Environmental "Remediation" Expenses and a Natural Interpretation of the Capitalization Requirement

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ENVIRONMENTAL "REMEDIATION" EXPENSES AND A NATURAL INTERPRETATION OF THE CAPITALIZATION REQUIREMENT
THEODORE S. SIMS*

INTRODUCTION
The income taxation of outlays for environmental restoration (or "remediation") has become a hot topic once again. It elicited extensive consideration a decade ago, when the focus was on the treatment of expenses of surface mining reclamation and nuclear power plant decommissioning, now explicitly covered by Sections 468 and 468A of the Internal Revenue Code. As a formal matter, those specific matters are just examples, conspicuous by their size, of the more general question of how an income tax should account for "future costs." Although not currently controversial, surface mining affords a simple illustration. As a condition of mining coal by surface methods, a coal mine operator is unconditionally required by state law to restore its site, when no longer actively mined, to a reasonable facsimile of the condition the land was in before mining operations commenced. Based on its experience, it can estimate with reasonably accuracy (1) when it will cease its mining operations, and (2) how much it will cost to reclaim the land.

How should the anticipated reclamation costs be taxed? There is no dispute about whether they are deductible. The controversy is about when, and there are two basic possibilities. One is to allow a deduction where the reclamation costs are actually paid. Equivalently, one could discount the entire future cost to its present value, using an after-tax discount rate, and allow a deduction in that discounted amount now, but no further deduction at any other time. I will refer to these approaches as "cash" (or "cash-equivalent") accounting for future costs.¹

The basic alternative is some form of "accrual." In the literature, the accrual approaches are described in a variety of ways, and justified by appeal to a variety of analogies, but they are similar in both provenance and operational content.²

Operationally, they all allow the present value of the liability—determined using a pretax discount rate—to be deducted when the liability first becomes fixed and reasonably determinable, and thereafter to allow the balance of the liability to be deducted over time as it accrues. All of them have some kinship to Samuelson's (1964) article on "economic" depreciation.

This fundamental underlying question is not, it should immediately be said, the source of current controversy. The work ten years ago (and since) has not produced agreement on how this problem properly should be solved. As the result of legislation largely enacted with the Tax Reform Act of 1984, however, the basic issues have been by and large resolved. The statute now leans heavily in the direction of cash-equivalent accounting. To capture the flavor of the current controversy, one might add to the surface mining hypothetical the further fact, not anticipated when mining operations were begun, that those operations caused serious environmental contaminants to leach into the surrounding soil, adding to the cost of restoration. Nevertheless, in this paper I wish to revisit the underlying issue, for I think there may be more that can be said. Specifically, I think that Samuelson's original article, typically illustrated using simple discrete time examples, actually speaks not merely to the problem of asset "depreciation" conventionally understood, but more generally to the deductibility of expenses and, in principle at least, to the equally fundamental matter of "capitalization." Thus, in what follows, I introduce a modification into Samuelson's original analysis that takes explicit account, not merely of the depreciation of an initial investment, but also of subsequently incurred expenses. This treatment has the virtue of clarifying (at least in principle) the confusing distinction between the treatment of "ordinary and necessary" future expenses and future "capital" costs. It also helps to identify more precisely the methodological divide between proponents of accrual and those (presumably including Congress) who claim that cash equivalent accounting is theoretically correct. In particular, it suggests that there will always be tax invariant solutions to the problem of future costs; that they all can be accounted for within the framework of Samuelson's solution to the problem of determining "economic" depreciation; but that they all will have the property of apparently requiring a zero rate of tax.

Thereafter, I will turn briefly to the matters of current interest, which I think should be somewhat less difficult to resolve.

ECONOMIC DEPRECIATION

An Outlay for a Net Revenue Stream

Theory

As the result of Samuelson's (1964) paper, it is now widely understood, not only by economists but by lawyers preoccupied with income tax policy, that asset values are invariant to their holders' tax rates—which I shall henceforth denote by "tax invariant," or simply "invariant"—if and only if asset depreciation is economic. Specifically, Samuelson began by representing with the Fisher integral the value \( V(t) \) of an asset that produces a continuous net revenue stream \( N(t) \), known with certainty in advance, in an environment in which the pretax interest rate is \( y \):\(^6\)

\[
V(t) = e^{yt} \int_{t}^{T} N(s) e^{-ys} ds.
\]

The time derivative of equation 1 is given by:
The taxable counterpart to equation 1, with tax imposed at rate $z$ and depreciation allowed in computing taxable income at a rate (possibly) dependent on the marginal tax rate, and therefore denoted $D(t,z)$, is

$$V(t) = e^{-zt} \int_{s=0}^{s=t} \{N(s) - z[N(s) - D(s,z)]\} e^{-ys} ds.$$  

Samuelson (1964) showed that equation 3 is tax-rate invariant if and only if

$$D(t,z) = m = N(t) - yV(t) = -V'(t)$$

that is, only if the depreciation allowance is equal to the change in the asset’s value, given by the negative of its time derivative $V'(t)$.

