algebraically in Box 3–4 .

As is discussed below, both current rent methods have major advantages in that they are easy to calculate on the basis of data BEA currently uses in its accounts (primarily profits and capital stock and consumption data). They both suffer from the serious disadvantage that they rely on

Box 3–4: Formulas for Current Rent Method II

$$\text{total mineral reserve value}_t = V_t = [p_t - a_t - K_t/R_t]R_t$$

$$\text{additions}_t = [p_t - a_t - K_t/R_t] \times A_t$$

$$\text{depletions}_t = [p_t - a_t - K_t/R_t] \times q_t$$

$$\text{revaluations}_t = V_t - V_{t-1} + \text{depletions}_t - \text{additions}_t$$

where variables are as defined in Box 3.3.

the Hotelling valuation principle, thereby tending to overvalue reserves.

Net Present Value Estimates

If the basic assumptions of the Hotelling valuation principle do not hold—and there is strong evidence that they do not, as discussed below—life becomes much more complicated for national accountants. One approach that is sound from an economic point of view is to value reserves by estimating the present discounted value of net revenues. To render the present value approach workable, BEA makes three simplifying assumptions. First, it assumes that the quantity of extractions from an addition to proved reserves is the same in each year of a field's life. The quantity of depletions in any year is assumed to result equally from all vintages (cohorts) still in the stock, i.e., all vintages whose current age is less than the assumed life. Second, the life for a new addition is assumed to be 16 years until 1972 and 12 years thereafter. Third, BEA assumes that the discount rate applied to future revenues is constant at a rate of either 3 percent per year or 10 percent per year above the rate of growth of the net revenues (where the latter equals the rate of growth of the price of the resource).[6]

These assumptions lead to a tractable set of calculations. The present discounted value of the mineral stock as calculated using this present value method is simply the stock and flow values calculated with current rent method II, multiplied by a "discount factor" of between 0.86 and 0.89 for the 3 percent discount rate and between 0.63 and 0.70 for the 10 per cent discount rate.[7] The calculated values are, then, lower than the values derived using current rent method II, with the difference depending on the discount rate employed.

Additions and depletions are then calculated in a manner similar to that used with current rent method II. The average unit reserve value is calculated by dividing the total reserve value by the quantity of reserves, and then using this unit value to value additions and depletions. Additions would be calculated as 84 percent of the value of additions according to current rent method II if the discount rate is 3 percent per year, and 59 percent of the value of additions according to current rent method II if the discount rate is 10 percent. The calculated value of depletions would be 83 percent of the value of depletions under current rent method II at a 3 percent discount rate, and 60 percent at a 10 percent discount rate.

In summary, the present value method as implemented by BEA takes the values of additions, depletions, and stocks calculated according to current rent method II and multiplies them by discount factors of between 59 and 88 percent. The reason for the discount is straightforward. Under current rent method II, which relies on the Hotelling valuation principle, it is assumed that net revenues rise at the discount rate. Under the present value approach, net revenues are assumed to rise at rates that are 3 or 10 percent slower than the discount rate applicable to mineral assets. The higher percentage is the discrepancy between the rise in net revenues and the discount rate; the lower is the discount factor. The NPV approach is shown in Box 3–5 .[8]

Replacement Cost

The fourth method of calculating the value of the mineral stock is used only for oil and gas reserves. Despite its name, this approach is similar to the NPV method, not to the replacement cost method described earlier. It adopts the approach of Adelman (1990), who calculates the present value of an oil field using special assumptions. It is assumed that the production from an oil or gas field declines exponentially over time. Under the assumption that the decline rate is constant and

6. According to BEA, the rates were chosen to illustrate the effects of a broad range of approaches. The 3 percent per year discount rate has been used by some researchers to approximate the rate of time preference, while the 10 percent rate has been used by some researchers to approximate the long-term real rate of return to business investment.

7. At the 3 percent discount rate, the 0.86 discount factor holds for the years 1958 through 1977, with the rate edging upward thereafter as a result of commingling of reserves that were developed prior to 1973 (which BEA assumes are extracted over 16 years) with those developed in 1973 or later (for which a 12-year life is assumed). For the 10 percent discount rate, the 0.63 factor holds for the years 1958 through 1974. In 1987, the year for which BEA calculates a more complete set of satellite accounts, the rate is 0.88 for the 3 percent discount rate and 0.69 for the 10 percent discount rate.

8. As with the calculation of mineral values, the factors shown in Box 3–5 vary depending on the year of the analysis. The factors reported are those for the 1987 calculation. The factors differ in the various formulas because of the differing treatment of the timing of depletions and additions from reserves.

that the net revenue rises at a fixed constant rate that is less than the discount rate, a barrel factor is calculated. This barrel factor is multiplied times net revenue to obtain the present value of the reserves. Adelman estimates that the barrel factor is usually around 0.5. BEA does not give the barrel factor used in its calculations, which should vary by deposit and depend on the rate at which future cash flows are discounted, but we estimate that it averages approximately 0.375.

The value of the asset—calculated with current rent method II using the Hotelling valuation principle—is then multiplied by the barrel factor. The justification is that this NPV approach, unlike the Hotelling approach, takes the physical specifics of oil and gas extraction into account and accordingly adjusts the unit value of reserves downward. As with the NPV approach discussed in the last section, this adjustment accounts for the overvaluation inherent in the Hotelling valuation principle.

Once the value has been adjusted downward, BEA must again subtract the value of capital associated with the asset. With this method, the value of capital associated with each unit of existing reserves is assumed to be the current-year expenditure on exploration and development for oil and gas, divided by the quantity of oil and gas extracted during the year. This approach is loosely based on Adelman's suggestion that the value of capital associated with a unit of production can be approximated by measuring the value of capital associated with finding new reserves. The replacement cost method is shown in Box 3–6 .

Transaction Price Method

When oil and gas firms desire additional reserves, they can either buy them from other firms or find new ones through exploration and development. In the absence of risk, taxes, and other complications, the transaction price of purchasing new reserves should represent the market value of those reserves. For this reason, according to BEA, "if available, transaction prices are ideal for valuing reserves" (Bureau of Economic Analysis, 1994b:57).

In fact, transactions in reserves are few and far between outside of oil and gas, and even in oil and gas suffer from problems discussed above. To estimate transaction prices, BEA derived prices from publicly available data on the activities of large energy-producing firms for the period 1977 to 1991. The gross value of reserves was estimated by dividing expenditures for the purchase of the rights to the proved reserves by the quantity of purchased reserves. The result was then adjusted for associated capital using the same method as

Box 3–5: Formulas for Net Present Value Method

$$\text{total mineral reserve value}_{t@3\text{ percent discount rate}} = 0.88[p_t - a_t]R_t - 0.88K_t$$

$$\text{total mineral reserve value}_{t@10\text{ percent discount rate}} = 0.69[p_t - a_t]R_t - 0.69K_t$$

$$\text{additions}_{t@3\text{ percent discount rate}} = 0.84[p_t - a_t - K_t/R_t]\times A_t$$

$$\text{additions}_{t@10\text{ percent discount rate}} = 0.59[p_t - a_t - K_t/R_t]\times A_t$$

$$\text{depletions}_{t@3\text{ percent discount rate}} = 0.83[p_t - a_t - K_t/R_t]\times q_t$$

$$\text{depletions}_{t@10\text{ percent discount rate}} = 0.60[p_t - a_t - K_t/R_t]\times q_t$$

$$\text{revaluations}_t = V_t - V_{t-1} + \text{depletions}_t - \text{additions}_t$$

where variables are as defined in Box 3–3.

Note: The numerical values in this box apply to 1987. As explained in the text, slightly different values will apply for different years.

Box 3–6: Formulas for Replacement Cost Method

$$\text{total mineral reserve value}_t = V_t = \{0.375[p_t - a_t] - Z_t/q_t\}R_t$$

$$\text{additions}_t = \{0.375[p_t - a_t] - Z_t/q_t\} \times A_t$$

$$\text{depletions}_t = \{0.375[p_t - a_t] - Z_t/q_t\} \times q_t$$

$$\text{revaluations}_t = V_t - V_{t-1} + \text{depletions}_t - \text{additions}_t$$

where Z_t = value of exploration and development expenditures in year t, and other variables are as defined in Box 3–3.

