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# 3 Alternative Measures of Capital and Its Rate of Return in United States Manufacturing

Robert M. Coen

## 3.1 Introduction

The recent benchmark revisions of the national income accounts of the United States incorporate new measures of capital consumption that depart substantially from the old.[1] The prior estimates were based largely on tax return data on depreciation and thus were subject to capricious variations associated with changes in tax depreciation policy and enforcement practices. They had the further shortcoming of embodying valuations reflecting original acquisition prices (historical costs) of capital goods rather than the current prices employed in valuing other flows in the accounts. The new measures, by contrast, make use of current capital goods prices to value "real depreciation," the latter being obtained by consistently applying given depreciation formulas to real capital expenditures over time.

Users of the accounts will no doubt welcome these changes, since many had already been following similar procedures in their own work involving measures of capital, capital consumption, and income. Indeed, the Commerce Department has for some time been inconsistent in its behavior, maintaining the tax return measures of capital consumption in the national accounts while rejecting them in its own computations of capital stocks (U.S. Department of Commerce, OBE 1971). Perhaps all of us can now enjoy a less complicated existence—keeping one set of books instead of two.

I say perhaps, because there are aspects of the new approach that merit close scrutiny. The first is largely a factual matter: Are the asset

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service lives and depreciation patterns employed in deriving the new series reasonable? The second is largely methodological: Is the approach founded upon a measure of income to which economists would generally subscribe? A major purpose of this paper is to examine these questions. Since my answers are in part negative, I construct alternative measures of capital consumption that, though basically in the same spirit as the new Commerce approach, embody different assumptions. I then compare my own estimates with those of the Commerce Department to determine whether the different constructs have substantially different implications regarding matters of ultimate concern to economic analysts—the growth of capital and fluctuations in profits and rates of return. The empirical results to be reported pertain to total manufacturing over the period 1947–74.

I should emphasize that my intention is *not* to establish whether the new Commerce approach is right or wrong. To point out weaknesses or problems in the application of the approach is not necessarily to condemn it, especially in the difficult area of capital and income measurement. As Hicks has so aptly stated and carefully demonstrated: "At bottom, they [capital and income] are not logical categories at all; they are rough approximations, used by the business man to steer himself through the bewildering changes of situation which confront him" (1946, p. 171). I hope to clarify some issues raised by the Commerce approach and to establish whether the businessman (or the economist) would perceive the situation differently and therefore be likely to steer a different course (recommend a different policy) if he were to use approximations other than the Commerce Department's.

## 3.2 A Critique of the Commerce Approach

The new Commerce method of estimating capital consumption can be stated in simplified form as follows. Let $I_\tau$ be capital expenditures at date $\tau$ (end of period), $w_i$ be the depreciation rate of capital in the $i$th period of its service life, and $n$ be the service life. Then capital consumption in period $t$ arising from capital acquired in period $\tau$ is

$$(1)\qquad \begin{cases} D_{t\tau} = 0, & t > \tau + n. \\ D_{t\tau} = w_{t-\tau} I_\tau, & \tau < t \leq \tau + n \end{cases}$$

The contribution of vintage $\tau$ acquisitions to capital stock at the end of period $t$ is

$$(2)\qquad K_{t\tau} = I_\tau - \sum_{j=\tau+1}^{t} D_{j\tau}.$$

Total capital consumption and capital stock for period $t$ are obtained by summing the above expressions over all vintages.

In Commerce's latest capital stock study (U.S. Department of Commerce 1976*a*), these calculations are performed in two ways. The first uses $I_\tau$ in nominal terms, valuation being at the original acquisition price. This leads to what are referred to as historical-cost measures of capital consumption and capital stock. The second uses $I_\tau$ in real terms, obtained by deflating nominal expenditures in period $\tau$ by an index of capital goods prices for that period. This leads to what are referred to as constant-cost measures of capital consumption and captial stock, which when multiplied by the capital goods price index for period $t$, yield the so-called current-cost variants of the variables. It is this current-cost variant of capital consumption that now enters the national income accounts. The service life and depreciation pattern are the same in both sets of calculations.

Applying this approach requires information on service lives and depreciation patterns of various types of capital goods, but little appears to be known about these key parameters. The Treasury Department has occasionally conducted surveys of company (usually company engineers') estimates of service lives, the most noteworthy of these occurring in the 1930s and resulting in the detailed, prescribed lives of the Treasury's Bulletin F. After weighing other fragmentary evidence, Commerce decided to use service lives that are 85% of those appearing in Bulletin F. Since shorter lives are assumed for alterations and additions to structures, the average lives applied to structures expenditures are about 68% of the Bulletin F lives for new buildings. On the matter of depreciation patterns, even more guesswork was necessary, the final decision being to assume straight-line depreciation of all capital goods ($w_i = 1/n$ for $i = 1, n$).

In my own recent research (Coen 1974, 1975) I have explored a new method of inferring service lives and depreciation patterns of capital goods from the historical behavior of capital expenditures. Adopting a neoclassical, capital-stock-adjustment formulation of the investment decision that links net investment to changes in output and the real implicit rental price of capital, I experimented with alternative specifications of service lives and depreciation patterns in measuring both net investment and the rental price to determine which specification best accounted, on the average, for observed fluctuations in gross capital expenditures. The best-fitting alternatives may be viewed as the service life and depreciation pattern revealed or indicated by investment behavior.

It is important to note that the capital stock concept appropriate to the study of investment decisions is not market value of fixed assets but current productive capacity of fixed assets. By the same token, the appropriate depreciation concept is not loss of market value but loss of productive capacity or efficiency of fixed assets. A rather farfetched but simple example might help illustrate this point. Suppose we wished to explain the investment behavior of a firm producing light, the desired output of light being the amount emitted by one light bulb (the firm's capital asset). Investment would take place only intermittently, as the bulb burned out. If we knew the average life of a bulb, we could accurately predict the firm's capital expenditures. Put another way, we should be able to infer from the firm's capital expenditures over time that its capital asset has a certain average service life and does not lose efficiency during the service life. Furthermore, the firm's capital stock measured in terms of current productive capacity never changes. Nonetheless, its capital stock in value terms does change through time. A used light bulb, though equivalent to a new one in ability to emit light, will be worth less because it embodies a smaller stream of future services. Depreciation in an economic sense occurs even though depreciation in a loss-of-efficiency sense does not.

Thus, we must clearly distinguish between loss of efficiency and economic depreciation and recognize that analyses of investment behavior can tell us about the former but not the latter. But if our ultimate objective is to measure income, then we must find some way to translate loss of efficiency into economic depreciation—a problem I shall take up in a moment.

My empirical investigations of service lives and loss-of-efficiency patterns covered equipment and structures used in the manufacturing sector, disaggregated into twenty-one subindustries. The revealed lives and patterns are shown in table 3.1.[2] Table 3.2 indicates the industrial breakdown. The weighted-average equipment life for total manufacturing is about twelve years, while that for structures is about thirty-two years.[3] The Bulletin F average lives are about sixteen years for equipment and forty to fifty years for structures. Thus, the revealed life for equipment is about 75% of that in Bulletin F, significantly shorter than the life assumed by the Commerce Department. On the other hand, the revealed life for structures is about 65–70% of that in Bulletin F, in line with that assumed by Commerce.

The predominant loss-of-efficiency pattern in table 3.1 is the one denoted as GD-FIN, which is characterized by geometrically decaying weights truncated at the end of the service life, the rate of decay being twice the reciprocal of the service life. The straight-line (SL) loss-of-efficiency pattern did, however, yield superior results in many instances. Although there is, of course, no way of aggregating the loss-of-efficiency patterns, it seems fair to say that something approximating geometric decay rather than straight-line loss of efficiency is typical of capital used in manufacturing, particularly since the SYD and GD-FIN patterns both suggest greater loss of efficiency in the early years of the service life than in the later years. Hence, if Commerce's choice of a straight-

**Table 3.1** **Service Lives and Loss-of-Efficiency Patterns Revealed by Investment Behavior**

| | Equipment | | Structures | |
|---|---|---|---|---|
| SIC Industry Code[a] | Service Life (in Years) | Capacity Depreciation Pattern | Service Life (in Years) | Capacity Depreciation Pattern |
| 20 | 12 | SL | 20 | SL |
| 21 | 10 | SL | 20 | SYD |
| 22 | 18 | GD-FIN | 20 | OHS |
| 23 | 10 | SYD | 40 | GD-FIN |
| 24 | 8 | SL | 50 | GD-FIN |
| 25 | 20 | GD-FIN | 50 | OHS |
| 26 | 10 | GD-FIN | 30 | SL |
| 27 | 22 | SL | 20 | SYD |
| 28 | 14 | GD-FIN | 25 | SL |
| 29 | 10 | SL | 45 | GD-FIN |
| 30 | 10 | SYD | 40 | GD-FIN |
| 31 | 10 | GD-FIN | 20 | GD-FIN |
| 32 | 10 | GD-FIN | 35 | GD-FIN |
| 33 | 16 | GD-FIN | 40 | GD-FIN |
| 34 | 10 | GD-FIN | 45 | SL |
| 35 | 10 | GD-FIN | 20 | GD-FIN |
| 36 | 6 | SL | 30 | SL |
| 37+19–371 | 8 | SYD | 40 | GD-FIN |
| 371 | 8 | GD-FIN | 45 | GD-FIN |
| 38 | 10 | GD-FIN | 20 | GD-FIN |
| 39 | 20 | SL | 25 | SYD |

*Note*: A capacity depreciation pattern is defined by a set of parameters $d_j$, $j = 1, \ldots, n$, where $d_j$ is the loss of productive capacity of an asset in year $j$ of its service life, relative to its productive capacity when new, and $n$ is the service life. The patterns appearing in this table have the following characteristics:

for SL, $d_j = 1/n$.

for GD-FIN, $d_j = (2/n)[1 - (2/n)]^{j-1}$

for SYD, $d_j = (n + 1 - j) \sum_{i=1}^{n} i$.

for OHS, $d_j = 0$, for $j = 1, \ldots, n - 1$, and $d_n = 1$.