The decomposition of the depreciation schedule, equation 4, merits careful attention. It says that, for an investor who receives an (includible) net receipt $N(t)$ at time $t$, a principal element of the depreciation allowance is a deduction equal to the amount of the receipt. The intuition underlying this feature of the schedule is that two things occur simultaneously at time $t$: one is that the investor is enriched by the amount of the receipt; the other, however, is that the stream of remaining receipts to which ownership of the asset entitles the investor declines by an exactly offsetting amount. Hence, her net worth is unaffected by the mere conversion into cash of her claim to the receipt at time $t$.

The significance of the second term of equation 4, $-yV(t)$, becomes clear if equation 4 is substituted into equation 3 to obtain the actual tax-rate-invariant expression for $V(t)$:

$$V(t,z) = V(t) = e^{-zt} \int_{s=0}^{s=t} \{N(s) - zyV(s)\} e^{-ys} ds.$$  

The important feature of equation 5 is that, when economic depreciation is allowed, the only thing that is taxed is the instantaneous accrual of yield (at rate $y$) to the net value $|V(t)|$ of the asset itself. Thus, while most of the attention has been devoted to the allowance of economic depreciation, the equally fundamental implication of allowing economic depreciation is that it leads to the taxation of just $yV(t)$. In other words, economic depreciation implements a pure accrual tax.7

An example

Before proceeding further, it is worth turning to a simple illustration, used by Sunley (1984), and elaborated on in detail by Fiekeowsky (1984) and Cunningham (1985), in exploring the taxation of a “negative salvage value” asset, one that requires an extraordinary outlay at the close of the asset’s service life. First, however, I consider the asset in the absence of the final outlay, assuming that it has five years of constant productivity, generating annual net income of $1,000, in an environment with a ten percent pretax discount rate and a 30 percent tax rate. If acquired for $3,791, the asset’s internal rate of return equals the pretax discount rate (and its net present value is zero).

The standard treatment of that asset, if purchased for $3,791, is illustrated in Table 1. Column (3) of Table 1 contains
<table>
<thead>
<tr>
<th>Period</th>
<th>(1) Outlay</th>
<th>(2) Revenue</th>
<th>(3)$ PV at Period n (at 10 Percent)</th>
<th>(4)$ Σ PV at Period n</th>
<th>(5)$ Depreciation</th>
<th>(6)$ Taxable Income</th>
<th>(7)$ Tax (at 30 Percent)</th>
<th>(8)$ AT Cash Flow</th>
<th>(9)$ PV (at 7 Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3,790.79</td>
<td></td>
<td></td>
<td>3,790.79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>909.09</td>
<td>3,169.87</td>
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<td>379.08</td>
<td>113.72</td>
<td>886.28</td>
<td>828.30</td>
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<td></td>
<td>826.45</td>
<td>2,486.85</td>
<td>683.01</td>
<td>316.99</td>
<td>95.10</td>
<td>904.90</td>
<td>790.37</td>
</tr>
<tr>
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<td></td>
<td>751.31</td>
<td>1,735.54</td>
<td>751.31</td>
<td>248.69</td>
<td>74.61</td>
<td>925.49</td>
<td>755.40</td>
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<tr>
<td>4</td>
<td>1,000.00</td>
<td></td>
<td>683.01</td>
<td>909.09</td>
<td>826.45</td>
<td>173.55</td>
<td>52.07</td>
<td>947.93</td>
<td>723.17</td>
</tr>
<tr>
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<td></td>
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<td>0.00</td>
<td>909.09</td>
<td>90.91</td>
<td>27.27</td>
<td>972.73</td>
<td>693.54</td>
</tr>
</tbody>
</table>

Total 3,790.78

$The payment in each period $n$ in column (2), discounted for $n$ periods at ten percent.
$The present values of all remaining payments as of the end of each period $n = 0, 1, 2, 3, 4$, consisting of the sum of the first $5 - n$ entries in column (3).
$The change from period $n - 1$ to period $n$ in the present value of all remaining payments, as given in column (4).
$Column (2) minus column (5).
$Column (6) times 0.30.
$Column (2) minus column (7).
$The amount in each period $n$ in column (8), discounted for $n$ periods at seven percent.
the present value of each $1,000 receipt, discounted to time 0 (the beginning of period 1) at ten percent, while column (4) computes the sum of the present values of all remaining payments, first at time 0, and then as of the end of each of periods 1 through 4. The standard way of determining economic depreciation of this asset is to compute the successive changes in the values reported in column (4), which I report in column (5).8

The equivalent procedure implied by equation 4 is to subtract from each periodic payment in column (2) the product of (1) the asset’s ten percent internal rate of return and (2) its remaining value as of the close of the preceding period, as reported in the preceding line of column (4). The reader can easily verify that this produces the same schedule of depreciation as the “standard” method.9 In columns (6) through (8) I compute taxable income, tax, and after-tax cash flow from the asset, and discount the latter to time 0 at an after-tax discount rate of seven percent, verifying that the asset value is unaffected by the tax. The important thing to note, however, as suggested by equation 5 and as the reader can again easily verify, is that the amount ultimately taxed to the holder is just the product of (1) the ten percent internal rate of return and (2) the asset’s remaining value as of the close of the preceding period.