Box 3–7: Formulas for Transaction Price Method

$$\text{total mineral reserve value}_t = V_t = (TV_t/TQ_t - K_t/R_t)R_t$$

$$\text{additions}_t = (TV_t/TQ_t - K_t/R_t)\times A_t$$

$$\text{depletions}_t = (TV_t/TQ_t - K_t/R_t)\times q_t$$

$$\text{revaluations}_t = V_t - V_{t-1} + \text{depletions}_t - \text{additions}_t$$

where TV_t = value of reserve transactions, and TQ_t = total quantity of reserves transacted, and other variables are as defined in Box 3–3.

in current rent method II. The transaction price method is shown in Box 3–7 .

Data Requirements

On the whole, the five valuation methods used by BEA are relatively parsimonious, and therefore the data requirements are not unduly burdensome. For quantity data, only reserves are considered, so the quantities of mineral stocks are easy to obtain. Most of the data required for valuation under the five methods either are already used by BEA in their construction of the NIPA or are publicly available or available at a modest cost from private sources. Constructing the accounts for subsoil minerals, therefore, required no independent data collection or survey by BEA. Nevertheless, there is no single consolidated source for the data needed, and considerable effort was expended by BEA staff in collecting the data.

Preliminary Results

The first set of estimates in the IEESA contains many important and useful conclusions. We highlight some of the key findings in this section.[9]

The calculations present a number of interesting findings for the overall economy. All five evaluation methods indicate that the value of the stock of oil and gas reserves in the United States exceeds the value for all other minerals combined. For all subsoil minerals, the calculated value of reserve additions has approximately equaled the value of depletions over the 1957–1991 period. Consequently, the value of reserves (in constant prices) has changed little during the reporting period. BEA finds that the value of the mineral component of a mineral asset is about 2 to 4 times the value of the associated capital, so the value of the mineral makes up 67 to 80 percent of the total value of any mineral asset.

The results are also helpful in understanding returns to capital of U.S. companies. Standard rate-of-return measures include profits on mineral assets in the numerator, but exclude the value of mineral reserves in the denominator. Gross rates of return for all private capital decline from 16 percent per year if mineral reserves are excluded to 14–15 percent if mineral reserves are included. BEA does not present net returns, however. Because net post-tax returns on nonfinancial corporate capital have averaged around 6 percent per year over the last three decades, our estimate of the profitability of American corporations would be significantly modified if the 1–2 percentage point decline in the gross return carried over to the net return.

In quantity terms, the physical stock of aggregate metal reserves has tended to decline over time, while the physical stock of coal reserves has increased. Quantities of oil, gas, and industrial minerals ("other minerals" in BEA's five broad categories) have remained stable. Revaluations have tended to be positive primarily because the prices of most subsoil minerals have risen over the period under investigation.

BEA estimates the value of the nation's stock of mineral reserves, after deduction of associated capital, to be between $471 billion (current rent method I) and $916 billion (current rent method II) for 1991; this figure amounts to between 3 and 7 percent of the value of produced assets (existing produced structures, equipment, and inventories). Current rent method II yields the highest stock and flow values for all mineral types. Current rent method I yields the lowest values for coal, metals, and other minerals, while the transaction price method yields the lowest value for oil, and the replacement cost method yields the lowest value for gas. (Recall that these last two methods are used only for oil and gas.) Given the algebra of the different valuation techniques, it is not surprising that the replacement cost method yields lower values than the current rent methods for gas since the replacement cost method is really current rent method II multiplied by 0.375.

One important question concerns the impact of including subsoil minerals in the overall national accounts. In 1987, the year for which BEA presents the IEESA asset accounts, the calculated value of reserve additions roughly offsets reserve depletions, so including mineral assets in the NIPA for that year would not substantially alter the estimate of the level of net domestic product (NDP). It would, however, increase the level of GDP by between $17 and $65 billion (0.4 to 1.4 percent of GDP), depending on the method used to value reserve additions. The only year in which the mineral accounts would have a substantial impact on the growth of real GDP or NDP is 1970, the year Alaskan reserves were added. Box 3–8 shows the calculations of real GDP (in 1987 prices) with and without mineral additions for that year. The large surge of oil reserves erases the recession of 1970 and leads to a downturn in growth in 1971. While this kind of volatility is unique in the period analyzed by BEA, it does indicate that in-

9. These findings are presented in Bureau of Economic Analysis (1994b) and summarized in Table 4–1 in Chapter 4 of this report.

Box 3–8: Growth in Real Gross Domestic Product and Net Domestic Product With and Without Mineral Additions[a]

	(1) Conventional GDP	(2) GDP with Mineral Additions
1969	2.72	2.37
1970	0.03	3.14
1971	2.85	-0.08

	(3) Conventional NDP	(4) NDP with Mineral Additions and Depletions
1969	2.53	2.13
1970	-0.40	2.98
1971	2.71	-0.48

[a] Percent per year.

Source: Conventional GDP and NDP in 1987 prices were calculated by BEA (*U.S. Congress Economic Report of the President, 1995*). GDP with mineral additions was calculated based on data in columns (1) and (3) and estimates of mineral additions and depletions from Bureau of Economic Analysis (1994b:60). Mineral additions and depletions in this calculation rely on current rent method I.

troducing minerals into the accounts might lead to large changes in measured output that would reflect primarily changes in mineral reserves.

EVALUATION OF BEA'S APPROACH

This section evaluates the methodology of BEA's preliminary approach to accounting for subsoil minerals. We begin with the advantages of the approach and then review some issues and concerns.

Advantages

Feasibility

Phase I of BEA's plan for extending the national accounts to include supplemental mineral accounts is now complete. In accordance with the recommendations of the United Nations System of National Accounts (SNA), BEA limited the focus of Phase I to mineral reserves. This is probably the simplest of the natural-resource sectors to include because the output is completely contained in the current national accounts and involves primarily estimating and valuing reserve changes. The data, although obtained from various sources, are publicly available from the (former) Bureau of Mines, the U.S. Geological Survey, the U.S. Department of Energy, and the Bureau of the Census. Some minor adjustments of the data were needed in cases where the definition of reserves changed over time.

BEA began this work in 1992 and completed it in April 1994. Given the late start and limited resources of the U.S. natural-resource accounting effort, along with the sparsity of observable market prices with which to value mineral additions, depletions, and stocks, the progress made by BEA to date is remarkable. Furthermore, the task was completed by a group of eight BEA officials working part time on this assignment while continuing with their regular duties. The result is a partially completed satellite account that fits into the current definitions of the U.S. NIPA and can be readily prepared in a short amount of time. BEA's approach is therefore clearly feasible and relatively inexpensive.

Consistency with Other Valuation and Accounting Frameworks

BEA treats mineral additions in parallel with other forms of capital formation. In this respect, the U.S. accounts differ from the System of Integrated Environmental and Economic Accounting (SEEA), an alternative satellite accounting system proposed by the United Nations. In both accounting systems, depletions are treated as depreciations of the fixed capital stock. Under the SEEA, however, additions are not included as income and do not appear in the production accounts as capital formation.

In calculating GDP, the SEEA considers as capital formation only investments in "made capital" and not mineral finds, treating discoveries as an "off-book" entry. This approach avoids the volatility associated with mineral finds, which, if included in GDP, makes GDP a volatile series (see Box 3–8). BEA, on the other hand, treats mineral assets on the same basis as fixed capital. For example, according to BEA calculations, booking the exceptional Alaskan oil finds in 1970 augmented the existing stock of U.S. oil assets by nearly 50 percent, or almost $100 billion in 1987 prices, despite exploration investments on these reserves that were only a fraction of this amount. Including the increase in mineral reserves in private investment would have increased gross investment by 26 percent in 1970 and would have increased net investment by 42 percent. As is seen in Box 3–8 , the trend in real nonminerals GDP growth would have been seriously distorted, wiping out the 1970 recession and causing an apparent recession in 1971. Thus, while including mineral additions as capital formation treats made and natural capital augmentations in a parallel fashion, the aggregate GDP series may become more volatile and may not accurately reflect movements in production and employment.

A second concern with treating mineral additions as capital formation is that the two do not necessarily have the same effect on the economy. In particular, when fixed capital is added to the capital stock, payments have been made to the factors of production involved in producing the capital. Mineral-stock additions, in contrast, reveal themselves as increases in land value, which are balance sheet adjustments rather than payments to factors of production. It is for this reason that the United Nations SEEA approach omits additions from net investment in the production accounts and introduces a reconciliation term in the asset accounts to capture additions.

Finally, it has been argued by some that mineral stocks are inventory and should be treated as such in the NIPA. BEA chooses to treat mineral stocks as fixed capital, suggesting that, just as with produced fixed capital, expenditures of materials and labor are needed to produce these mineral assets, which in turn yield a stream of output over an extended period of time. The treatment of mineral stocks then becomes consistent with the treatment of traditional capital in the NIPA. Of course, the concept of a satellite account allows individual policy researchers to take the information in these accounts and make their own adjustments to the NIPA. The BEA approach is just one potential way of treating natural capital formation and depletion.