[a]See table 3.2 for identification of SIC (standard industrial classification) industry codes.

line formula is meant to refer to loss of efficiency, it appears to be wide of the mark.

Commerce's treatment of the depreciation formula is confusing, however, since the very same formula is alternatively applied to nominal and real capital expenditures. If the formula refers to loss of efficiency, then it makes sense to apply it to real expenditures, but the resulting "depreciation" measures the real replacement expenditures needed to maintain the productive capacity of the capital stock. Multiplying real replacement requirements by current prices of capital goods yields an estimate of current-dollar replacement, which is not an appropriate concept to use in measuring income. If the formula refers to economic depreciation (loss of value), then it makes sense to apply it to nominal expenditures, giving a historical-cost measure of economic depreciation that would be appropriate to the measurement of income provided prices of capital goods are not changing over time. The point is that one formula cannot serve both purposes. Because the Commerce approach fails to distinguish between loss of efficiency and loss of value, or replacement requirements and economic depreciation, it is difficult to interpret the resulting estimates. Moreover, the approach lacks an articulated concept of income, without which economic depreciation cannot be defined and made operational. The following section presents an explicit and consistent framework for measuring economic depreciation, income, and capital.

## 3.3 Historical-Cost and Current-Cost Concepts of Economic Depreciation

### 3.3.1 The Historical-Cost Concept

In my earlier papers (Coen 1974, 1975) I showed how a loss-of-efficiency pattern of a capital good can be translated into a pattern of economic depreciation, depicting the loss in value of the capital good as it ages. To illustrate, let us consider an asset whose service life is three years. Let $d_j$ be the loss of productive capacity of the asset in year $j$ of its life relative to its efficiency when new. Suppose that the asset, when new, adds $X$ units to real net output (net of materials costs, labor, etc.) and that the price, $P$, at which output may be sold remains constant through time. The asset will then give rise to the following stream of net money returns:

| *Year of Service Life* | *Net Money Return* |
|---|---|
| 1 | $PX$ |
| 2 | $PX(1 - d_1)$ |
| 3 | $PX(1 - d_1 - d_2)$ |

The value of the asset at the end of each year is given by the present value of the stream of net money returns from that year to the end of the service life. If $r$ is the discount rate (assumed constant over time), then for the asset being considered we have

$$C_0 = \frac{PX}{1+r} + \frac{PX(1-d_1)}{(1+r)^2} + \frac{PX(1-d_1-d_2)}{(1+r)^3} \tag{3}$$

$$Z_1 = \frac{PX(1-d_1)}{1+r} + \frac{PX(1-d_1-d_2)}{(1+r)^2} \tag{4}$$

**Table 3.2 Standard Industrial Classification Codes and Descriptions of Industries Referred to in table 3.1**

| SIC Code | Description |
|---|---|
| 20 | Food and kindred products |
| 21 | Tobacco manufactures |
| 22 | Textile mill products |
| 23 | Apparel and related products |
| 24 | Lumber and wood products, except furniture |
| 25 | Furniture and fixtures |
| 26 | Paper and allied products |
| 27 | Printing and publishing |
| 28 | Chemical and allied products |
| 29 | Petroleum and related industries |
| 30 | Rubber and miscellaneous plastic products |
| 31 | Leather and leather products |
| 32 | Stone, clay, and glass products |
| 33 | Primary metal industries |
| 34 | Fabricated metal products |
| 35 | Machinery, except electrical |
| 36 | Electrical machinery |
| 37+19–371 | Transportation equipment and ordnance, except motor vehicles |
| 371 | Motor vehicles and equipment |
| 38 | Instruments and related products |
| 39 | Miscellaneous manufacturing industries |

(5) $$Z_2 = \frac{PX(1 - d_1 - d_2)}{1 + r}$$

(6) $$Z_3 = 0,$$

where $C_0$ is the original cost of the asset, $Z_1$ is the value of the asset at the end of its first year of service, and so forth. Depreciation each year, that is, the loss in value of the asset, is given by

(7) $$D_1 = C_0 - Z_1$$

(8) $$D_2 = Z_1 - Z_2$$

(9) $$D_3 = Z_2 - Z_3,$$

and depreciation charges summed over the service life equal the eventual replacement cost of the asset.

What property do these measures of depreciation possess? The fundamental point is as follows. In each year of the asset's life, it generates a certain amount of money receipts. The problem of depreciation accounting is to decompose these receipts into two components, of which we call one income, the other depreciation. If we define income as the portion of receipts that *could be* consumed (or withdrawn for some other purpose) and still leave the owner with the same real wealth at the end of the year as he possessed at the beginning of the year, then the depreciation method proposed here is the appropriate one, *provided that the price of a comparable new asset is not changing over time.*

To establish that this proposition is correct, let us examine the situation in the first year of the asset's life. Suppose we denote income in year 1, as income was defined above, by $Y_1$. The owner's nominal wealth at the beginning of year 1 is simply $C_0$, and his real wealth is one (one capital good). If the price of new capital goods of this type is constant through time, then we require that the owner's wealth at the end of year 1 be $C_0$, so that his real wealth will not have changed. He will, of course, have a used asset worth $Z_1$ at that time, and he will have $PX - Y_1$ in cash. Thus, if his wealth at the end of year 1 is to be $C_0$, we must have

$$PX - Y_1 + Z_1 = C_0. \tag{10}$$

But $PX - Y_1$ is what we would identify as depreciation in year 1, $D_1$, so that

$$D_1 = C_0 - Z_1. \tag{11}$$

Receipts in the second year are composed of two flows: the net money return generated by the asset, $PX(1 - d_1)$, and interest on depreciation set aside in year 1, $rD_1$. Also, the owner's wealth at the end of year 2 is composed of two items: the two-year-old asset worth $Z_2$, and the amount of cash set aside for depreciation in year 1, $D_1$. Again assuming that the price of a new capital good similar to the used one has not changed, we require that the owner's wealth at the end of year 2 be $C_0$. Thus income in year 2 is implicitly defined by

$$PX(1 - d_1) + rD_1 - Y_2 + Z_2 + D_1 = C_0. \tag{12}$$

Since $D_2$ is $PX(1 - d_1) + rD_1 - Y_2$, that is, total receipts minus income, we have

$$D_2 = C_0 - Z_2 - D_1 = C_0 - Z_2 - C_0 + Z_1 = Z_1 - Z_2. \tag{13}$$

Similar reasoning would lead to the conclusion that $D_3 = Z_2 - Z_3$.

With depreciation in each year defined by these expressions, it can easily be shown that income in each year of the asset's life is the same and equal to $rC_0$ and that the rate of return is the same each year and equal to $r$.

Thus, under the assumption of constant prices the calculation of depreciation is straightforward. For our purposes it is convenient to normalize the depreciation flows in the above example on the initial value of the asset. This gives us a set of parameters $v_j$, defined as

(14) $$v_1 = \frac{C_0 - Z_1}{C_0}$$

(15) $$v_2 = \frac{Z_1 - Z_2}{C_0}$$

(16) $$v_3 = \frac{Z_2 - Z_3}{C_0},$$

which characterize the pattern of economic depreciation on the asset. In other words, the $v_j$ depict the pattern of economic depreciation on an asset of this type costing one dollar when new. Note that under this normalization, the term $PX$ will not appear in the $v_j$. They will depend only on the parameters characterizing capacity depreciation and on the discount rate. Depreciation in each year and the value of the asset at the end of each year can then be expressed in terms of the original cost of the asset:

(17) $$D_1 = v_1 C_0 \qquad Z_1 = (1 - v_1)C_0$$

(18) $$D_2 = v_2 C_0 \qquad Z_2 = (1 - v_1 - v_2)C_0$$

(19) $$D_3 = v_3 C_0 \qquad Z_3 = 0.$$

This approach, based as it is on the assumption of constant prices, is certainly rather unrealistic. Its implementation results in depreciation measures reflecting the historical, or original, cost of assets. In times of changing prices, historical-cost depreciation will be incorrect in the sense that the measure of income associated with it will not properly indicate how much of current receipts can be consumed and still leave real wealth intact. Nonetheless, the simplicity of historical-cost depreciation and its conceptual similarity to tax accounting practices in the United States are notable features.