Tables 2A and 2B, which add to Table 1 a $1,401 outlay to be made in period 6, replicate the actual example in Sunley (1984). I have, however, explicitly decomposed the cash flows associated with the asset into revenues and costs. Thus, except for the addition of the $1,401 outlay in period 6 in column (1), columns (1) through (4) of Table 2A are identical to Table 1, while column (5) computes the value of the final cost, discounted to the end of periods 0 through 6. The net value of the asset at each point in time is the difference between columns (4) and (5), reported in column (6). Economic depreciation now consists of the successive changes in the entries in column (6), and is reported in column (7).

The actual computations of taxable income, tax, and after-tax cash flows are reported in Table 2B, which replicates Sunley’s (1984) observation that economic depreciation again produces tax-invariant valuation. But there are some features to Tables 2A and 2B that merit additional consideration. Note, first, that the introduction of the final cost has reduced the present value of the combined stream of revenues and expenses—and, presumably, the price an investor would be willing to pay—from $3,791 to $3,000.10 Nevertheless, the depreciation properly allowable has increased. This is perhaps the most confusing, potentially misleading, and operationally perplexing aspect of the treatment of future costs. A system of depreciation geared to historical acquisition cost will have an unavoidably hard time dealing with (“properly” depreciable) future costs.

Sunley (1984) himself explains the depreciation schedule with the observation that the asset’s value declines from its $3,000 acquisition to —$1,401, producing $4,400 in allowable depreciation. As with Table 1, however, the alternative account suggested by equation 4 is that the depreciation in each period consists of the $1,000 receipt, reduced by the product of the internal rate of return and the asset’s value at the beginning of that period. In Table 2A, however, the net value of the asset in each period [reported in column (6)] is, because of the final cost, less than the corresponding value reported in Table 1. So the allowable depreciation has increased. In fact, the depreciation schedule in Table 2A is
### TABLE 2A
COMPUTATION OF ECONOMIC DEPRECIATION WITH FINAL COST

<table>
<thead>
<tr>
<th>Period</th>
<th>(1) Expense (Initial Outlay)</th>
<th>(2) Revenue (at 10 Percent)</th>
<th>(3) PV (Revenue)</th>
<th>(4) PV at Period n (at 10 Percent)</th>
<th>(5) PV at Period n (at 10 Percent)</th>
<th>(6) PV at Period n (Net Value)</th>
<th>(7) Depreciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(3,000.00)</td>
<td>3,790.79</td>
<td>790.83</td>
<td>2,999.96</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>2,999.96</td>
<td>700.00</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1,000.00</td>
<td>826.45</td>
<td>2,486.85</td>
<td>1,529.95</td>
<td>770.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1,000.00</td>
<td>751.31</td>
<td>1,735.54</td>
<td>682.95</td>
<td>847.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1,000.00</td>
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<td></td>
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<tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td>6</td>
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<td>1,401.00</td>
<td>1,401.00</td>
<td>127.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,400.96</td>
</tr>
</tbody>
</table>

*The payment in each period n in column (2), discounted for n periods at ten percent.

bThe present values of all remaining payments as of the end of each period n = 0, 1, 2, 3, 4, consisting of the sum of the first 5 - n entries in column (3).

cThe present value of the outlay in period 6 in column (1), discounted at ten percent to the end of period n = 0, 6.

dColumn (4) - column (5).

Table 2A suggests that Samuelson’s (1964) basic insight applies both to outlays made initially to acquire an asset and to those made at the close of its useful life. In either event, deductions for economic depreciation appear to produce invariant asset valuation (although we have not formally established that this will always be the case). That has not, however, served to quiet the debate. For one thing, Samuelson’s article is expressly about depreciation. Adherents of cash-equivalent accounting...
expressly dispute its validity in the case of outlays other than conventional “investments” in durable goods, made in advance of production. I will turn to those concerns in the final section of the paper.

Furthermore, even observers like Sunley (1984), who subscribe to the analysis, leave almost entirely unexplained (and, indeed, unexplored) the means by which to distinguish between (in Sunley’s words) “an investment expenditure that must be incurred in the future if income is going to be earned currently,” for which depreciation is appropriate to begin with, and an ordinary and necessary expenditure to operate an asset, for which some different treatment presumably would be prescribed. In point of fact, the entire distinction between future “current” and future capital outlays, here, as elsewhere, has introduced substantial confusion into the debate. Direct marginal costs of current production are perhaps readily to be distinguished from an investment in the machine with which current output is produced. But the issue is rarely that simple.