In terms of valuation methodology, the BEA approach is consistent with current mineral asset valuation theory.

Utility

BEA presents an IEESA Asset Account and an IEESA Product Account that supplement the NIPA. Researchers, businesses, and policy makers can use the satellite accounts to adjust output and income measures as they see fit, focusing on any or all of the five valuation methods used by BEA. Moreover, BEA presents separate entries for five types of mineral assets, including three types of fuels, and an aggregate mineral category.

This level of detail makes the satellite accounts useful to policy makers who wish to focus on particular mineral issues. The data on the value of mineral stocks, additions, depletions, and revaluations (the residual) are given annually for the 1947–1991 period for oil and gas (the two most important mineral groupings in terms of total stock value) and from 1958 to 1991 for the other three mineral groupings. The constant (1987) dollar figures for the aggregate mineral stock show a price-weighted index of the stock, as well as of additions and depletions to the aggregate, and are useful for determining whether the aggregate price-weighted quantity of U.S. mineral reserves is changing over time. One of the important findings from the BEA data is that the index of the total constant-price stock of mineral assets has been approximately constant from 1957 to 1991. This implies that the nation has on average replaced reserve depletions with an equivalent quantity of reserve additions (or, more precisely, quantities of reserve additions and depletions of different minerals weighted by 1987 prices).

Issues and Concerns

BEA's approach to calculating mineral stock and flow values raises a number of issues related both to measurement problems and to conceptual concerns with the individual valuation techniques. Some of these issues are intrinsic to any accounting approach in which data on prices or quantities must be imputed or constructed, while other issues arise for particular methodologies. The major issues are reviewed here.

Heterogeneity of Reserves

A major problem with most accounting approaches is that they assume all reserves are homogeneous in terms of grade and costs. For example, under the Hotelling valuation principle, average extraction cost should be calculated as the average cost of extraction from all reserve classes. In practice, most techniques use the extraction cost of currently extracted reserves. The reality is that a nation's reserves are not all in one cost class. It has already been noted that reserves are likely to exist in a number of classes, ranging from high quality (low cost) to low quality (high cost). Resource accounting, such as that in the current IEESA, generally treats the entire national stock as one heterogeneous deposit whose value is calculated by multiplying the average unit value of that reserve by the quantity of the reserve.

An example will illustrate the issues raised by resource heterogeneity. Suppose that a nation owns 100 million ounces of subsoil gold reserves whose total value is $1 billion, for an average unit value of $10 per ounce. In a given year, the nation extracts 1 million ounces, with no additions, and the value of the remaining reserves with unchanging gold prices is $989 million. Accordingly, the depletion is measured at $11 million, with an average value of $11 per ounce extracted. This pattern is typical of many extraction profiles in which the lowest-cost and highest-value resources are extracted first.

Note that the correct depletion charge is the value of the extracted ore times the quantity extracted, for a total of $11 million. If we were instead to use the average value of the ore of $10 per ounce to value depletion, we would be underestimating depletion at $10 million rather than $11 million. Moreover, if we used the value of the extracted reserve to value the remaining reserves of 99 million ounces, we would incorrectly value reserves at 99 x $11 = $1089 million, rather than the correct $989 million. This example shows that with reserve heterogeneity, using the average reserve value to estimate depletion is likely to understate depletion, while using the value of the extracted resource to value remaining reserves is likely to overstate the value of reserves.

This example is useful because common practice in constructing national resource accounts, and one of BEA's approaches, uses the average value of the extracted resource to value the entire reserve stock. Nor can average costs from current production be used to calculate the net present value of additions. Because of the random quality of additions, it is not possible to determine whether additions will be undervalued or overvalued using these cost data. Heterogeneity of reserves poses problems for the transactions approach because transaction values need not reflect the average value of the total reserves, as those parcels of reserves sold in any one period may have a quality above or below the average. All these problems of heterogeneity are particularly severe for metals, because there is a clear tendency for ore grades to fall over time. The issue is less clear for petroleum because new findings may have lower cost than current production, but the general trend in petroleum has been for lower finding rates per unit drilling.

Putting the point differently, the difficulty in valuing the stocks and flows arises because the prices of reserves are not readily available. Although the commodities, such as gold and oil, trade frequently, the underlying assets tend to trade infrequently. There is no organized market for oil or gold properties, and there is such great heterogeneity in these assets that there is no standard for classifying them as there is for oil or gold (in terms of sulfur content, purity, and the like). When reserves are transacted, the prices are not generally publicly available, which means the reserve prices are generally not observable. A further difficulty is that the tendency is to observe the value of the total bundle of assets and liabilities (reserves, associated capital, environmental liabilities, royalty and tax obligations, and so on), so that even if the transaction price were observed, the price of the mineral reserve could not readily be determined. All these complications mean that the values of reserve stocks, additions, and depletions—which are essential for the construction of national accounts for subsoil assets by BEA and other statistical agencies—must be estimated using the relevant economic and financial theories of valuation.

In principle, the heterogeneity problem could be overcome by calculating reserve values for each reserve class and then aggregating across reserve classes. This approach is likely to be quite costly, and extraction data may not be available for all reserve classes, particularly those not yet being exploited. However, since these disaggregated calculations are not undertaken by BEA, its estimated values for the total reserve stock are likely to be too high for many of the minerals.

If in fact the lowest-cost and highest-value reserves are extracted first, the use of extraction costs from current depletion will provide a biased estimate of reserve values. All of the BEA valuation methods except the transaction cost method use an inappropriate measure of reserve values based on the cost of current extraction. Although BEA does not report total mineral asset and mineral resource values separately, the estimation bias in the asset value will flow through to the calculation of the mineral value that BEA does report in Table 1, rows 36 through 41 (Bureau of Economic Analysis, 1994a). The result will be an upward bias in the mineral-resource values calculated with current rent method II. Whether this bias carries through to the calculation of mineral-resource values in the other calculation methods is unknown since, as discussed below, the deductions for capital may be too high or too low with the other approaches.

A similar problem arises in valuing reserve additions, since BEA assumes they have the same characteristics as current depletions. Consequently, if the quantity of additions equals the quantity of depletions, the value of additions will equal the value of depletions, even though the grade of reserves may be quite different for depletions and additions. BEA's approach is likely to overvalue additions. With the best deposits extracted first, additions are likely to be of less value than current depletions. This discrepancy will affect the IEESA production account since with a lower value for additions, the adjusted GDP and NDP figures will be lower. The discrepancy also introduces a downward bias into the revaluations of minerals because of the overstatement of additions.

Measures of Resource Quantities

Although most of the issues in minerals accounting involve valuation, issues involving the quantity of reserves or resources are also important in a few areas.

The first of these issues relates to the comprehensiveness of the resource base considered by BEA. In constructing product and asset accounts, one is concerned with valuing the stock of the nation's mineral resources and estimating changes in the value of the stock due to depletions, additions, and revaluations. These quantities are measured with considerable uncertainty. An important issue here (as it is throughout the federal statistical system) is developing measures of accuracy, both for satellite accounts and the main accounts. Mineral resources other than reserves are often unknown or not well established and thus are also quite difficult to measure with any accuracy. In all cases, even where quantities are known, their value is not easily calculated. For example, resource class N in Figure 3–2 has an average current extraction cost above price; thus, according to the Hotelling valuation principle, its value is zero. All resources other than reserves (classes N and above in Figure 3–2) are assigned zero value. For both practical and economic reasons, BEA considers only reserves in its IEESA. Hence, BEA's asset account includes a blank row for measures of stocks and of additions to and depletions from unproved subsoil assets. Yet these nonreserve resources are likely to have some positive market value because of their option value.

A related flaw in the BEA preliminary accounting framework is that current additions to reserves produce no compensating depletion of nonreserve resources. Yet every ton of reserves comes from nonreserve resources. If nonreserve resources have economic value (as they certainly do in the case of many oil and gas properties), the result will be an upward bias in the current estimates of net capital formation (additions minus depletions) in mineral resources. The failure to consider nonreserve resources means that additions to, as well as depletions from, different categories of nonreserve mineral assets are ignored. For example, adjacent drilling may lead to moving a resource from the speculative to the hypothetical category or from an inferred submarginal resource to a demonstrated subeconomic resource (see Figure 3–1). Proven reserve quantities sometimes change dramatically because previously uncertain nonreserve resources are found to be economic (e.g., Alaskan oil). Because the option values of different grades will differ, the overall bias in mineral capital formation could be in either direction. The basic problem again is valuing nonreserve resources. BEA intends ultimately to include unproved resources as a part of nonproduced environmental assets.