These results can be stated in a more general way. If $d_j$ is the fraction of an asset's original productive capacity that is lost in period $j$ of its service life (with $d_0 = 0$), and if the asset has a productive capacity of unity when new, then the value of the asset at the end of period $j$ of its service life is

(20) $$V_j = \sum_{k=j}^{n} \left(1 - \sum_{i=0}^{k} d_i\right) (1 + r)^{-k+j-1}, \quad j = 0,n.$$

The fraction of the asset's original value, $V_0$, lost in period $j$ of its service life—economic depreciation in period $j$—is

(21) $$v_j = (V_{j-1} - V_j)/V_0, \quad j = 1,n.$$ [4]

By the nature of these definitions, the sum of the economic depreciation weights, the $v_j$s, over the life of the asset must be unity. Then historical-cost economic depreciation on vintage $\tau$ capital goods in period $t$ is given by

$$(22)\qquad \begin{cases} D_{t\tau} = v_{t-\tau} I_\tau, & \tau < t \leq \tau + n \\ D_{t\tau} = 0, & \tau > \tau + n, \end{cases}$$

where $I_\tau$ is measured in nominal terms at the original acquisition price.

The contribution of vintage $\tau$ capital goods to what I shall call the book value of capital at the end of period $t$ is

$$(23)\qquad B_{t\tau} = I_\tau - \sum_{j=\tau+1}^{t} D_{j\tau}.$$

Equations (22) and (23) are identical in form to those used by the Commerce Department in calculating historical-cost depreciation and capital stock. But here the depreciation rates are explicitly related to the underlying loss-of-efficiency pattern and service life, and the "capital stock" is explicitly referred to as "book value of capital" to distinguish it from a physical measure of productive capacity.

### 3.3.2 The Current-Cost Concepts

Capital goods prices commonly change over time, raising serious difficulties in the measurement of depreciation and income. While knowledge of the causes of these changes, as well as whether they are foreseen or unforeseen, is required to take proper account of them, we can do little but speculate about such matters. Consequently, any approach to depreciation measurement under conditions of changing prices is necessarily somewhat arbitrary. We can formulate a set of assumptions and examine their implications, but we must recognize that a different, and perhaps equally plausible, set of assumptions may lead to different results.

Here I shall examine the implications of three assumptions regarding price expectations:

*Case A*: Firms expect last period's price level to prevail indefinitely, so that any change in the price level is a surprise.

*Case B*: Firms expect last period's rate of inflation to prevail indefinitely, so that any change in the rate of inflation is a surprise.

*Case C*: Firms can perfectly predict the rate of inflation.

In each case I shall assume that these expectations pertain to product prices, that changes in capital goods prices result solely from changes in prices of the outputs they produce, and that the value of a capital good is equal to the present value of the expected stream of net money returns it will produce.

Before proceeding, it is worth noting that cases A and C might be viewed as two ends of a continuum running from complete inability to predict prices to perfect foresight, while B lies somewhere between these extremes. As we shall see, one of the extremes—Case C—gives rise to current-cost accounting procedures that are analogous to those adopted by the Commerce Department.

The depreciation measures appropriate to these special cases are most easily derived from a general accounting framework incorporating changing prices. Suppose an individual purchases a new capital good at the end of year 0 for $C_0$ dollars. The capital good has a three-year life, and its capacity depreciation in year $j$ of its life is $d_j$. We shall assume that the purchase price equals the present value of the stream of expected future net money returns. In addition, we shall assume that at the time of purchase the asset's owner expects the rate of inflation to be $\gamma^e{}_1$ and expects the nominal rate of interest to adjust so as to keep the real rate of interest constant at $r$. Thus,

$$(24) \qquad C_0 = \frac{(1+\gamma^e{}_1)P_0X}{(1+r)(1+\gamma^e{}_1)} + \frac{(1+\gamma^e{}_1)^2\, P_0X(1-d_1)}{[(1+r)(1+\gamma^e{}_1)]^2} + \frac{(1+\gamma^e{}_1)^3\, P_0X(1-d_1-d_2)}{[(1+r)(1+\gamma^e{}_1)]^3} = \frac{P_0X}{1+r} + \frac{P_0X(1-d_1)}{(1+r)^2} + \frac{P_0X(1-d_1-d_2)}{(1+r)^3},$$

the same as in equation (3).

If the price level in the first year of the asset's life turns out to be $P_1 = (1+\gamma_1)P_0 \neq (1+\gamma^e{}_1)P_0$, and if the owner changes his expected rate of inflation to $\gamma^e{}_2$, then the value of the used asset at the end of the first year will be

$$(25) \qquad Z_1 = \frac{(1+\gamma^e{}_2)\, P_1X(1-d_1)}{(1+r)(1+\gamma^e{}_2)} + \frac{(1+\gamma^e{}_2)^2\, P_1X(1-d_1-d_2)}{[(1+r)(1+\gamma^e{}_2)]^2} = \frac{P_1X(1-d_1)}{1+r} + \frac{P_1X(1-d_1-d_2)}{(1+r)^2} = (1+\gamma_1)(1-v_1)C_0,$$

where $v_1$ is defined as in equation (14); that is, $v_1$ is the first-year historical-cost depreciation rate.

A new asset of the same type should sell at the end of year 1 for

$$(26) \qquad C_1 = \frac{(1+\gamma^e{}_2)P_1X}{(1+r)(1+\gamma^e{}_2)} + \frac{(1+\gamma^e{}_2)^2\, P_1X(1-d_1)}{[(1+r)(1+\gamma^e{}_2)]^2} + \frac{(1+\gamma^e{}_3)^3\, P_1X(1-d_1-d_2)}{[(1+r)(1+\gamma^e{}_2)]^3} = (1+\gamma_1)C_0.$$

We see then that under our assumptions the price of new capital goods and the value of used capital goods should rise or fall at the same rate as the output price level.

Nominal ex post income in the first year of the asset's life is implicitly given by

(27) $$P_1X - Y_1 + Z_1 = C_1;$$

so depreciation in that year is

(28) $$D_1 = C_1 - Z_1 = (1 + \gamma_1)C_0 - (1 - v_1)\ (1 + \gamma_1)C_0$$
$$= (1 + \gamma_1)v_1C_0.$$

Thus, first-year current-cost depreciation is the first-year historical-cost depreciation, $v_1C_0$, multiplied by one plus the actual rate of inflation. This result, which is evidently independent of the manner in which price expectations are formed, is in accord with a frequently recommended change in tax depreciation policy, namely, that firms be permitted to inflate their historical-cost depreciation by a factor reflecting the rate of change of the price level. When we move on to the second year, however, we see that the situation is not quite so simple.

Suppose that the price level in the second year is $P_2 = (1 + \gamma_2)P_1 \neq (1 + \gamma^e{}_2)P_1$, and suppose that the owner once again revises his expected rate of inflation to $\gamma^e{}_3$. The value of the used asset at the end of the second year should then be $Z_2 = (1 - v_1 - v_2)(1 + \gamma_2)(1 + \gamma_1)C_0$, and a new asset of the same type should sell for $C_2 = (1 + \gamma_2)(1 + \gamma_1)C_0$. Since the owner anticipated an inflation rate of $\gamma^e{}_2$ in the second year, it seems reasonable to assume that he would have held his depreciation reserve in a form that (*a*) would yield a nominal rate of return of $(1 + \gamma^e{}_2)r$ and thus a real rate of return of $r$ and (*b*) would have appreciated at the rate of $\gamma^e{}_2$. Hence, receipts in the second year consist of $P_2X(1 - d_1)$ from production and $(1 + \gamma^e{}_2)r\ D_1$ in interest on the depreciation reserve; and at the end of the second year the owner has a used asset worth $Z_2$ and a depreciation reserve amounting to $(1 + \gamma^e{}_2)D_1$. Nominal ex post income in the second year is implicitly given by

(29) $$P_2X(1 - d_1) + (1 + \gamma^e{}_2)rD_1 - Y_2 + Z_2$$
$$+ (1 + \gamma^e{}_2)D_1 = C_2;$$

so depreciation in that year is

(30) $$\begin{aligned} D_2 &= C_2 - Z_2 - (1 + \gamma^e{}_2)D_1 \\ &= (1 + \gamma_2)(1 + \gamma_1)C_0 \\ &\quad - (1 - v_1 - v_2)(1 + \gamma_2)(1 + \gamma_1)C_0 \\ &\quad - (1 + \gamma^e{}_2)(1 + \gamma_1)v_1\ C_0 \\ &= (1 + \gamma_2)(1 + \gamma_1)v_2C_0 + \\ &\qquad (\gamma_2 - \gamma^e{}_2)(1 + \gamma_1)v_1C_0. \end{aligned}$$

The first term in the final expression for $D_2$ is the second-year historical-cost depreciation inflated to the price level of year 2, but to this we must add an adjustment of the first-year current-cost depreciation, marking it up by the excess of the actual over the expected rate of inflation in year 2.

The key assumption here is that the depreciation reserve (in this case the first-year current-cost depreciation) does not appreciate pari passu with the price level in year 2; instead, it appreciates at the *expected* rate of inflation in year 2. Hence, insofar as the actual price increase in year 2 exceeds the expected increase, additional depreciation must be claimed, so that the total reserve at the end of year 2, when added to the value of the used asset, equals the purchase price of a new asset of the same type. This assumption would be incorrect if the depreciation reserve were held in the form of commodities or capital goods whose value automatically rose at the actual rate of inflation; but it would be correct if, for example, the reserve were held in the form of financial assets whose terms were fixed contractually at the end of the first year. It is nearly impossible, of course, to identify in practice the form or forms in which firms hold their depreciation reserves, since these reserves are often mere accounting entries. Lacking clear evidence one way or the other, I am inclined to follow a more conservative course and presume that firms are at best able to earn nominal capital gains on their depreciation reserves at a rate equal to the expected rate of inflation, in which case the real value of reserves would be maintained only if the expected and actual rates of inflation were the same.