Costs, explicitly considered

In light of these considerations, it seems natural to ask what happens in Samuelson’s formulation when costs are explicitly introduced. To that end, define

\[ N(t) = R(t) - C(t) \]

where \( R(t) \geq 0 \) and \( C(t) \geq 0 \) are gross revenues and costs, respectively, both expressed as continuous functions of time, and rewrite equation 1 as

\[ \dot{V}(t) = e^{\frac{\gamma}{1 + z}} \int_{t}^{T} \{ R(s) - C(s) \} e^{-\frac{\gamma}{1 + z} ds} \]

the time derivative of which is

\[ \dot{V}(t) = yV(t) - R(t) + C(t). \]

The general formulation of the cost function \( C(t) \) says nothing in particular about whether, in conventional terms, the costs are current or capital. Some care must therefore be taken in deciding how to rewrite equation 3. To allow the solution to the problem to tell us just what is deductible, regardless of whether it is deductible as a current expense or as depreciation, I define \( d(t,z) \) to be the total amount deductible from the gross revenue stream, and rewrite equation 3 as

\[ \dot{V}(t) = e^{\frac{\gamma}{1 - z}} \int_{t}^{T} \{ R(s) - C(s) \} e^{-\frac{\gamma}{1 - z} ds} - z[R(s) - d(s,z))] e^{-\frac{\gamma}{1 - z} ds}. \]

The partial derivative of equation 3a with respect to time is

\[ \frac{\partial \dot{V}(t,z)}{\partial t} = y(1 - z) \dot{V}(t,z) - R(t) + C(t) + zR(t) - zd(t,z). \]

As in Samuelson (1964), if equation 3a is to be independent of \( z \), that is, if we are to have

\[ \dot{V}(t,z) = \dot{V}(t,0) = \dot{V}(t), \]

then we can equate equation 2a and 7 to find that

\[ d(t,z) = d(t) = R(t) - y\dot{V}(t) = -\dot{V}(t) + C(t). \]

The tax-invariant depreciation schedule
in the reformulated problem appears to differ in an important respect from equation 4. Bearing in mind that, by definition, \( V(t) = V(t) \), the last line of equation 4a suggests that the revised schedule exceeds the original schedule by \( C(t) \), indicating that the costs at time \( t \), in addition to economic depreciation, are properly allowable as deductions. In fact, however, the appearance of gross revenues in (4a) limits the extent to which the costs may be deducted. To be completely explicit (if somewhat redundant) about equation 4a, the amount deductible at \( t \) will be

\[
d(t) = \begin{cases} 
N + C - y\hat{V}, & R > C \\
R - y\hat{V}, & 0 < R \leq C \\
y\hat{V}, & R = 0.
\end{cases}
\]

Thus, if revenues exceed costs, the costs are allowable as deductions. If, however, revenues are less than costs, the amount allowable is limited to revenues (reduced by the instantaneous accrual of yield). In short, costs in excess of current gross revenues are not deductible. They are, instead, to be accounted for through depreciation.

At first this may seem strange. But the intuition again is relatively simple. In Samuelson’s solution, depreciation is a function of the change over time in the value of the net revenue stream \( N(t) \). To the extent that current expenses do not exceed current gross revenues, they can be applied to reduce gross revenue and subsumed into the depreciation schedule itself. To the extent, however, that current costs exceed current revenue, they will—irrespective of whether they are conventionally capital or current—influence the change in the asset’s value over a longer horizon than the current period, and therefore should properly be accounted for through depreciation.

In a sense, this is a kind of “natural” capitalization rule. It offers some insight into otherwise puzzling facts. Recall that the intuition underlying Samuelson’s depreciation schedule is that a receipt, formally includible in gross income, is exactly offset by a decline in the remaining net income from the asset. Exactly the same is true of current outlays. The outlay itself, although reducing the holder’s net worth, is exactly offset by a reduction in the holder’s remaining payment obligation, so that, once again, the net consequence is a wash.\(^{12}\)

The insight that conventionally current expenditures have no impact on an investor’s net worth has exactly the same flavor as the insight underlying the capitalization requirement itself. The exchange of, e.g., cash, for a durable income-producing asset, does not affect the purchaser’s net worth, and it is for that very reason that the outlay may not be currently deducted. The similarity between the underlying insights suggests, in turn, that despite our instinctive beliefs that certain kinds of outlays are inherently current while others are naturally capital, the analysis exemplified by Sunley (1984) is properly to be applied to any current period expenditure in excess of current revenue, in any current period, regardless of whether the expenditure conventionally seems to be ordinary and necessary or not. It thus has the virtue (at least in theory) of providing a guide to determining when an income-producing expenditure is properly to be accounted for through depreciation, regardless of whether it occurs near the beginning, in the middle or at the end of an asset’s productive life.