It is recognized that current estimates of mineral capital formation are incomplete and likely to be biased. BEA correctly notes that an operational methodology for valuing these nonreserve resources is not yet available. As with reserves, market prices based on resource transactions are not widely available, especially outside of oil and gas, and unit prices must be deduced using related economic series. Economists are currently involved in developing methods for valuing such resources. However, official natural-resource accounting procedures have without exception omitted nonreserve mineral assets. Fortunately, the omitted value may not be great.[10]

A final issue is that BEA values only a subset of U.S. mineral reserves. Omitted are several heavily mined industrial minerals such as sand and gravel, which may have small scarcity or Hotelling rents because of their superabundance but Ricardian rents because of their location. In production terms, BEA considers minerals that made up 77 percent of the value of mineral and energy production in the United States in 1970, a year in the middle of the available time series (Bureau of Mines, 1972). The BEA series is incomplete, but it values the most important mineral reserves, at least in terms of production value, in the United States.

Measurement of Associated Capital

Accounting for minerals poses serious issues of jointness of value of the mineral resource

10. Kilburn (1990) suggests that the value of metalliferous ores in unexplored land is $Canadian 400 per 16.3 hectares. This equates to $US 7 per acre. Maintaining mineral claims in the United States requires an annual payment of $5 per acre, which, at a discount rate of 10 percent per year, equates to a net present value of $50 per acre. Hence, unexplored leased land with some indication of mineral potential would appear to have a market value of at least $50 acre. If 100 percent of the 387,000,000-acre U.S. land mass is mineable in the future (an obvious overestimate), the current value of subsoil mineral resources other than reserves is on the order of $19.4 billion at $50 per acre. Even when allowance is made for energy resources and industrial minerals and offshore petroleum potential, the total present value of resources, other than reserves, is unlikely to exceed $100 billion. BEA calculates a current reserve stock value of some $700 billion.

and the associated capital. Because these are complementary factors, dividing the total value between capital and minerals is difficult and involves somewhat arbitrary accounting conventions. Similarly, when minerals are extracted, the value of the existing mineral asset diminishes. Some of the decreased value is depreciation of capital, while some is depletion of the mineral reserve. The total depreciation in asset value due to extraction must be apportioned between the two in resource accounting. With capital depreciation being determined by guidelines that apply to capital more generally, the residual loss in value is then applied to depletion (see Cairns, 1997). The only rules that apply are that total depletions over the life of the asset must sum to the value of the resource, and the total depreciation over the life of the asset must sum to the value of installed capital. Hence in an accounting framework that must separate depletion from depreciation on an annual basis, the depletion numbers are based arbitrarily on the depreciation schedule chosen, being less than the total decrease in the value of the asset, but greater than zero. One comforting factor, however, is that although the breakdown in value or change in value between the capital component and the minerals component is somewhat arbitrary, this affects only the composition of the depletion and depreciation values and not the total asset value.

Once the value of a mineral asset has been calculated, the value of associated capital must be deducted to produce the mineral-reserve value. Only current rent method II and the transaction price method deduct associated capital appropriately. Because the value of the asset is likely to be overestimated through use of the Hotelling valuation principle, current rent method II will nevertheless tend to overvalue the stock of mineral reserves. Setting aside issues of heterogeneity and assuming that appropriate corrections are made for associated assets and liabilities, the transaction price method is the only method that in principle can provide unbiased estimates of the mineral value.

Current rent method I deducts depreciation and the gross return for capital per unit of extraction from gross price (see Box 3–3). Since one does not know whether this subtraction is more or less than the subtraction under current rent method II, one cannot say whether the calculated value of mineral-resource value using current rent method I will be too high or too low, even given its upward bias in the calculation of the total asset value due to use of the Hotelling valuation principle. In the case of the metals category, however, current rent method I gives negative values for the stock of metal reserves in the 1980s, which are clearly biased downward. It appears, then, that with current rent method I, the upward bias in measurement of total asset value due to use of the Hotelling valuation principle is outweighed by an excessive deduction for associated capital.

As noted in the previous section, the NPV method deducts some fraction of the value of associated capital. Doing so would make sense only if the value of the associated capital were thought to be less than its replacement cost. On average, one would expect the value of the associated capital to equal its replacement cost. The deduction for capital cost under the replacement cost method (see Box 3–6) also will generally not reflect the value of associated capital.

BEA includes exploration and finding costs as part of associated capital and then deducts these costs as part of the capital costs when valuing mineral reserves. This practice raises the question of what BEA is actually trying to value. If, for example, a gold deposit before the installation of any development expenditures or physical capital can be sold for $10 million dollars, some would suggest this is the value of the mineral reserves. BEA subtracts past exploration costs from this figure, and thus would value the mineral component of the property at less than $10 million. The former approach values the asset as a “gift of nature,” while BEA values it as the product of previous human endeavor and charges the stock account with the cost of moving the mineral from the resource to the reserve category.

Early models of mineral value suggested that depletion can be calculated as current net revenue less capital depreciation less a return to capital, and BEA follows this approach with current rent method I. Subsequent research, however, has shown that this approach overestimates depletion (Cairns, 1997; Davis, 1997). As a result, estimates of depletion with current rent method I are too high, perhaps by as much as half. The depletion calculations with each of the other methods, including current rent method II, do not conform to any known depletion formulations, and the level or direction of measurement bias cannot be determined. Nevertheless, the panel’s review indicates that the depletion calculations with current rent method I represent an *upper bound* on depletion. Moreover, according to Cairns (1997) and Davis (1997), depletion can be appropriately calculated if one takes depletion as estimated by current rent method I (that is, current net revenue less capital depreciation less a return to capital) and subtracts from this amount a return to the mineral resource.[11]

Production Constraints and the Hotelling Assumptions

As noted earlier, current rent methods I and II calculate total asset values based on the Hotelling valuation principle, which assumes that producers face no production constraints and that the net price rises at the rate of interest. In general, producers do face production constraints, and net prices rise at less than the rate of interest. The Hotelling principle is used as a valuation tool because of its extreme simplicity; yet, as discussed above, it has been shown both theoretically and empirically to substantially overvalue mineral reserves. Cairns and Davis (1998a, 1998b) and Davis and Moore (1997, 1998) demonstrate that asset values calculated using the Hotelling principle tend to be up to twice the market values. Thus caution is necessary in using this approach to provide asset or mineral-resource values.

Because of the potential for overvaluation using the Hotelling valuation principle, BEA uses the NPV method to adjust the stock estimates from current rent method II downward. For purposes of the present discussion, BEA's approach is termed NPV variant I. As shown above in Box 3–5, this method takes the current rent method II stock values and adjusts them downward by 12 and 31 percent using the two assumed discount rates.

The replacement cost formula is based on a model that does not require the strict assumptions of the Hotelling valuation principle and implicitly takes into account the capital constraints on oil and gas production (see Cairns and Davis, 1998a). Therefore, given the appropriate value for average costs, the model is likely to yield an accurate estimate of asset values. There has been no empirical verification of Adelman's replacement cost rule for valuing the associated capital, however, so it is not possible to judge the accuracy of the BEA method for deducting the value of associated capital to obtain the value of a mineral resource. BEA might, however, consider an alternative approach (termed here replacement cost variant II) that would subtract the replacement cost of capital from the asset value as in current rent method II, rather than the value of exploration and development expenditures.

11. In mathematical terms, $\text{depletions}_t = [p_t - a_t - r_t K/q_t - D_t/q_t - rV_t/q_t] \times q_t$, where the variables are as defined in Box 3–3.

Royalty and Severance Fees

The transaction price approach has the potential to yield reasonable mineral-reserve values since it is based on observed market prices that in principle account for production constraints, market discount rates, actual reserve quality, and other factors that affect the value of mineral reserves. As noted elsewhere, however, the market value of an asset depends on the liabilities attached to the asset. In the case of minerals, production often incurs royalties, severance fees, and taxes payable to third parties as production proceeds. These and other liabilities attached to current and future production reduce the observed market value of the reserve and are deducted from the asset value by the purchaser during a reserve transaction. Thus, the observed transaction value does not represent the value of the reserves, but the value of a bundle of financial and real assets and liabilities, of which the reserves are one aspect (a point illustrated above in Box 3–2).