A similar result holds for current-cost depreciation in the third year. If at the end of year 2 the owner expects the inflation rate to be $\gamma^e_3$ in the third year and beyond, he should hold his total depreciation reserve, $(1 + \gamma^e_2)D_1 + D_2 = (1 + \gamma_2)(1 + \gamma_1)(v_2 + v_1)C_0$, in a form that yields a nominal rate of return of $(1 + \gamma^e_3)r$ and that appreciates at the rate $\gamma^e_3$. The used asset should be worth $(1 + \gamma_3)(1 + \gamma_2)(1 + \gamma_1) \cdot (1 - v_1 - v_2 - v_3)C_0 = 0$ at the end of year 3, and a comparable new asset should sell for $(1 + \gamma_3)(1 + \gamma_2)(1 + \gamma_1)C_0$, where $\gamma_3$ is the actual rate of inflation in year 3. Nominal ex post income in year 3 is given by

$$\begin{aligned}(31) \qquad & P_3X(1 - d_1 - d_2) + (1 + \gamma^e_3)r \\ & [(1 + \gamma^e_2)D_1 + D_2] - Y_3 \\ & + (1 + \gamma^e_3)[(1 + \gamma^e_2)D_1 + D_2] + Z_2 = C_3,\end{aligned}$$

from which it follows that

$$\begin{aligned}(32) \qquad D_3 &= C_3 - Z_3 - (1 + \gamma^e_3)\,[(1 + \gamma^e_2)D_1 + D_2] \\ &= (1 + \gamma_3)(1 + \gamma_2)(1 + \gamma_1)v_3C_0 \\ &+ (\gamma_3 - \gamma^e_3)(1 + \gamma_2)\,(1 + \gamma_1)(v_2 + v_1)C_0.\end{aligned}$$

The first term in the final expression for $D_3$ is the third-year historical-cost depreciation inflated to the price level of the third year, and to this we must again add an adjustment of the depreciation reserve accumulated at the end of the previous year, marking it up by the excess of the actual over the expected rate of inflation in year 3.

Making use of these expressions for current-cost depreciation, we can derive the following measures of income over the life of the asset:

$$Y_1 = (1 + \gamma_1)rC_0 \tag{33}$$

$$\begin{aligned} Y_2 = {} & (1 + \gamma_2)(1 + \gamma_1)rC_0 - \\ & (\gamma_2 - \gamma^e{}_2)(1 + r)(1 + \gamma_1)v_1C_0 \end{aligned} \tag{34}$$

$$\begin{aligned} Y_3 = {} & (1 + \gamma_3)(1 + \gamma_2)(1 + \gamma_1)rC_0 - \\ & (\gamma_3 - \gamma^e{}_3)(1 + r)(1 + \gamma_2) \\ & (1 + \gamma_1)(v_2 + v_1)C_0. \end{aligned} \tag{35}$$

If the actual rate of inflation were always perfectly foreseen, the second terms of $Y_2$ and $Y_3$ would be zero, nominal income would rise pari passu with the price level, and the real rate of return on the asset would be constant at $r$. Should the actual rate of inflation continually exceed (fall below) the expected rate, however, nominal income will rise less (more) rapidly than the price level and the real rate of return on the asset will decline (rise) over the service life.

Perfect foresight regarding inflation corresponds to case $C$ above, whereas for case A we have $\gamma^e{}_i = 0$ and for case B we have $\gamma^e{}_i = \gamma_{i-1}$. Thus, only case $C$ results in measures of depreciation that imply constant real income over the life of an asset. On the other hand, only case A results in depreciation allowances that sum over an asset's life to its eventual replacement cost; in an inflationary environment, total depreciation allowances associated with cases B and C will fall short of replacement cost, although the depreciation reserves accumulated by the end of an asset's life, which include capital gains on the reserves held during the life of the asset, will equal the replacement cost.

We can now illustrate how these current-cost measures of depreciation will be applied to firms that invest year after year. Let $I_\tau$ once again be nominal gross capital expenditures in year $\tau$; let $c_t$ be an index of capital goods prices in year $t$; and let $D_{t\tau}$ be current-cost depreciation in year $t$ on vintage $\tau$ capital goods. Noting that prices of new capital goods rise or fall at the same rate as product rises, according to our assumptions, and that for $t > \tau$, $c_t = (1 + \gamma_t)(1 + \gamma_{t-1}) \ldots (1 + \gamma_{\tau+1})c_\tau$, we have:

$$(36)\quad \textit{Case A}:\; D_{t\tau} = \frac{c_t}{c_\tau} v_{t-\tau} I_\tau + \frac{c_t - c_{t-1}}{c_\tau} \left( \sum_{j=1}^{t-\tau-1} v_{t-\tau-j} \right) I_\tau$$

$$(37)\quad \textit{Case B}:\; D_{t\tau} = \frac{c_t}{c_\tau} v_{t-\tau} I_\tau + \left( \frac{c_t}{c_{t-1}} - \frac{c_{t-1}}{c_{t-2}} \right) \frac{c_{t-1}}{c_\tau} \left( \sum_{j=1}^{t-\tau-1} v_{t-\tau-j} \right) I_\tau$$

$$(38)\quad \textit{Case C}:\; D_{t\tau} = \frac{c_t}{c_\tau} v_{t-\tau} \mathrm{I}_\tau,$$

all of which hold for $\tau < t \leq \tau + n$, where $n$ is the service life. Since our assumptions also imply that the values of used capital goods rise or fall at the same rate as product prices, the contribution of vintage $\tau$ capital goods to the book value of capital at the end of period $t$ does not depend on the expectations hypothesis and can be expressed in each case as:

$$(39)\qquad B_{t\tau} = \frac{c_t}{c_\tau}\left[ 1 - \sum_{j=\tau+1}^{t} v_j \right] I_\tau .$$

In case A, calculating $B_{t\tau}$ in this way is the same as subtracting accumulated depreciation charges from real vintage $\tau$ capital expenditures valued at current prices. But this is not true of cases B and C; in these latter cases, $B_{t\tau}$ is real vintage $\tau$ capital expenditures valued at current prices less the depreciation reserve at the end of year $t$, which includes capital gains on previous depreciation charges.

Comparing these measures with the Commerce procedures, we see that there is a close parallel between equation (38) and what Commerce calls current-cost depreciation. According to equation (38), we should calculate current-cost depreciation by applying a given depreciation schedule to real capital expenditures ($I_\tau/c_\tau$) and valuing the result at current prices, which is what Commerce does. The only difference in our approaches lies in the choice of a depreciation schedule; while Commerce assumes a straight-line formula with lives 15% shorter than Bulletin F, I base my $v$s on the loss-of-efficiency patterns and service lives revealed by investment behavior. Like equation (38), however, the Commerce procedure is now seen to be appropriate only if firms are able to predict perfectly the rate of inflation (and if all the other assumptions we have made hold). That expectations are so accurate is doubtful, I believe, and it therefore seems worthwhile to compare the implications of this extreme hypothesis with those associated with imperfect foresight (cases A and B).

Although equation (38) does not appear to resemble equation (2), in fact it does. In computing its current-cost capital stock, Commerce first computes a constant-cost measure of capital stock using equation

(2), with $I_\tau$ defined as *real* vintage $\tau$ capital expenditures and $D_{j\tau}$ defined as *real* depreciation in period $j$ on vintage $\tau$ capital. Real depreciation is obtained by applying the depreciation rate $w$ to real capital expenditures. Multiplying the constant-cost capital stock, $K_{t\tau}$, by the capital goods price index in period $t$, $c_t$, Commerce arrives at its current-cost capital stock. Thus, differences between my current-cost book value and Commerce's current-cost capital stock result solely from differences in the service lives and depreciation patterns employed, and we see that Commerce's procedure is equivalent to subtracting the depreciation reserve (*not* accumulated depreciation charges) at the end of year $t$ from vintage $\tau$ capital expenditures valued at current prices.

Finally, Commerce's so-called constant-cost measures of depreciation and capital stock appear to have no obvious parallels in these results. We could, of course, deflate my measures for $D_{t\tau}$ and $B_{t\tau}$, and the associated nominal income estimates, by $c_t$ to obtain constant-dollar variants of them, but this would provide little additional information; indeed, it would have no effect on my estimates of rates of return. What can be of interest, however, are estimates of real replacement requirements, which differ conceptually from constant-dollar depreciation. The real capital expenditure, $R_{t\tau}$, required in year $t$ to maintain the productive capacity (*not* the real value) of vintage $\tau$ capital goods is found by applying the appropriate loss-of-efficiency pattern to real capital expenditures of year $\tau$:

(40) $$R_{t\tau} = d_{t-\tau} I_\tau / c_\tau.$$ [5]

Current-dollar replacement is then given by

(41) $$c_t R_{t\tau} = c_t\, d_{t-\tau}\, I_\tau / c_\tau.$$

Equations (40) and (41) resemble Commerce's formulas for calculating constant-cost and current-cost depreciation, but here the $d_j$s explicitly refer to loss of efficiency. Because Commerce fails to make any distinction between loss of efficiency and loss of value, the concepts of depreciation and replacement, as well as the related notions of value of capital and of productive capacity, are obscured. If the depreciation schedule Commerce adopts is meant to depict loss of efficiency, then what Commerce calls constant-cost depreciation ought to be called constant-cost replacement, and what Commerce calls current-cost depreciation ought to be called current-cost replacement.