In fact, this generalized depreciation schedule can easily accommodate the initial (capitalized) investment in the asset itself, which typically is treated instead as a separate event, distinct from the matter of depreciation. To see this, assume that (1) \( R(0) = 0 \), (2) \( C(t) = 0 \).
and $R(t) = N(t)$ for $0 < t \leq T$, and (3) set $C_0 = -\dot{V}(0)$ (determined without regard for $C_0$). “Cost” now consists solely of a time 0 outlay equal to the present value of the entire net revenue stream, so that overall this is a zero-net present value investment. Now, in accordance with equation 4a, the amount deductible in connection with the initial outlay is

$$-y\dot{V}(0) = 0$$

since $R(0) = \dot{V}(0) = 0$. Thus, the natural capitalization rule replicates conventional capitalization of an investment made in advance.

In practice, however, the implications of this analysis will not be quite as radical as at first they might appear. Both Samuelson’s analysis and the modest elaboration offered here assume that revenues and expenses are known with certainty in advance. Outlays that are directly related to current production (and conventionally regarded as deductible) in excess of current revenues will typically be contemplated in advance only by a producer who plans on pricing below marginal cost, or, given the absence of uncertainty, otherwise engaging in suboptimal conduct like unnecessarily stockpiling raw materials in advance. With no uncertainty, it is therefore reasonable to expect that the relationship between revenues and costs that determines whether, in the analysis above, an outlay is to be depreciated, will conform to conventional understandings of whether it is capital or current. If, however, some originally unanticipated outlay becomes necessary, as when a producer discovers only ex post that its activities have been causing environmental degradation, modifications to the basic analysis may be required. In the balance of the paper, then, I go on to illustrate the application of the analysis to anticipated costs, after which I turn to those not anticipated in advance.

**FUTURE ENVIRONMENTAL COSTS**

Advocates of accrual accounting for future costs have frequently appealed to tax-rate invariance as the standard by which different methodologies are to be judged. As a casual matter, it is hard to imagine that tax-rate invariance could be judged desirable with respect to investments in conventionally capitalized depreciable assets but not with respect to future costs. One virtue of the analysis above is that, as a formal matter, it justifies those appeals.

**Anticipated Costs**

**In principle**

As an illustration, we can justify formally the treatment of the example in Tables 2A and 2B. To do so, assume first that the asset can be described by equation 1, with pretax value $V(t)$, and then add the following assumptions:

$$R(t) = \begin{cases} N(t), & 0 \leq t < T \\ R(t) = 0, & t = T \end{cases}$$

$$C(t) = \begin{cases} 0, & 0 \leq t < T \\ C_T > R(T) \geq 0, & t = T. \end{cases}$$

Thus, gross revenues are simply equal to net revenues, except for a single expenditure (for remediation) made at time $T$. $C_T > R(T) \geq 0$ implies that the (pretax) value of the asset, taking account of the remediation expense, is

$$\dot{V}(t) = e^{rt} \left\{ \int_{s=t}^{T} N(s)e^{-ys} \, ds - e^{-yT} C_T \right\} < V(t).$$

The tax-invariant depreciation schedule
for equation 1b, the negative of its time derivative, or

$$N(t) - y\dot{V}(t)$$

has the same form as Samuelson’s depreciation schedule (equation 4). But $\dot{V}(t) < V(t)$ implies that the amount allowable as depreciation at time $t$ exceeds the depreciation that would have been allowable in the absence of the final payment $C_T$ by

$$ye^{-\gamma t} C_T,$$

the instantaneous increase at time $t$ in the present value of $C_T$.$^{13}$

Each conclusion conforms to what we observed in Table 2. The pretax present value of the asset declined; total depreciation increased; and the amount by which depreciation in each period increased equaled the change in the present value of the final $1,401$ payment ($C_T$).

**Economic depreciation and cash-equivalent accounting**

A second virtue of the analysis is that it can be used to pinpoint more precisely the difference between economic depreciation and cash-equivalent accounting for future costs. For, despite all the legislation enacted in 1984, there remain serious differences of opinion about what is theoretically correct. We can, however, use the analysis above to shed light on just why it is that economic depreciation, elsewhere so widely regarded as theoretically appropriate, has been so vehemently resisted in the case of future costs. In fact, Samuelson’s analysis can in principle be applied to future costs. But the tax-invariant depreciation schedule turns out to require (at least apparently) a zero rate of tax, a conclusion that is hard to reconcile with an income tax.

To pursue this, I assume that the investor in the asset described by equation 1b operates in an economic environment such that she can increase her prices so as to raise additional revenues having an aggregate pretax present value equal to the required final payment $C_T$. Specifically, I assume that the additional revenues are described by some continuous function $f(t)$ defined on $0 < t < T$, satisfying

$$\int_{s=0}^{T} f(s) e^{-\gamma s} ds = e^{-\gamma T} C_T.$$ 

With hesitation, I suggest thinking of $f(t)$ as generating a "fund" dedicated to satisfying $C_T$.$^{14}$ As so considered, it is clear that the value of the original asset, freed of the burden of satisfying the final payment, would once again be given by $V(t)$ (rather than $\dot{V}(t) < V(t)$), and depreciation of the asset itself could, once again, be geared to its historical cost.