The treatment of these costs is not clear in BEA accounts. It appears that royalty and severance taxes are included in the unit costs used to calculate net rent in valuation methods other than the transaction method for oil and gas. This treatment is inconsistent with that under BEA's transaction price method, whereby no adjustment is made for the present value of taxes and royalties. In both cases, the pre-tax-and-royalty value of the resource will be underestimated by BEA's methods.

Revaluation

Revaluation effects are an additional element of natural-resource accounting and some other augmented accounts that are not present in the current U.S. NIPA. As discussed earlier, changes in the value of reserves are composed of additions, depletions, and revaluations (see equation 3.5 in Box 3–2).

For a simple gold-reserve case, revaluations enter the equation when reserve values adjust during the accounting period to reflect unexpected price changes. For example, suppose the average price of the existing gold-reserve stock is \$10 per ounce at the start of the year, then jumps to an average of \$20 per ounce on December 31. The revaluation equation becomes: revaluations (\$1 billion) = closing stock value (\$2.019 billion) – opening stock value (\$1 billion) – additions (\$30 million) + depletions (\$11 million). This example shows that revaluations are calculated as a residual—the change in the value of the stock through price changes that are not taken into account in the depletion and addition calculations. Given the volatile nature of mineral prices, the revaluation component is substantial, often larger than additions or depletions. Yet the revaluation term is not directly calculated; it will include any errors in calculating additions, depletions, and opening and closing stock values.

Mineral-stock revaluations caused by unexpected changes in unit prices for reserves are calculated by BEA as a residual, and therefore are also affected by the capital depreciation schedule chosen. In the BEA data, mineral-stock revaluations are usually greater than either reserve additions or depletions, implying that most mineral wealth creation or loss comes not from additions to or depletions of the mineral-reserve base, but from large mineral price changes. Several resource economists have suggested that these revaluations are important indicators of economic welfare and should be considered equivalent to investment (gross domestic capital formation).[12] For example, a small nation could in principle sell its mineral assets to a foreign producer, and hence an upward revaluation of its assets would create wealth and higher sustainable consumption for the nation. BEA does not include revaluations in the gross domestic capital formation column of its IEESA Production Account and thereby ignores this aspect of sustainable national income.

Short-Run Volatility in Price

Where the value of a mineral asset is a function of the current extracted mineral price, as in current rent methods I and II, the NPV method, and the replacement cost method, short-run volatility in mineral commodity prices makes the value of the stock of mineral assets itself a volatile series. To the extent that price movements are temporary excursions from long-run levels, these changes in stock value will show up as revaluations. Current measures of national saving do not include revaluation effects, but future measures might do so. It should be noted that the revaluation effects in mineral assets pale in comparison with the revaluation effects from security markets.

In addition, the depletion calculations depend in part on current prices and will also be affected by price volatility. For example, consider an economy that is running down its mineral reserves at a constant rate, with no reserve additions. Depletion values will depend on current mineral prices. If nominal mineral prices increase sharply in a given year, the depletion charge will also rise sharply.

The dependence of additions and depletions on current mineral prices will affect the current value or nominal value of augmented GDP if minerals are included. Sharp changes in mineral prices could also lead to a significant change in the augmented-GDP deflator or chain-weighted price index. The volatility of prices would not lead to volatility in the constant-price or chain-weighted indexes of real output under current concepts applied in the U.S. national accounts, but it would affect those measures of sustainable income that include elements of revaluation. These effects will necessitate considerable care in interpreting movements in GDP and its components if additions and depletions are to be added to the core GDP accounts.

BEA mitigates problems of price volatility by arbitrarily using annual prices averaged over 3 years. In addition, quantity additions and depletions are in most years nearly offsetting; thus, given BEA's approach of valuing additions at the same unit price as depletions, price fluctuations will have little impact on adjusted NDP figures. Price fluctuations do impact the stock revaluations column, but these data are not currently used in current accounting measures.

Scarcity and Long-Run Price Trends

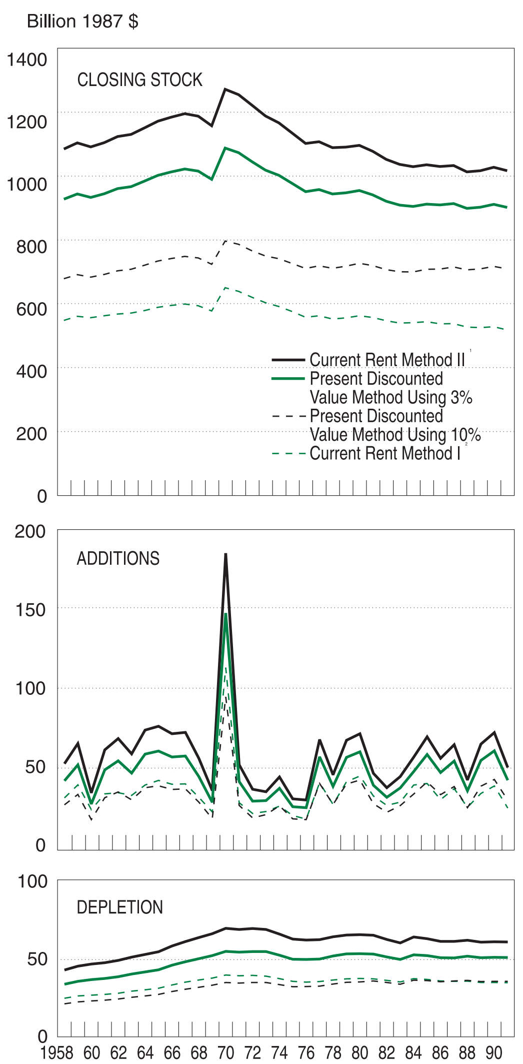
One possible use of a series showing the change in quantity and value of a nation's stock of minerals is for assessing trends in mineral scarcity. In quantity terms, increasing scarcity might be reflected in a declining constant-dollar stock of mineral resources or of some component of mineral resources. On this front, BEA is developing a constant-1987-price series for mineral stocks, shown in Figure 3–4, that is equivalent to a physical quantity series, aggregated across different mineral types on the basis of 1987 mineral prices. This graph shows that the stock of mineral assets as a whole has been roughly constant over the 1958–1991 period. This finding might be interpreted as indicating that additions have offset depletions and that concerns about the United States running out of oil and other minerals are unfounded. Figure 3–5 shows the value of stocks and changes in current prices (from Bureau of Economic Analysis, 1994b).

The constant-price stock has limited utility as an indicator of natural-resource scarcity, however. Depletion of a physical resource indicates nothing about scarcity if that commodity is

12. The issue of inclusion of revaluation in income is considered in Chapter 2.

becoming worthless to society, since its disappearance will have no economic consequences. (In this respect, even chain-price indexes will not produce improved indicators.) Stock measures are particularly questionable indicators for commodities that are heavily involved in international trade, which includes all major mineral commodities. For example, many countries have seen the economic value of their domestic coal stocks decline, primarily because of the availability of low-cost coal on the world market, but this is not taken as an indicator of coal scarcity.

Relative price is usually a better index of economic scarcity, with increasing relative prices indicating that a unit of the particular asset is becoming more valuable to society, and hence more scarce, relative to other assets.[13] Thus a mineral reserve's unit price is an indicator of its value to society. Increasing scarcity would be indicated by rising average reserve prices relative to other prices; for example, one might compare the relative prices of reserves and consumption goods and services or the ratio of reserve prices to the prices of other inputs, such as wage rates. These scarcity indices are not currently presented in satellite accounts. BEA does not report unit prices for reserves, and thus it is difficult to determine the implications of its findings for trends in mineral scarcity. If scarcity indicators are desired, deflated per unit prices for each type of mineral reserve should be presented.



1. Based on the value of capital stock.
2. Based on the average return to invested capital.

FIGURE 3-4 Stocks and Changes in the Stocks of Subsoil Assets in Constant 1987 Dollars for the United States, 1958 to 1991. Source: Bureau of Economic Analysis (1994b:Chart2).

Data Availability Issues

Although BEA's valuation methods require limited data, all may suffer from potentially significant measurement error. For example, while the replacement cost method of valuing oil and gas reserves is conceptually appropriate, it requires an estimate of the value of associated capital that cannot be measured directly and must be estimated through current exploration and development expenditures. There is no indication that this estimate, as proposed by BEA, has any empirical validity. The transaction price method is also conceptually correct, but one must make adjustments to the transactions, as listed in Box 3–2, to obtain the reserve value. The necessary data may not be available for each transaction, causing the method to lose its appeal. The current rent methods, once correctly formulated to take production constraints into account, will require average cost data that are not always observable in markets.