## 3.4 Empirical Comparisons of Alternative Measures of Depreciation and Their Implications

Table 3.3 presents annual estimates of historical-cost and current-cost depreciation in total manufacturing for 1947–74, prepared accord-

Table 3.3 **Alternative Estimates of Capital Consumption, Total Manufacturing, 1947–74 (in Billions of Dollars)**

| | | BEA | | Coen | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Economic Depreciation | | | | Current-Cost Replacement |
| | | | | | Current Cost | | | |
| Year | Tax | Historical Cost | Current Cost | Historical Cost | A | B | C | |
| 1947 | 2.422 | 2.286 | 3.276 | 2.513 | 8.817 | 4.471 | 3.413 | 3.371 |
| 1948 | 2.859 | 2.666 | 3.923 | 3.217 | 5.535 | −0.947 | 4.232 | 4.060 |
| 1949 | 3.246 | 2.991 | 4.216 | 3.737 | 4.983 | 3.504 | 4.743 | 4.479 |
| 1950 | 3.497 | 3.287 | 4.562 | 3.990 | 7.934 | 7.585 | 5.124 | 4.823 |
| 1951 | 4.049 | 3.651 | 5.390 | 4.255 | 10.679 | 7.599 | 5.798 | 5.512 |
| 1952 | 4.703 | 4.055 | 5.794 | 4.802 | 7.989 | 2.415 | 6.287 | 5.938 |
| 1953 | 5.573 | 4.437 | 6.166 | 5.284 | 7.553 | 5.728 | 6.702 | 6.367 |
| 1954 | 6.378 | 4.828 | 6.449 | 5.756 | 7.288 | 6.374 | 7.082 | 6.721 |
| 1955 | 7.177 | 5.220 | 6.932 | 6.228 | 8.840 | 8.576 | 7.565 | 7.157 |
| 1956 | 7.747 | 5.679 | 7.858 | 6.643 | 14.106 | 12.715 | 8.463 | 8.116 |
| 1957 | 8.558 | 6.208 | 8.668 | 7.399 | 14.008 | 7.639 | 9.515 | 9.267 |
| 1958 | 9.110 | 6.659 | 9.003 | 8.076 | 10.373 | 5.477 | 9.995 | 9.665 |
| 1959 | 9.136 | 6.989 | 9.280 | 8.239 | 10.986 | 10.556 | 10.036 | 9.748 |
| 1960 | 9.680 | 7.364 | 9.517 | 8.407 | 10.650 | 9.637 | 10.069 | 9.733 |
| 1961 | 10.162 | 7.730 | 9.721 | 8.697 | 10.616 | 9.964 | 10.151 | 9.889 |
| 1962 | 11.998 | 8.082 | 9.951 | 8.890 | 11.525 | 11.037 | 10.252 | 9.867 |
| 1963 | 12.771 | 8.484 | 10.251 | 9.193 | 11.963 | 10.624 | 10.509 | 10.185 |
| 1964 | 13.688 | 8.948 | 10.659 | 9.589 | 13.053 | 11.531 | 10.917 | 10.666 |
| 1965 | 14.856 | 9.578 | 11.316 | 10.212 | 13.767 | 11.539 | 11.561 | 11.368 |

Table 3.3 (continued)

| Year | Tax | BEA | | Coen | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Economic Depreciation | | | | Current Cost Replacement |
| | | Historical Cost | Current Cost | Historical Cost | Current Cost | | | |
| | | | | | A | B | C | |
| 1966 | 16.127 | 10.448 | 12.378 | 11.244 | 15.782 | 13.493 | 12.745 | 12.748 |
| 1967 | 17.661 | 11.436 | 13.655 | 12.635 | 19.049 | 15.934 | 14.423 | 14.312 |
| 1968 | 19.393 | 12.413 | 14.835 | 13.939 | 20.770 | 15.926 | 16.052 | 15.692 |
| 1969 | 20.921 | 13.443 | 16.471 | 14.960 | 26.217 | 21.181 | 17.607 | 17.059 |
| 1970 | 22.099 | 14.459 | 18.162 | 16.138 | 29.276 | 19.716 | 19.474 | 18.784 |
| 1971 | 23.320 | 15.328 | 19.587 | 17.065 | 33.005 | 22.091 | 21.136 | 20.420 |
| 1972 | 24.813 | 16.255 | 20.716 | 17.629 | 27.865 | 14.597 | 21.786 | 21.097 |
| 1973 | 25.840 | 17.401 | 22.402 | 18.568 | 34.760 | 28.249 | 23.224 | 22.537 |
| 1974 | 27.364 | 18.791 | 25.416 | 20.165 | 45.959 | 33.138 | 26.535 | 25.733 |

ing to the procedures described in sections 3.2 and 3.3. The Commerce Department, or Bureau of Economic Analysis (BEA), estimates (from 1976*a*) appear in columns 2 and 3. My estimates, appearing in columns 4 through 7, represent aggregates of separately calculated equipment and structures estimates for the twenty-one subindustries shown in table 3.2. For comparative purposes, two additional series are included in the table—the BEA's tax-return measure of depreciation and my measure of current-cost replacement.

My historical-cost series exceeds the BEA's in every year, being about 10% higher in 1947 and 7% higher in 1974. Since my service lives for equipment are shorter on average than those assumed by Commerce and my depreciation patterns are generally more accelerated, this outcome was to be expected. Both historical-cost series display smoother growth over time than does the tax-return measure, since the latter is influenced by accelerated amortization during World War II and the Korean period, by the introduction of accelerated tax write-off methods in 1954, and by reductions in tax service lives in 1962 and 1971. According to either the BEA's estimates or my own, depreciation allowances for tax purposes began to substantially exceed consistently measured historical-cost depreciation about 1954, the excess growing to 36–46% by 1974.

As we saw above, the formula used by the BEA to calculate current-cost depreciation resembles the one that emerges in my case C, and we see in table 3.3 that these two measures of current-cost depreciation are empirically very similar. My case C current-cost depreciation somewhat exceeds the BEA's for the same reasons that my historical-cost depreciation exceeds the BEA's—shorter service lives for equipment and higher depreciation rates in the early years of the service lives.

On the other hand, variants A and B of my current-cost estimates differ radically from the BEA's, with the possible exception of the period of relatively stable prices from 1959 to 1964. For these cases of imperfect foresight, the rate of inflation of capital goods prices has a much more pronounced influence on measured depreciation. Inflation enlarges measured depreciation not only by raising proportionately the amount that would otherwise have been claimed in a given year, as in case C, but also by adjusting upward the depreciation claimed in prior years. In case A this latter adjustment is larger the higher the current inflation rate and will be negative when prices fall; in case B the adjustment is larger the larger the excess of the current over the lagged rate of inflation and will be negative when the rate of inflation declines. These adjustments result in wide fluctuations in measured depreciation, with variant B actually turning negative in 1948 because of the sharp decline in the rate of change of structures prices from 21% in 1947 to only 1% in 1948. Recall that by the assumptions of case B, the depreciation reserve at the end of 1947 would appreciate during 1948 at a rate equal to the 1947 rate of inflation; and given this substantial appreciation of the reserve, a negative addition to the reserve would be called for in 1948.

Although variant A exceeds the other current-cost measures in every year, there is no consistent relation between variants B and C. When the rate of inflation changes little from year to year, variants B and C are roughly the same; and when the inflation rate rises at a steady pace, variant B exceeds variant C. But when the inflation rate undergoes marked year-to-year changes, variant B is sometimes above and sometimes below variant C.

How do tax depreciation allowances measure up when compared with these consistent current-cost estimates of depreciation? It is often claimed that depreciation permitted for tax purposes has been inadequate in the inflationary environment of recent years, because tax regulations allow only the original cost of an asset to be written off. This deficiency of the tax laws may be more or less offset, however, by reductions in asset service lives for tax purposes or by acceleration of tax depreciation over the allowable service lives. The evidence in table 3.3 indicates that tax depreciation exceeded consistently measured current-cost depreciation during the period 1962–66, no matter which current-cost concept one chooses. After 1966, tax depreciation continues to exceed the BEA current-cost series and my variant C, but it drops below variant A beginning in 1967 and below variant B beginning in 1973. Thus, unless we believe that firms persistently expected a zero rate of inflation during the late 1960s and early 1970s—the assumption characterizing variant A, and one that seems rather implausible—we must conclude that reductions in tax service lives in 1962 and 1971 have, on the whole, more than compensated for the underdepreciation associated with historical-cost accounting for tax purposes. In any event, tax depreciation allowances in the 1960s and 1970s must certainly be regarded as generous when viewed relative to the situation in the 1940s and 1950s. Moreover, tax write-offs consistently exceeded current-cost replacement requirements since 1961; and although the ratio of tax depreciation to replacement requirements fell sharply in 1974, it still remained well above the levels prevailing before 1961.