The important question is how to account for the fund. Advocates of cash-equivalent accounting, such as Fie-kowsky (1984), would claim that I have already misspecified the problem. They assert that the additional revenues collected to meet the final payment should be defined by the assumption that, when reduced to present value using an after-tax discount rate, they equal the present value of $C_T$. Formally, the required revenues should be given by some other function $g(t)$ satisfying

$$\int_{s=0}^{T} g(s) e^{-\gamma(1-\delta)t} ds = C_T e^{-\gamma(1-\delta)T}.$$ 

With those assumptions, and the addi-
tional assumption that the final payment itself would be deductible when made, it follows automatically that consistency is achieved only if (1) the revenues "contributed" to the fund are deductible when contributed, but (2) the fund itself is taxed. That is because, by definition,

\[ e^{\gamma(1-n)t} \int_{s=0}^{T} (1 - z) g(s) e^{-\gamma(1-n)s} ds \]

\[ = e^{\gamma(1-n)t} (1 - z) C_t e^{-\gamma(1-n)t} \]

\[ = (1 - z) C_t. \]

That treatment, however, sacrifices the Samuelson property: the additional revenue required to fund the final liability will increase with a producer's marginal rate of tax, as can easily be seen by differentiating either side of equation 8a with respect to \( z \). So if, for example, the ability to raise prices to provide for the final liability were to be constrained by competition, those taxed at lower marginal rates would be better situated to do so.

The revenues raised to provide for the final payment \( C_t \) can, alternatively, be taxed so as to make them tax invariant. To derive the solution, let the present value at time \( t \) of the remaining stream of receipts, net of the present value of the final payment \( C_t \), be given by

\[ F(t) = e^t \{ \int_{s=t}^{T} f(s) e^{-\gamma s} ds - e^{-\gamma t} C_t \}. \]

Note, first, that by reason of equation 8, \( F(0) = 0 \), and, second, that as time passes, the value of the remaining stream of receipts declines, whereas the present value of the final payment grows, so that \( F(t) < 0 \) for \( t > 0 \). Finally, since equation 9 has the same form as equation 1b, we can expect to find a stream of deductions that will render it tax invariant.

But we can be more specific. Using the properties of the integral and equation 8, equation 9 can be rewritten as

9a

\[ e^t \left\{ \int_{s=0}^{T} f(s) e^{-\gamma s} ds - \int_{s=0}^{T} f(s) e^{-y s} ds \right\} \]

\[ - e^{-\gamma t} C_t \]

\[ = - e^t \int_{s=0}^{T} f(s) e^{-\gamma s} ds. \]

What equation 9a says is that the amounts already received \( f(t) \) from time 0 to any time \( t \), together with accumulated interest, will be just sufficient to offset the amount by which the present value of the final liability exceeds the present value of the revenues yet to be received. In the abstract, this really is a representation of a fund, held to satisfy the final payment \( C_t \). It then follows from Samuelson's original derivation that the amount deductible from the revenues \( f(t) \) to insure invariant valuation of the fund is given by

\[ F(t) = f(t) - yF(t) > f(t) > 0 \]

since \( F(t) < 0 \).

Expression 10 is of more than passing interest. It says, formally, that invariant valuation of a fund, held to satisfy a future liability, can be achieved in the presence of an income tax, but if (and only if) the investor is permitted to deduct the sum of (1) the revenues received to fund the liability, plus (2) the interest accruing on the accumulated fund.15 Suppose, then, we were to imagine funds being "set aside" to satisfy a future cost, and suppose also that
we were to assume that both contributions to the fund and earnings from investing those contributions were to be taxed, subject only to the allowance of a deduction sufficient to preserve tax-invariance. According to equation 10, the required deduction would equal the fund’s entire gross income, producing (at least apparently) a zero rate of tax. That is, a zero rate of tax, and only a zero rate of tax, can insure invariant valuation of a fund held to satisfy a future cost.

This finding serves to explain why those who have searched for “neutral” means by which to tax future costs have so frequently produced solutions that seem to entail a zero rate of tax. Expression 10 suggests that this feature will be exhibited by any tax-rate invariant solution to the problem of future costs. It also helps to explain why this problem has so sharply divided a distinguished and dispassionate group of analysts, many of them committed to an income tax. To those who advocate cash-equivalent accounting, it simply must be that earnings on assets held to satisfy a future cost are taxed, and that revenues must be “set aside” to satisfy the liability on that assumption. However, it generally is not the case that producers taxed at different rates will be free to charge different prices for their products, and for a given amount of revenue, cash-equivalent solutions generally will not be tax invariant. For advocates of economic depreciation (or “neutrality,” by any name), on the other hand, tax-invariant solutions are available, but they seem to entail taxation of producers that is not easily reconciled with an “income” tax. Expression 10 suggests that this will always be the case. Thus, the analysis developed here more clearly outlines the implications of the two basic alternatives identified in the introduction to this paper.