Other Issues

Whenever asset valuation requires discounting of future cash flows, as is the case in the valuation of mineral stocks, questions arise as to the appropriate discount rate. Finance theory offers some theoretical guidelines, but practical implementation is difficult. The popularity of the formula based on the Hotelling valuation principle derives in part from the fact that it does not require a discount rate, but this advantage comes at the cost of an implausible assumption about the increase in net mineral rents. In constructing present

13. Measures of resource scarcity are reviewed in Fisher (1981: Ch. 4).

value estimates, it is difficult to justify the extremely low real discount rate of 3 percent per year used by BEA if the purpose of the estimates is to determine the market value of the reserves.

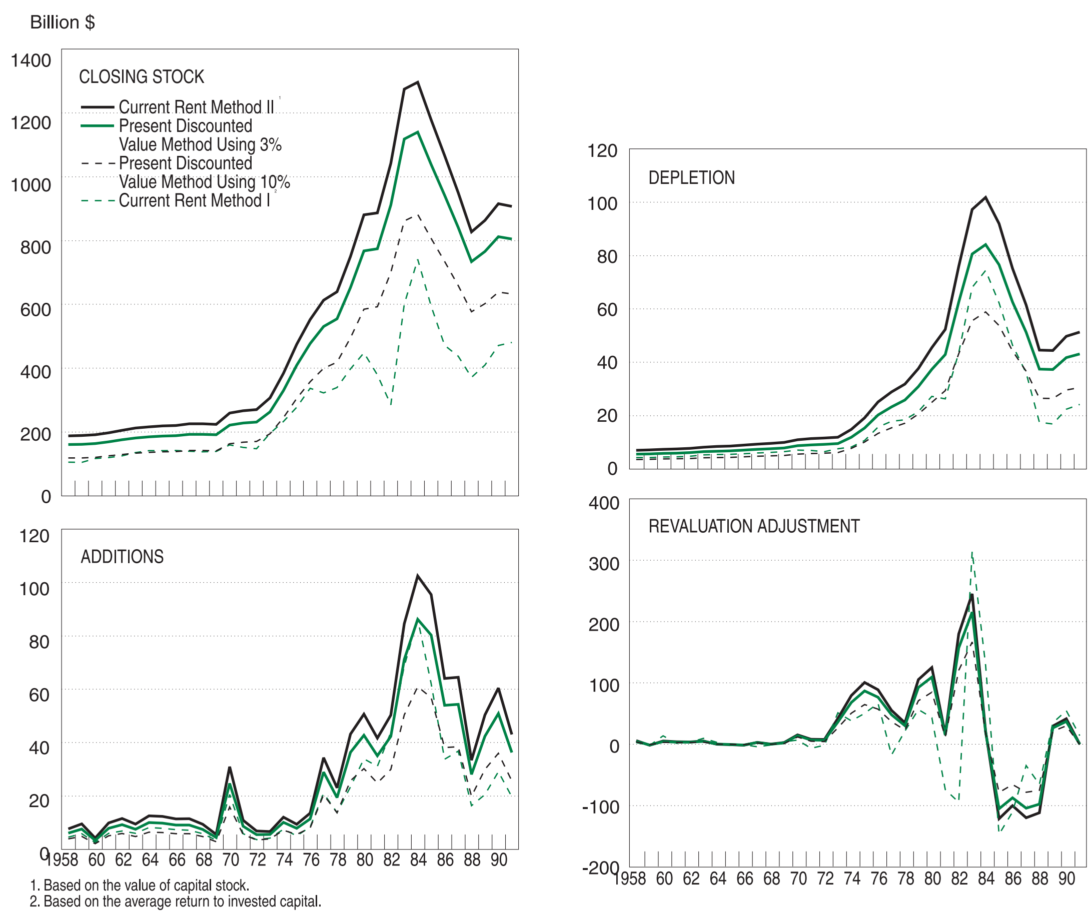
All NPV techniques, which include both current rent methods and the replacement cost method, omit asset value that is created by managerial flexibility (see Davis, 1996). With mineral assets, the ability to alter extraction as prices move up or down can create significant option value, especially for marginal deposits. Of the valuation techniques used by BEA, only the transaction approach includes these option values, since they will be included in the observed asset price.

BEA's results show clearly the potential margin for error among the various techniques, for they yield widely different estimates. In some cases, the net change in the value of reserves (additions minus depletions) even has a different sign under different valuation techniques. All of this suggests that correctly accounting for mineral stocks and flows in a set of satellite accounts will be just as intensive an accounting exercise as current accounting for the stocks and flows of produced capital in the NIPA.

OTHER APPROACHES AND METHODOLOGIES

Efforts in Other Countries

Mineral accounts are currently constructed by many countries. The current rent and discounted present value valuation approaches used by BEA to calculate resource stock and flow values are similar to those employed in other countries, with current rent method I being used most widely. The shortcomings of this approach were discussed earlier. Other countries assume that the current rent, after a return to capital is deducted, represents the current unit price of all reserves; they then calculate the present value by discounting the projected rent using an arbitrary discount rate. Again, as noted above, this is an unrealistic method of pricing reserve stocks or flows.



1. Based on the value of capital stock.
2. Based on the average return to invested capital.

FIGURE 3-5 Stocks and Changes in the Stocks of Subsoil Assets in Current Dollars for the United States, 1958 to 1991. Source: Bureau of Economic Analysis (1994b:Chart 1).

Although BEA estimates only a set of monetary accounts, most other countries compute both physical and monetary accounts for reserves. In Europe the most important minerals are oil and gas under the North Sea. Indeed, the discovery of these resources and the economic-policy problems they created led Norway to pioneer the development of resource accounting in the 1970s. Most other minerals appear to have a market value barely in excess of production costs, and hence the valuations applied to subsoil assets result in a very small value for the stocks and depletion. In Canada and Australia, however, other minerals have a significant economic value.

Coverage

The types of minerals covered in studies for other countries are similar to those covered in the IEESA. Most countries tend toward a slightly broader definition of reserves: instead of the "proven" reserves included by BEA (those that are currently known to be commercially exploitable at today's prices and technology), other countries often include "probable" reserves (defined as those having a better than 50 percent chance of being commercially exploitable in the future). Canada and Norway distinguish between "developed" or "established" and undeveloped reserves. This distinction is useful for assessing options for the future schedule of extraction. The distinction is also necessary when applying current rent method II, under which the value of associated fixed capital is deducted from the value of the reserve, and which therefore applies properly only to those reserves for which all fixed capital needed to extract the reserves is already in place.

The minerals covered by studies for other countries include oil and gas, coal, and a selection of metal ores, depending on what appears important in a given country. Hence Canada includes about 8 basic metals, while Australia values nearly 30 minerals, including precious metals and gold. In Europe, however, most minerals other than North Sea oil and gas appear to have a very small value, and efforts have not focused on them.

Valuation

The valuation methods used by other countries are generally the same as those reviewed earlier. As in the BEA work, total resource values are a small fraction of national wealth. The starting point is physical data on the stock and annual use of the minerals. As noted early in this chapter, the simplest valuation techniques are current rent methods I and II, which derive a resource rent for the current period as the difference between the extraction costs and the wellhead or surface price of the mineral. Often this margin is relatively small and can be highly volatile when the selling price of the mineral fluctuates while extraction costs undergo little change. In some cases, such as coal extraction in many parts of Europe, the minemouth price of coal is consistently less than extraction costs, and extraction continues only because of subsidies. A negative asset value in this case may actually be realistic.

Most countries assume that the Hotelling hypothesis is inadequate and instead use the present discounted value of the expected future income stream from extracting mineral reserves. The future schedule of extraction is often assumed to be constant, or it may actually be determined by contracts with purchasers of the mineral. In the absence of other knowledge, prices are assumed to rise with expected future inflation. The discount rate used tends to be the historical average interest rate on government bonds (typically around 6 percent), which is taken to represent the opportunity cost of funds. Normal rates of return for industry generally, or the mining industry specifically, have also been tested. Because these returns include a risk premium, they are higher than government interest rates. An interesting and quite different valuation method adopted in The Netherlands is described in the next section.