Table 3.4 presents seven measures of profit-type income in manufacturing for 1947–74, each one derived using a depreciation series in table 3.3. In all cases, profit-type income is the return to capital net of capital consumption and interest, but before income taxes. The only ingredient that varies from one measure to another is the estimate of capital consumption. A profit-type income series corresponding to my current-cost replacement is not shown because, as I argued above,

**Table 3.4 Alternative Estimates of Profit-type Income, Total Manufacturing, 1947–74 (in Billions of Dollars)**

| | | BEA | | Coen | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Current-Cost Depreciation | | |
| Year | Tax Depreciation | Historical-Cost Depreciation | Current-Cost Depreciation | Historical-Cost Depreciation | A | B | C |
| 1947 | 13.129 | 13.265 | 12.275 | 13.038 | 6.734 | 11.080 | 12.138 |
| 1948 | 16.244 | 16.437 | 15.180 | 15.886 | 13.568 | 20.050 | 14.871 |
| 1949 | 15.353 | 15.608 | 14.383 | 14.862 | 13.616 | 15.095 | 13.856 |
| 1950 | 19.786 | 19.996 | 18.721 | 19.293 | 15.349 | 15.698 | 18.159 |
| 1951 | 23.569 | 23.967 | 22.228 | 23.363 | 16.939 | 20.019 | 21.820 |
| 1952 | 20.845 | 21.493 | 19.754 | 20.746 | 17.559 | 23.133 | 19.261 |
| 1953 | 21.007 | 22.143 | 20.414 | 21.296 | 19.027 | 20.852 | 19.878 |
| 1954 | 18.396 | 19.946 | 18.325 | 19.018 | 17.486 | 18.400 | 17.692 |
| 1955 | 24.137 | 26.094 | 24.382 | 25.086 | 22.474 | 22.738 | 23.749 |
| 1956 | 22.525 | 24.593 | 22.414 | 23.629 | 16.166 | 17.557 | 21.809 |
| 1957 | 21.880 | 24.230 | 21.770 | 23.039 | 16.430 | 22.799 | 20.923 |
| 1958 | 17.425 | 19.876 | 17.532 | 18.459 | 16.162 | 21.058 | 16.540 |
| 1959 | 24.231 | 26.378 | 24.087 | 25.128 | 22.381 | 22.811 | 23.331 |
| 1960 | 22.164 | 24.480 | 22.327 | 23.437 | 21.194 | 22.207 | 21.775 |
| 1961 | 21.031 | 23.463 | 21.481 | 22.496 | 20.577 | 21.229 | 21.042 |
| 1962 | 23.822 | 27.738 | 25.869 | 26.930 | 24.295 | 24.783 | 25.568 |
| 1963 | 26.646 | 30.933 | 29.166 | 30.224 | 27.454 | 28.793 | 28.908 |
| 1964 | 29.516 | 34.256 | 32.545 | 33.615 | 30.151 | 31.673 | 32.287 |
| 1965 | 35.711 | 40.989 | 39.251 | 40.355 | 36.800 | 39.028 | 39.006 |

Table 3.4 (continued)

| | | BEA | | Coen | | | |
|---|---|---|---|---|---|---|---|
| | | | | | Current-Cost Depreciation | | |
| Year | Tax Depreciation | Historical-Cost Depreciation | Current-Cost Depreciation | Historical-Cost Depreciation | A | B | C |
| 1966 | 38.705 | 44.384 | 42.454 | 43.588 | 39.050 | 41.339 | 42.087 |
| 1967 | 34.574 | 40.799 | 38.580 | 39.600 | 33.186 | 36.301 | 37.812 |
| 1968 | 37.277 | 44.257 | 41.835 | 42.731 | 35.900 | 40.744 | 40.618 |
| 1969 | 32.473 | 39.951 | 36.923 | 38.434 | 27.177 | 32.213 | 35.787 |
| 1970 | 22.501 | 30.141 | 26.438 | 28.462 | 15.324 | 24.884 | 25.126 |
| 1971 | 27.637 | 35.629 | 31.370 | 33.892 | 17.952 | 28.866 | 29.821 |
| 1972 | 34.961 | 43.519 | 39.058 | 42.145 | 31.909 | 45.177 | 37.988 |
| 1973 | 35.278 | 43.717 | 38.716 | 42.550 | 26.358 | 32.869 | 37.894 |
| 1974 | 22.788 | 31.361 | 24.736 | 29.987 | 4.193 | 17.014 | 23.617 |

*Note*: Profit-type income is gross product originating minus employee compensation, net interest, indirect business taxes, and depreciation.

current-cost replacement is not an appropriate measure of capital consumption for purposes of income measurement.

The two profits series based on historical-cost depreciation are relatively similar, reflecting the similarity of the depreciation estimates. They both remain very close to tax-based profits until 1954, but liberalizations of tax write-offs thereafter lead to growing excesses of consistently measured profits over tax-based profits. By 1974, taxable profits are understating consistently measured profits by 24–27%.

Profits based on the BEA's current-cost depreciation and my variant C display a very different pattern. They fall roughly in line with taxable profits until 1962 and exceed taxable profits for the rest of the period. The excesses are not as great as for the BEA's historical-cost series, but they are sizable, even in 1974.

Profits based on my variant A approximate taxable profits only during the period 1958–67. Aside from a few other isolated years, this series is well below taxable profits as well as the other estimates. Profits are generally acknowledged to be highly unstable, and it is interesting to note how the inflation-adjusted depreciation modifies their instability in this case. The post–World War II recessions or retardations before 1967 were usually periods of deflation or decelerating inflation, either of which tends to moderate the growth of current-cost depreciation in case A and therefore attenuates the decline in profits. This is clearly evident in table 3.4. Taxable profits declined by 5.5% in the 1949 recession, 12.4% in the 1954 recession, and 20.4% in the 1958 recession, but the inflation-adjusted measure rose by 0.4% in 1949 and declined by only 8.1% and 1.6% in 1954 and 1958. When recession is accompanied by inflation or accelerating inflation as in recent years, however, the inflation adjustment leads to more marked deterioration in profits. The most notable example of this is, of course, 1974.

Profits based on my variant B resemble most closely those associated with variant C. When the inflation rate changes sharply, however, the two series part company, as in 1948, 1952, 1956–58, and 1972–74. Since we assume in case B that firms adjust their price expectations in line with their most recent experience, depreciation rises less rapidly in recent years and profits decline less dramatically than in case A. Nonetheless, both case A and case B profits fall substantially below taxable profits in 1974, unlike case C profits or the BEA series.

The BEA's estimates of depreciated stocks of fixed capital are shown in the first two columns of table 3.5, and my estimates of book value of fixed capital appear in the last two columns. It should be recalled that my measure of book value is independent of the price-expectations hypothesis adopted; hence, the current-cost series shown in the last column of table 3.5 is appropriate to cases A, B, and C. Although the four variants are at different levels, their average annual growth rates

**Table 3.5 Alternative Estimates of Book Value of Equipment and Structures, Total Manufacturing, 1947–74 (in Billions of Dollars at End of Year)**

| | BEA | | Coen | |
|---|---|---|---|---|
| Year | Historical-Cost Valuation | Current-Cost Valuation | Historical-Cost Valuation | Current-Cost Valuation |
| 1947 | 27.5 | 40.2 | 25.2 | 33.4 |
| 1948 | 32.0 | 45.7 | 29.4 | 37.9 |
| 1949 | 34.7 | 47.8 | 31.4 | 39.3 |
| 1950 | 37.0 | 52.6 | 33.2 | 42.4 |
| 1951 | 41.3 | 58.9 | 37.0 | 49.2 |
| 1952 | 45.3 | 62.2 | 40.4 | 52.6 |
| 1953 | 49.1 | 64.5 | 43.4 | 55.0 |
| 1954 | 52.6 | 67.3 | 46.2 | 56.6 |
| 1955 | 56.0 | 73.3 | 48.9 | 59.1 |
| 1956 | 61.7 | 82.1 | 53.7 | 66.9 |
| 1957 | 67.6 | 87.7 | 58.6 | 73.5 |
| 1958 | 70.7 | 88.9 | 60.3 | 73.6 |
| 1959 | 72.8 | 89.5 | 61.3 | 73.6 |
| 1960 | 75.6 | 90.7 | 63.2 | 74.2 |
| 1961 | 77.8 | 91.5 | 64.6 | 74.5 |
| 1962 | 80.2 | 93.1 | 66.5 | 76.0 |
| 1963 | 83.2 | 95.6 | 68.9 | 78.3 |
| 1964 | 87.6 | 100.1 | 72.8 | 82.5 |
| 1965 | 94.7 | 108.6 | 79.4 | 89.4 |
| 1966 | 104.5 | 121.1 | 88.6 | 99.5 |
| 1967 | 114.6 | 133.6 | 97.6 | 110.7 |
| 1968 | 122.9 | 146.5 | 104.4 | 119.8 |
| 1969 | 131.8 | 162.5 | 112.1 | 132.8 |
| 1970 | 139.6 | 176.1 | 118.3 | 144.8 |
| 1971 | 145.2 | 185.1 | 122.3 | 155.7 |
| 1972 | 151.7 | 195.6 | 127.5 | 162.2 |
| 1973 | 162.2 | 216.0 | 136.9 | 177.2 |
| 1974 | 176.0 | 245.2 | 149.5 | 199.8 |

over the entire period are very similar—7.1, 6.9, 6.8, and 6.8%, respectively. However, while each historical-cost variant grows at about the same rate over the subperiods 1947–65 and 1965–74, the current-cost variants grow only about three-fifths as fast in the first subperiod as in the second. The current-cost variants grow especially slowly relative to the historical-cost variants over the period of generally stable prices from 1957 to 1963. It is apparent from these comparisons that differences in service lives and basic depreciation patterns produce only minor variations in the estimates of growth of value of capital. What does produce large variations in the estimates is the valuation basis.