Unanticipated Expenses

What, at this juncture it might reasonably be inquired, does any of this have to do with Technical Advice Memoranda Numbers 9240004 and 9315004, or, for that matter, with the decisions in Indopco v. Comm’r and Plainfield Union Water Company, often mentioned in connection with those rulings? Perhaps not a lot. But possibly not nothing.

The general flavor of what I have called a natural approach to capitalization, outlined in the preceding section, certainly suggests that expenditures that are large by comparison with current revenues are likely to influence the value of an activity over time that extends beyond the period in which they are actually incurred. Viewed from that perspective, and otherwise considered in a vacuum, many of the expenditures currently in controversy seem to share that characteristic. “Remedial” removal of PCBs or asbestos may not strike everyone as “bettering” the land or the machines, but, by comparison with those same assets in contaminated form, their long-term net productivity would reasonably seem to be enhanced. The same might plausibly be said of the cement linings added to Plainfield Union Water’s pipes. Arguments to the contrary seem strained, and I do not find it surprising that such considerations influenced the Service’s, and may influence the Treasury’s, stance.

At the same time, the theoretical treatment of costs outlined in the preceding section is theoretically appropriate only to the valuation of streams of revenue (or expense) known with certainty in advance. In addition, for two somewhat different reasons, the analysis above may actually imply a different treatment for the unanticipated outlays considered here. If, first, one subscribes to cash-equivalent accounting for future costs, a
natural implication would seem to be that if, instead of having been anticipated in advance, the costs first become known when they must actually be paid, they should be deductible at that time. At least some adherents to the cash-equivalence position seem to be of just that view. On the other hand, most of the outlays with respect to which specific legislation was enacted in 1984 were associated with the close of a project’s service life, so that at worst they should have been deductible at that time. In contrast, many of the items currently in controversy are associated with ongoing projects, leaving open the possibility that they may in part relate to future productivity, in which even conventional analysis would suggest that they be capitalized in part.

Suppose, however, that one subscribes (at least in principle) to using economic depreciation to account for future costs. Although not immediately obvious, the analysis of the preceding section indicates that, when accounted for using economic depreciation, a future cost affects the aggregate stream of allowable deductions only up until the point that it actually is paid. In other words, with economic depreciation, an anticipated cost will already have been deducted by the time that it is paid. The unambiguous implication is that costs that materialize ex post should be allowed as a deduction when they are paid.\textsuperscript{19}

There is yet another way of looking at remediation expenses like those in Technical Advice Memoranda Numbers 9240004 and 9315004. The removal of the asbestos or the PCBs may very well have enhanced the value of those assets if compared to just before the removal was undertaken, but the same cannot be said if the comparison is to the self-same assets before the contaminants (or the need for their removal) were first discovered. It requires no formal analysis to see that the belated discovery of some environmental contaminant, and the (costly) need for its removal, depresses the value of the contaminated asset, thereby inflicting a loss on its holder. If those losses were deductible, I suspect that the arguments now being made on behalf of the ordinary and necessary character of rather substantial remedial outlays, that unambiguously affect the value and long-term productivity of the assets to which they relate, would strike a great deal many more people as strained.

Standing alone, however, such losses obviously are not deductible. In short, a major underlying problem here is the realization requirement itself. And, perhaps, the soundest structural (as opposed to economic) argument to be made for currently deducting the costs of environmental restoration is simply that they are made to offset the consequences of an unrealized and otherwise nondeductible loss.\textsuperscript{20} Under a pure accrual tax, the losses, but not the costs of restoration, would generally be deductible. Permitting a deduction for the costs of restoration roughly replicates that result. That is the most sensible interpretation of the Plainfield Union Water case. That, in fact, was precisely the effect of the Court’s comparing the value of the pipes after restoration with their value before the tuberculation first appeared.\textsuperscript{20}

I do not claim the argument to be decisive. In particular instances its application may be unwarranted, as where an apparent loss is more illusory than real.\textsuperscript{21} More generally, it would, if accepted, tend increasingly to make the realization requirement a “one-way” street. All the same, the allowance for depreciation is itself a sizable exception to the realization rule. So, as this argument would in many instances just substitute one ex-
ception to the realization requirement for another, perhaps it deserves to be seriously considered.22

ENDNOTES

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1 Some will object to the implications of this terminology, which I adopt in the interests of convenience. Actually, any stream of deductions with the property that their aggregate present values, consistently computed using an after-tax discount rate, just equals the future outlay, should produce what I have called a cash-equivalent outcome. Compare Bailey (1974). Devotees of this approach include, in particular, Fiekowsky (1984) and Cunningham (1985), as well as current Sections 468 and 468A.

2 A useful summary can be found in Cunningham (1985), who, however, disagrees with them all.


4 Section 461(h) largely dictates "cash." Sections 468 and 468A, although appearing to allow some form of advance accrual, actually operate to allow deductions whose aggregate present values, computed using an after-tax discount rate, are equal to the present value of a deduction for the expenses when they are actually paid. See note 1.