Practice in Selected Countries

Australia. The Australian Bureau of Statistics publishes values of reserves and changes in reserves for nearly 30 minerals, including oil and gas, uranium, and gold. The valuation method used is essentially BEA's current rent method I. Even in resource-rich Australia, the reported value of subsoil assets is only one-tenth the value of the fixed capital in structures and equipment. The Australian Bureau of Statistics notes that economically exploitable reserves are only a very small proportion of the total resource. It also points out that its valuation techniques can give a misleading impression both of the value of reserves and of year-to-year changes in reserves because mineral prices fluctuate considerably.

Canada. Statistics Canada has estimated the value of reserves of oil, gas, coal, and eight metals using both current rent methods I and II, although its preferred valuation technique is the latter. Current rent method I sometimes produces negative values for mineral reserves.

Because Canada is concerned with regional depletion issues, it produces monetary and physical accounts for each province.

The Netherlands. Statistics Netherlands estimates the value of gas under the North Sea, the country's principal natural resource, by an unusual method. In all North Sea operations, governments (United Kingdom, Norway, The Netherlands) attempt to appropriate most of the resource rent through royalties and taxes. Instead of estimating the resource rent indirectly by the methods employed elsewhere, the Dutch estimate the resource rent directly from known government receipts. Tests by other countries have shown this method performs reasonably well for the North Sea fields, where governments take 80 percent or more of the resource rent.

Norway. The first work on resource valuation was done in Norway in the 1970s, when North Sea oil suddenly appeared as a major influence on the Norwegian economy. The Norwegians were pioneers in natural-resource accounting, beginning with oil, but later extending to other assets, such as forests. Their studies have had a considerable effect on subsequent work in other countries. The 1970s was, however, a period of massive changes in world oil prices that produced huge swings in the apparent value of this resource; as a result, many Norwegians concluded that their estimates had serious shortcomings. A number of Norwegian analysts concluded that physical data on resources were more useful. Norway recently resumed valuing natural resources to complete the balance sheets of national wealth for SNA national accounts.

Sweden. For its national accounts balance sheets, Statistics Sweden has calculated reserves and depletion of subsoil assets, in particular metal ores. The reserves covered are proven reserves, which are valued by BEA's current rent method I. Because prices of metals are volatile, the calculated resource rents occasionally turn negative, a problem reduced but not removed by adopting a moving average of prices. As a result of a fall in world copper prices, a proportion of the country's mineral stock has ceased to be economically exploitable and therefore may disappear from proven reserves.

United Kingdom. Estimates of the depletion of U.K. oil and gas in the North Sea were published in 1996 for several successively broader categories of resources—proven, probable, possible, and undiscovered but inferred from geological evidence. Several valuation techniques were tested, including current rent methods similar to those of BEA and the present value of the future income stream. Significant differences were observed in the estimates derived with the various techniques.

Other countries. Valuation studies by developing nations including Brazil, China, and Zimbabwe have produced other important findings (see Smil and Yshi, 1998 ; Young and Seroa da Motta, 1995 ; and Crowards, 1996).

Alternative Methodologies

One quite different methodology has not been employed by BEA—that of relying on financial information for individual firms. At the level of the firm, the value of mineral reserves can be imputed from data on financial balance sheets. Figure 3–6 indicates the calculations required. This method calculates a nation's mineral wealth by aggregating the values of the domestic mineral resources held by all resident mineral firms. This is a laborious process that requires assessing the balance sheets of both listed and unlisted companies. It also provides only private reserve values, since the owners of the reserve implicitly deduct the value of any taxes, royalties, and other payments on the mineral assets when attaching a value to equity capital. Finally, as with any calculation of the value of the reserve stock, it is difficult to apportion changes in total values of the mineral reserves among additions, depletions, and revaluations.

A much simpler approach entails empirically based modifications to current rent method II. Cairns and Davis (1998a, 1998b) have found that multiplying the total asset value as calculated using current rent method II by a fixed fraction can eliminate the upward bias in total reserve value and produce estimates that are closely aligned with the observed market values of mineral assets. The fraction used, which lies between zero and one, varies by commodity. Cairns and Davis' work suggests a fraction of 0.7 for gold reserves. Work by Adelman suggests a fraction of 0.5 for oil and gas reserves. For other mineral reserves, the appropriate fractions have yet to be determined, but are likely in most instances to be around 0.6 according to Cairns and Davis (1998b). To estimate the value of the mineral reserves, the value of associated capital must still be deducted from the total asset value. This can be done in the same manner as in current rent method II. The mathematical formulation of this modified reserve valuation approach is shown in Box 3–9 .

Additions are simply the value of new reserves, which can be calculated with the same formula used for valuing total reserves, except that exploration and development expenditures, rather than existing associated capital, are deducted. The formula for valuing additions is given in Box 3–9 .

Depletion calculations have been studied by Cairns (1997) and Davis (1997), who suggest a modification to the BEA depletion calculations (see Box 3–9). Cairns and Davis take the depletion calculation of current rent method I and deduct an additional term that reflects a return

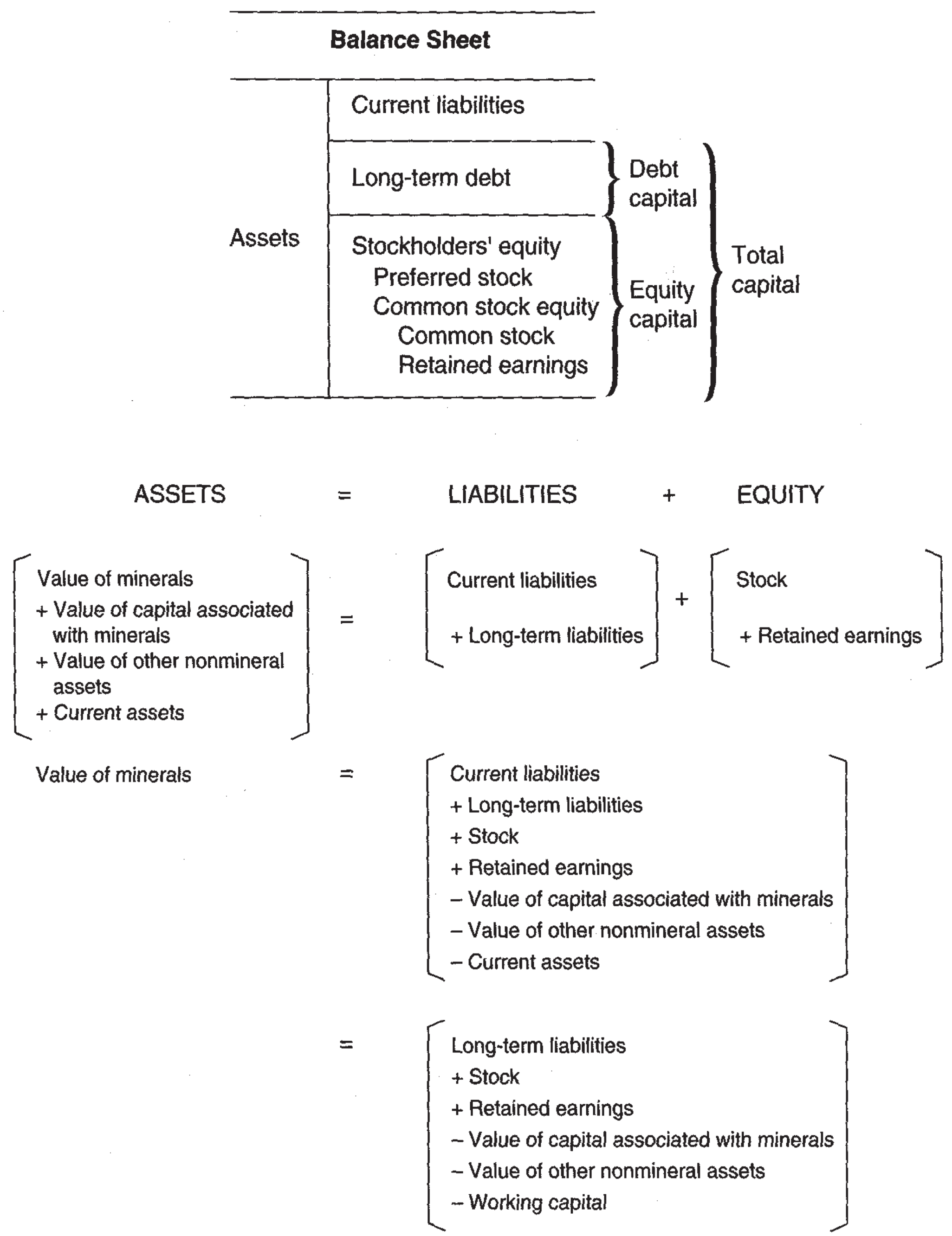


FIGURE 3-6 Imputing the Market Value of Mineral Resources from Balance Sheet Data,

to the mineral. This modification lowers the depletion calculation of current rent method I.