Combining the estimates of profit-type income and value of fixed capital, we can finally arrive at estimates of the rate of return on capital in manufacturing. To calculate the rate of return, we add net interest to profit-type income (table 3.4) and divide the result by the value of total capital—fixed capital (table 3.5) plus inventories. The value of capital is centered at the middle of the year by taking the average of beginning- and end-of-year figures. Omitted from the total capital estimates are land and any residential structures that might be owned by manufacturing firms. The rate of return is gross of income taxes.

Table 3.6 presents rate of return estimates for six variants of profit-type income and value of fixed assets. Table 3.7 shows the same series in index form with 1951 = 100, 1951 being the year in which four of the six series reach their peaks. Because the rate of return estimate for variant B in 1948 is abnormally disturbed by the extraordinary decline in the rate of change of structures prices, 1948 is omitted from table 3.7.

We might first note that the two historical-cost series are generally similar in both level and movement over time. The only notable differences in their fluctuations occur during the business expansions of the mid-1950s and mid-1960 when my historical-cost measure rises more briskly than the BEA's.

The current-cost measures of the rate of return are consistently below the historical-cost measures. Among the current-cost measures, the BEA series and my variant C differ only slightly in level and display nearly identical fluctuations. Relative to the historical-cost measures, they both indicate a more substantial increase in the rate of return from the late fifties to the mid-sixties and a more marked decline in the rate of return in 1974. On the whole, however, the cyclical patterns of these two current-cost series are not radically different from those found in the historical-cost series.

Variants A and B of my current-cost measures tell quite a different story. They both reach their peaks in 1965 rather than 1951, and they show greater resilience in the recessions of 1949, 1954, and 1958 than do the other measures. On the other hand, the combination of recession and high inflation in 1974 produces a more dramatic decline in these variants, with variant A dipping to only 16% of its 1951 level. These results reveal that an inflation adjustment that does not assume perfect foresight tends to moderate movements in the rate of return when prices rise or fall in parallel with general business activity; by the same token, such an inflation adjustment tends to accentuate movements in the rate of return when prices move in a direction contrary to that of general business activity.

**Table 3.6** **Alternative Estimates of Gross Rate of Return, Total Manufacturing, 1948–74 (Percentage)**

| | BEA | | Coen | | | |
|---|---|---|---|---|---|---|
| | | | | Current-Cost Valuation | | |
| Year | Historical-Cost Valuation | Current-Cost Valuation | Historical-Cost Valuation | A | B | C |
| 1948 | 28.8 | 21.6 | 29.1 | 21.6 | 31.9 | 23.6 |
| 1949 | 25.7 | 19.4 | 25.7 | 20.6 | 22.8 | 21.0 |
| 1950 | 30.8 | 23.6 | 31.4 | 21.9 | 22.4 | 25.9 |
| 1951 | 32.1 | 24.3 | 33.1 | 20.8 | 24.6 | 26.8 |
| 1952 | 25.7 | 19.6 | 26.3 | 19.3 | 25.4 | 21.2 |
| 1953 | 24.7 | 19.3 | 25.2 | 19.8 | 21.7 | 20.7 |
| 1954 | 21.4 | 16.9 | 21.8 | 17.8 | 18.7 | 18.0 |
| 1955 | 26.7 | 21.4 | 27.6 | 22.2 | 22.4 | 23.4 |
| 1956 | 23.1 | 17.9 | 23.8 | 14.6 | 15.9 | 19.7 |
| 1957 | 21.0 | 16.1 | 21.6 | 13.6 | 18.9 | 17.3 |
| 1958 | 16.8 | 12.8 | 17.0 | 13.2 | 17.2 | 13.5 |
| 1959 | 21.7 | 17.4 | 22.7 | 17.4 | 18.5 | 18.9 |
| 1960 | 19.4 | 15.8 | 20.5 | 16.9 | 17.7 | 17.4 |
| 1961 | 18.2 | 15.1 | 19.4 | 16.3 | 16.8 | 16.7 |
| 1962 | 20.8 | 17.7 | 22.5 | 18.8 | 19.2 | 19.8 |
| 1963 | 22.3 | 19.3 | 24.2 | 20.5 | 21.5 | 21.6 |
| 1964 | 23.7 | 20.8 | 25.8 | 21.7 | 22.7 | 23.2 |
| 1965 | 26.7 | 23.6 | 29.1 | 24.8 | 26.3 | 26.3 |
| 1966 | 26.5 | 23.3 | 28.7 | 24.2 | 25.6 | 26.0 |
| 1967 | 22.5 | 19.6 | 24.0 | 19.0 | 20.7 | 21.5 |
| 1968 | 22.8 | 19.6 | 24.1 | 19.0 | 21.4 | 21.3 |
| 1969 | 19.8 | 16.5 | 21.0 | 14.1 | 16.4 | 18.1 |
| 1970 | 15.4 | 12.1 | 16.0 | 8.9 | 12.9 | 13.1 |
| 1971 | 16.9 | 13.1 | 17.8 | 9.4 | 13.7 | 14.1 |
| 1972 | 19.5 | 15.2 | 20.9 | 14.3 | 19.4 | 16.7 |
| 1973 | 18.5 | 14.1 | 19.9 | 11.6 | 13.9 | 15.6 |
| 1974 | 12.4 | 8.5 | 13.1 | 3.3 | 7.3 | 9.3 |

*Note*: Gross rate of return equals profit income plus net interest divided by the average of book values of assets (equipment, structures, and inventories) at the beginning and end of the year.

No matter which series one considers, it is evident that the rate of return on capital has fallen to very low levels in recent years. Does this experience indicate in part a secular decline in the rate of return? I think not. Aside from the historical-cost measures, which are in principle unsatisfactory, in the mid-1960s the estimated rates of return all reach levels that are high by historical standards. If the economy can once again attain high real growth with moderate inflation, the rate of return, appropriately measured, will probably recover to more normal post–World War II levels.

**Table 3.7** **Alternative Estimates of Gross Rate of Return, Total Manufacturing, 1949–74 (Indexes, 1951 = 100)**

| | BEA | | Coen | | | |
|---|---|---|---|---|---|---|
| | | | | Current-Cost Valuation | | |
| Year | Historical-Cost Valuation | Current-Cost Valuation | Historical-Cost Valuation | A | B | C |
| 1949 | 80 | 80 | 78 | 99 | 93 | 78 |
| 1950 | 96 | 97 | 95 | 105 | 91 | 97 |
| 1951 | 100 | 100 | 100 | 100 | 100 | 100 |
| 1952 | 80 | 81 | 79 | 93 | 103 | 79 |
| 1953 | 77 | 79 | 76 | 95 | 88 | 77 |
| 1954 | 67 | 70 | 66 | 86 | 76 | 67 |
| 1955 | 83 | 88 | 83 | 107 | 91 | 87 |
| 1956 | 72 | 74 | 72 | 70 | 65 | 74 |
| 1957 | 65 | 66 | 65 | 65 | 77 | 65 |
| 1958 | 52 | 53 | 51 | 63 | 70 | 50 |
| 1959 | 68 | 72 | 69 | 84 | 75 | 71 |
| 1960 | 60 | 65 | 62 | 81 | 72 | 65 |
| 1961 | 57 | 62 | 59 | 78 | 68 | 62 |
| 1962 | 65 | 73 | 68 | 90 | 78 | 74 |
| 1963 | 69 | 79 | 73 | 99 | 87 | 81 |
| 1964 | 74 | 86 | 78 | 104 | 92 | 87 |
| 1965 | 83 | 97 | 88 | 119 | 107 | 98 |
| 1966 | 83 | 96 | 87 | 116 | 104 | 97 |
| 1967 | 70 | 81 | 73 | 91 | 84 | 80 |
| 1968 | 71 | 81 | 73 | 91 | 87 | 79 |
| 1969 | 62 | 68 | 63 | 68 | 67 | 68 |
| 1970 | 48 | 50 | 48 | 43 | 52 | 49 |
| 1971 | 53 | 54 | 54 | 45 | 56 | 53 |
| 1972 | 61 | 63 | 63 | 69 | 79 | 62 |
| 1973 | 58 | 58 | 60 | 56 | 57 | 58 |
| 1974 | 39 | 35 | 40 | 16 | 30 | 35 |

## 3.5 Concluding Remarks

The statistical results of the previous section indicate that different procedures for estimating depreciation can lead to substantially different assessments of tax depreciation policy and economic performance. Although the choice of asset service lives and depreciation patterns are of some importance, they seem on the whole to be less critical than the formulation of a current-cost concept of depreciation. We have seen that the Commerce Department's concept is appropriate provided, among other things, that firms can either (*a*) perfectly predict the rate of inflation or (*b*) imperfectly predict the rate of inflation but realize appreciation of their depreciation reserves at a rate equal to the actual rate of inflation. Of course, considerable uncertainly surrounds the choice of a price expectations hypothesis and the selection of a valuation procedure for depreciation reserves. I have not attempted to resolve these issues but only tried to highlight their importance and investigate the empirical implications of alternative approaches. With regard to price expectations, I suspect that my case A (the expected inflation rate is always zero) is as unrealistic as the assumption of perfect foresight; case B, or a more complicated form of adaptive expectations, is probably closer to the truth.