5 This, essentially, is the sort of cost required to be capitalized in Technical Advice Memorandum Number 9315004; removing asbestos insulation from existing machinery was somewhat similarly required to be capitalized by Technical Advice Memorandum Number 9240004.

6 To avoid unnecessary haggling about equilibrium interest rates, I do not here assume the existence of any hypothetical "no-tax" world. Expression 1 can simply be interpreted as the value of the asset to a tax-exempt investor in a taxable environment.

7 This is just a generalization of the more familiar observation that, for an asset with constant productivity (a "one-hoss shay"), economic depreciation produces a pattern of asset depreciation identical to the schedule of principal amortization for a level-payment fully amortized conventional mortgage loan. See Chirelstein (1994), Section 6.08(d). In the latter instance, it is familiar, of course, that the "proper" amount to be includable in the income of the lender (the "investor") is just the product of the outstanding "principal balance" and the instrument’s "yield-to-maturity," as now provided for in I.R.C. Section 1272(a). That is precisely what equation 5 produces in the way of taxable income to the holder of an asset subject to economic depreciation. It is somewhat more realistic to expect that we can achieve approximately accurate accrual taxation of debt than that we can of depreciable assets. For a careful study of the application of Samuelson’s (1964) theorem to depreciation when revenue profiles are known only statistically in advance, and of the difficulties in making the theorem operational when uncertainty is introduced, see Strnad (1991).

8 E.g., Chirelstein (1994) Section 6.08(d), and Sunley (1984).

9 For example, in period 1, depreciation would be \(1,000 - (0.1 \times 3,790.79) = 620.92\), as actually reported in column (5) for period 1.

10 It is, of course, unlikely that a simple reproducible asset in a market economy would sell for both $3,000 and $3,791, depending on whether it was acquired for a project with or without the future cost. An alternative way of looking at this example would be that, without the final cost, an investor requiring a pretax rate of return of ten percent would pay $3,000 for the asset even if it produced annual revenue of only $791; whereas, with the final cost, she would pay $3,000 only if the project produced annual revenue of $1,000.

11 For example, in period 1, the present value of the liability grows from $790.83 to $869.91, or by $79.08, which, when added to the $620.92 of period 1 depreciation reported in Table 1, produces total depreciation of $300.

12 It should be kept in mind at this juncture that, by hypothesis, both \(R(t)\) and \(C(t)\) are known in advance. As discussed in the next section, somewhat different considerations arise with respect to unanticipated costs.

13 Aggregate additional depreciation just equals the change in the present value of \(C_t\) between 0 and \(T\). It can be obtained by integrating the expression in the text from 0 to \(T\), and is given by

\[
(1 - e^{-y})C_T.
\]

14 Alternatively, one could imagine the investor as dedicating a portion of the original reve-
nue stream $R(t)$ to satisfying that liability, but the result would be equivalent and the effects somewhat more difficult to disentangle.

In technical terms, the difference between this particular version of Samuelson's (1964) depreciation and others is that the formal "value" of the fund is negative, so that interest accruing on the fund's value at time $t$, given by $yF(t)$, is added to, rather than subtracted from, the time $t$ receipt in determining the total amount allowable as a deduction.

In particular, if the investor were to receive a single payment at time 0, equal to the pretax present value of $C_T$, the analysis suggests that the initial receipt should be deducted (or, equivalently, excluded) and expression 10 says that the investor thereafter should be allowed to deduct

$$-yF(t) = ye^{(t-1)}C_T$$

the accrual of yield at time $t$ on the amount initially received. This is the case, studied in detail by Aidinoff and Lopata (1980), Halperin (1986), and more recently by Halperin and Klein (1988), in which the single payment received to fund the future liability is analogized to a loan, repayment of which is evidenced by a pure discount bond. By appeal to that analogy, those observers have argued that (1) the "loan proceeds" should be excluded from gross income when received, (2) the "interest" on the loan should be deductible as it accrues, and (3) "repayment" of the loan should not be allowable as a deduction.

I invoke this analogy with even greater reservation than I invoked the analogy to a fund. It leads to the same conclusions as Samuelson's (1964) analysis. But the latter is derived from the sole objective of achieving invariant taxation of the investor. In contrast, the loan analogy, while often quite informative, can, I think, also be misleading. In particular, it leads to the search for someone else—specifically for a "lender"—to whom the interest on the loan, not taxed to the investor, properly "should be" taxed. There is much to be said for such a search in the case of consensual financial transactions—deferred compensation, in particular, and things like "Mooney bonds." It strikes me as quite possibly less compelling in the case of future costs associated with the production of goods. At this juncture it is not obvious to me in just which situations it would be right to insist that someone else be taxed on the income otherwise untaxed by reason of equation 10.

REFERENCES


Kiefer, Donald W. "Economic Analysis of The Tax Treatment of Nuclear Power Plant Decommiss-