The discussion thus far has been aimed at estimating the value of the reserve stock and the value of depletions from and additions to that reserve stock. The discussion is guided by the notion that produced capital and natural capital are currently treated asymmetrically in national accounting and that this discrepancy should be corrected. There are yet other approaches that take a "sustainability" perspective. El Serafy (1989) has devised an alternative approach to adjusting NDP to account for mineral depletion. As currently measured, NDP is temporarily augmented during mineral extraction. El Serafy would convert the temporary revenue stream from mineral extraction into the equivalent infinite income stream, likening this latter stream to permanent income from the mineral asset. He thus advocates deducting an amount from the conventionally measured NDP during the extraction period to create an adjusted sustainable NDP.[14] It may be noted that the production of satellite accounts is intended to address just this type of concern, since those who prefer El Serafy's concept of sustainability to other accounting conventions can make their own adjustments to national output using the information contained in satellite accounts.

CONCLUSIONS AND RECOMMENDATIONS ON ACCOUNTING FOR SUBSOIL MINERAL RESOURCES

Appraisal of BEA Efforts

3.1 BEA should be commended for its initial efforts to value mineral subsoil assets in the United States.

At very limited cost, BEA has produced useful and well-documented estimates of the value of mineral reserves. These efforts reflect a serious and professional attempt to value subsoil mineral assets and assess their contribution to the U.S. economy. The methods employed by BEA are widely accepted and used by other countries that are extending their national income accounts.

3.2 The panel recommends that work on developing and improving estimates of subsoil mineral accounts resume immediately.

As a result of the 1994 congressional mandate, BEA was forced to curtail its work on subsoil assets. Its estimates of subsoil mineral assets are objective, represent state-of-the-art methodology, and will be useful for policy makers and analysts in the private sector.

Box 3–9: Modified Formulas for the Calculation of Reserve Stocks, Additions, and Depletions

$$\text{total mineral reserve value}_t = V_t = [\,p_t - \ a_t - K_t/R_t]\times R_t$$

$$\text{additions}_t = [\,p_t - \ a_t - Z_t/A_t]\times A_t$$

$$\text{depletions}_t = [p_t - a_t - rK_t/q_t - D_t/q_t - rV_t/q_t]\times q_t$$

where   is an empirically estimated adjustment coefficient with a value between zero and one, and all other variables are as defined in Boxes 3–3 and 3–6.

3.3 Because of the preliminary nature of the BEA estimates, as well as the potential volatility introduced by the inclusion of mineral accounts, the panel recommends that BEA continue to present subsoil mineral accounts in the form of satellite accounts for the near term.

Once the accounting procedures used for the mineral accounts have been sufficiently studied and found to be comparable in quality to those used for the rest of the accounts, it would be best to consider including the mineral accounts in the core GDP accounts. It is appropriate that assessments of changes in subsoil assets be presented on an annual basis, as BEA has done in its initial efforts.

3.4 The panel does not recommend that a single approach to mineral accounting be selected at this time.

No single valuation method has been shown to be free of problems. Thus BEA should continue to employ a variety of valuation methods, modifying them as warranted by new developments in the field.

3.5 The panel has identified a number of shortcomings in current valuation approaches, and it recommends that BEA consider modifying or eliminating some of its procedures in light of these findings.

The panel has identified problems involving appropriate adjustment of asset values for associated capital and other assets and liabilities, as well as potential overestimation of the value of assets, additions, and depletions by use of the Hotelling valuation technique. BEA should consider such findings in refining its techniques. Empirically based modifications to the Hotelling valuation

14. The deduction proposed by El Serafy is $R/(1+r)^{n+1}$ where R is the current depletion, r is an appropriate discount rate, and n is the number of years of mineral reserves remaining assuming a constant extraction path. See also Hartwick and Hageman (1993) and Bartelmus (1998).

technique along the lines suggested above should be examined.

3.6 The derivation of accurate and parsimonious valuation is an area of intensive current research, and BEA should follow new developments in this area.

The panel has identified a number of promising research efforts that may reduce the uncertainties among various approaches to valuing mineral resources. Most of the shortcomings of BEA's approaches identified in this chapter reflect data limitations and inherent problems that arise in estimating quantities and values that are not reflected in market transactions. Given the uncertainties involved, as well as the small share of total wealth represented by subsoil assets in the United States, a major commitment to data generation for these assets does not appear to be justified at this time. BEA should therefore emphasize valuation methods that rely on readily available data.

3.7 The most important open issues for further study are (1) the value of mineral resources that are not reserves, (2) the impact of ore-reserve heterogeneity on valuation calculations, (3) the distortions resulting from the constraints imposed on mineral production by associated capital and other factors, (4) the volatility in the value of mineral assets introduced by short-run price fluctuations, and (5) the differences between the market and social values of subsoil mineral assets.

One of BEA's most important contributions has been to stimulate discussion and research on resource-valuation methodologies. BEA's actual findings regarding the value of reserves—stocks, depletions, and additions—should be considered preliminary and tentative until there is a better understanding of the magnitude of the distortions introduced by the various techniques. It is recommended that close attention be paid to these five important open issues.

Implications for Measuring Sustainable Economic Growth

3.8 The initial estimates of the subsoil mineral accounts have important implications for understanding sustainable economic growth.

In one sense, the major results of the initial estimates are negative. Perhaps the most important finding is that subsoil assets constitute a relatively small portion of the total U.S. wealth and that mineral wealth has remained roughly constant over time. According to the IEESA results, the value of mineral resources is between 3 and 7 percent of the tangible capital stock of the country. If other assets, particularly human capital, were considered, mineral value would be an even smaller fraction of the country's wealth. This is an important and interesting result that was not well established before BEA developed its subsoil mineral accounts.

3.9 Alternative measures, along with measures of sustainability from a broader set of natural-resource and environmental assets, will be necessary to obtain useful measures of the impact of natural and environmental resources on long-term economic growth.

The mineral accounts as currently constructed are of limited value in determining the threat to sustainable economic growth posed by mineral depletion. The value of subsoil mineral assets in the United States could fall because much cheaper sources of supply are available abroad. Conversely, the value could rise because serious depletion problems are driving mineral prices up. The real prices of individual mineral commodities provide a more direct and appropriate measure of recent trends in resource scarcity than is offered by the total values of specific minerals in the mineral accounts.

3.10 The panel recommends that BEA maintain a significant effort in the area of accounting for domestic mineral assets.

While subsoil assets currently account for only a small share of total wealth in the United States and do not appear to pose a threat to sustainable economic growth at present, this situation could change in the future. A good system of accounts could address the widespread concern that the United States is depleting its mineral wealth and shortchanging future generations. By properly monitoring trends in resource values, volumes, and unit prices, the national accounts could identify the state of important natural resources, not only at the national level, but also at the regional and state levels. Better measures would also allow policy makers to determine whether additions to reserves and capital formation in other areas are offsetting depletion of valuable minerals. Development of reserve prices and unit values would help in assessing trends in resource scarcity. Comprehensive mineral accounts would provide the information needed for sound public policies addressing public concerns related to mineral resources.

3.11 Efforts to develop better mineral accounting procedures domestically and with other countries would have substantial economic benefit for the United States.

Other countries and international organizations are continuing to develop accounts that include subsoil assets and other natural and environmental resources. The United States has historically played a leading role in developing sound accounting techniques, exploring different methodologies, and introducing new approaches. A significant investment in this area would help improve such accounts in the broader world economy. Unfortunately, the United States has lagged behind other countries in developing environmental and natural-resource accounts, particularly since the 1994 congressional mandate suspending those efforts.

3.12 To the extent that the United States depends heavily on imports of fuels and minerals from other countries, it would benefit from better mineral accounts abroad because the reliability and cost of imports can be forecast more accurately when data from other countries are accurate and well designed.

International development of sound natural-resource accounts would be particularly useful for those sectors in which international trade is important. Indeed, as has been learned from cataclysmic events in financial markets such as the Mexican peso crisis of 1994–1995 or the financial crises of East Asian countries in 1997–1998, the United States suffers when foreign accounting standards are poor and is a direct beneficiary of better accounting and reporting abroad. Better international mineral accounts would help the nation understand the extent of resources abroad and the likelihood of major increases in prices of oil and other minerals such as those of the 1970s. Improved accounts both at home and abroad would help government and the private sector better predict and cope with the important transitions in energy and materials use that are likely to occur in the decades ahead.

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