Another troublesome set of assumptions which I have explicitly adopted and which the Commerce Department implicitly adopts is that the expected real rate of return on capital is constant and that the expected nominal rate of return equals the real rate plus the expected rate of inflation. The effect of these assumptions is to introduce constancy in the ratios of product prices to capital goods prices; that is, capital goods prices rise or fall at the same rate as product prices. But this is not generally the case in reality; and while there is obviously something wrong with one or both of these assumptions, there are no obvious, workable alternatives to them. It seems that attempts at greater realism in these areas are likely to make an already complex problem a hopelessly complex one.

# Notes

1. The revised accounts are presented and discussed in U.S. Department of Commerce (1976*b*). The new approach to measuring capital consumption is described in detail in Young (1975).

2. The service lives tested generally ranged from eight to twenty-two years in increments of two years for equipment and twenty to fifty years in increments of five years for structures. Five alternative loss-of-efficiency patterns were tested: (1) geometric decay at a rate equal to twice the reciprocal of the service life; (2) geometric decay as in (1), but truncated at the end of the service life; (3) a sum-of-years digits pattern; (4) a "one-horse-shay" pattern; and (5) a straight-line pattern. The lives and patterns reported in table 3.1 differ in many instances from those reported in Coen (1975). The current results are derived from somewhat revised data, particularly with regard to tax depreciation parameters (a 1971 Treasury survey of depreciation practices provided more up-to-date information on the parameters); also, they are based both on goodness of fit over the sample period 1949–66 and on accuracy in postsample predictions for 1967–71, whereas the earlier results were based solely on the former.

3. The weights used in computing these averages are proportional to capital expenditures in 1966.

4. In the empirical implementation of equations (20) and (21), it is assumed that $r$, which represents firms' marginal after-tax rate of discount or desired after-tax marginal rate of return on investments, is constant at a value of 10%

per year. Thus, changes in market rates of interest are assumed not to influence firms' valuations of their fixed assets.

5. Associated with this measure of real replacement is a measure of real capital stock, namely,

$$K_{tT} = (I_T/c_T) - \sum_{j=T+1}^{t} R_{jT}.$$

Summing $K_{tT}$ over all vintages yields a measure of the productive capacity of assets on hand at the end of period $t$. This is the appropriate measure of capital for analyzing production and real investment decisions.

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## Comment Solomon Fabricant

Professor Coen seeks to measure capital and rates of return by considering how capital consumption enters into the determination of gross

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capital formation. His approach is ingenious and theoretically appealing. I hope that further work along this line will lead to improvement in the underlying theory and in the data required to apply the theory, and thus eventually to measures deserving of serious consideration. His present measures, however, are not ready to be substituted for those of the Bureau of Economic Analysis (or existing modifications of the BEA's measures), uneasy though we may be with the latter.

Coen starts by noting that businessmen buy the plant and equipment they need with two objectives in mind. One is to replace the assets used up through depreciation, obsolescence, and other forms of capital consumption. The second is to meet the increase in capacity required by increased production. He knows past output and past plant and equipment expenditures, of course. Using these, and a function embodying a neoclassical theory of investment, he estimates the net investment or increase in the capital stock required by the changes in output. The difference between this net investment and the gross investment actually made must be the capital consumption recognized by the businessmen. He then asks, in effect, which among a set of forty possible mortality distributions—combinations of eight asset service lives and five depreciation patterns—would on the average yield a capital consumption allowance series closest to the derived capital consumption series. The calculations are done in real terms, for twenty-one separate manufacturing industries, over the period 1949–66, separately for equipment and for structures.

The procedure and the investment theory underlying it are set forth in Coen's paper in the *American Economic Review* (March 1975), to which the reader must turn if he is to understand the approach. It is sufficient here to recall that Coen assumes, first, a Cobb-Douglas production function. This is readily transposed into an investment function in which desired capital depends on output and the ratio of output price to the price (rental value) of capital's services. He assumes, second, that competition is sufficient to make the marginal product of capital's services equal to their price. And, third, he assumes that the rental price depends on the mortality distribution and the discount rate or rate of interest required to finance net investment (in what is a generalization of the Jorgenson function), with the discount rate assumed to be 10% for all years and industries. Inserting each of the various mortality distributions into his function, in accordance with this procedure, yields a standard error of estimate for each distribution. The best-fitting mortality distribution is the one indicated by the investment behavior of businessmen.

Coen states explicitly that the better mortality distributions are very close to one another, by his test; it cannot be claimed that the one chosen—the best or closest—is more than "marginally superior" to the others. He goes on to suggest, therefore, that "a more discerning test" would use postsample predictions. Disturbing changes in the ranking of the mortality distributions result when, in this paper, he applies his more discerning test to the data for 1967–71. In fact, half of the "best" distributions relating to equipment are no longer those in the *AER* paper, and this is true of two-thirds of those for construction. Also, the differences are often not of the sort suggested in the *AER* paper, namely that a short service life plus a slow depreciation of capacity is roughly equivalent to a long service life plus a fast capacity depreciation. In other words, the more discerning test raises some serious questions about the stability of the results produced by the theory and procedures Coen utilizes.

Coen goes on to make an important distinction between loss of value and loss of efficiency (or productive capacity) as an asset ages. (Coen mentions only aging, but he must mean also the obsolescence that occurs with the passage of time, as well as the wear and tear.) Loss of value reflects not only loss of efficiency but also decline in remaining life, and is a better measure of *economic* depreciation. A corresponding distinction is made between productive capacity and economic value of the capital stock.

It is worth taking a moment to make the distinction clear. Assume no change in the price of an asset over time, and consider a one-horse shay suffering no loss of efficiency by aging, except when the shay finally collapses. Yet there is economic depreciation as it ages; its economic value declines, although its efficiency and gross rental price do not. We may suppose, further, that the businessman owning and operating the shay would think of his net rate of return on the *economic* value of the shay as constant over its life. This implies that his net income is the constant gross rental of the shay minus a *rising* depreciation allowance. Only then will the declining net income, divided by the declining economic value of the shay, be constant. It may be noticed that if at the same time there is a decline in efficiency with age, economic depreciation inclusive of this decline in efficiency may rise less rapidly than in the one-horse-shay case. It may, in fact, remain more or less constant (and reasonably well approximated by a straight-line formula), or it may even decline.

Coen next considers the effect of increases in the prices of capital goods and their significance for calculating the current value of the capital stock and the rate of return. Rather than retrace his steps in arriving at his results, let me indicate what these results look like. The "current-cost depreciation" in the third year of a three-year-old asset is the sum of the historical-cost depreciation in the third year revalued to the current price level, *plus* the amount needed to adjust the first and second years' revalued depreciation to the third, current year's price level. Eventually, as Coen notes, the sum of depreciation charges so calculated will equal the dollar amount needed to replace the asset when it is retired. I suspect here a tendency by Coen to think of the depreciation reserve as a fund held in dollars or fixed-income securities, and of the need to include in the third year's depreciation the loss in purchasing power of the fund (expressed in terms of the price of the particular asset, not of the general price level). In any case, as Coen's table 3.3 shows, current-cost economic depreciation, so derived, is much greater in most years than the BEA's current cost, although in terms of historical cost the two series differ by a much more modest (and stable) amount.

I must admit I have strong doubts that Coen's estimates make sense. I agree with his third assumption, that the economic value of a capital good is (or tends to be) equal to the present value of the expected stream of net money returns it will produce. This is, indeed, the basis of the presumption in the Hulten-Wykoff paper that secondhand values of capital goods provide useful information on economic capital and capital consumption. But I cannot swallow, let alone digest, his other assumptions. As Coen is frank enough to admit, his present assumptions are necessarily somewhat arbitrary. Perhaps they will become more palatable as he proceeds in his research program.

To conclude: Coen's basic idea is intelligent and is consistent with the view that depreciation, profits, investment, and other variables are interrelated. But I have some questions—those already mentioned and some others: about the distinction between maintenance and capital expenditures; the treatment of subsoil assets (Soladay's worry), which is not a negligible item in one or two of the manufacturing groups; the measurement of depreciation as a function of volume of output; and the implications, for the effective application of Coen's procedures and the stability of his results, of Millard Hastay's and other papers in the Universities–National Bureau Committee's conference on the *Regularization of Investment*, published some twenty years ago.

As I have already implied, I look forward to the results of Coen's efforts to extend and improve his interesting analysis.