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1 Estimation of Capital Stock in the United States

Allan H. Young and John C. Musgrave

There are essentially two methods for estimating stocks of fixed capital—direct measurement of the stock and perpetual inventory calculations. Only limited use has been made of direct measurement in the United States because the existing data are incomplete and because there are problems in valuation of the assets in the stock. Extending the coverage and obtaining the information needed to assign the desired valuation to assets would require a substantial statistical program.

With the exception of stocks of autos, the United States Bureau of Economic Analysis (BEA) estimates are based on the perpetual inventory method. Section 1.1 of this chapter briefly reviews BEA's application of the perpetual inventory method and the resulting estimates of capital stocks and related estimates of capital consumption allowances in the national income and product accounts (NIPAs). Section 1.2 discusses concepts, definitions, and statistical problems involved in estimating capital stocks; considers direct measurement of stocks (under which we subsume the derivation of stocks from information carried on balance sheets of businesses); and takes note of capital stock estimates prepared by other researchers. A statistical appendix provides BEA's estimates of capital stocks valued in constant 1972 dollars for selected major aggregates.

1.1. The Bureau of Economic Analysis Estimates

The perpetual inventory method derives gross capital stock for a given year by cumulating past investment and deducting the cumulated value

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of the investment that has been discarded. Net capital stock is obtained in a similar manner by deducting the cumulated value of depreciation.

Estimates of fixed nonresidential business capital have been prepared in varying detail by BEA since the mid-1950s, and estimates of residential capital have been prepared since 1970. The latest BEA capital stock publication[1] contains annual estimates for the years since 1925 of gross and net stocks, depreciation, discards, ratios of net to gross stocks, and average ages of gross and net stocks in historical, constant, and current cost valuations by legal form of organization (financial corporations, nonfinancial corporations, sole proprietorships and partnerships, other private business). The fixed nonresidential business capital estimates are also available within each legal form by major industry group (farm, manufacturing, nonfarm nonmanufacturing), and the residential estimates are also available by tenure group (owner-occupied and tenant-occupied). Estimates of capital stocks and related measures by detailed types of assets are also available. Gross and net stocks of fixed nonresidential business and residential capital for selected aggregates are provided in the Appendix to this paper.

In addition to the published estimates of stocks of fixed nonresidential business and stocks of residential capital, preliminary estimates of stocks of durable goods owned by consumers[2] and stocks of fixed nonresidential capital owned by the federal government[3] and by state and local governments are also presented here. Final estimates of stocks of consumer durables and government capital will be published later in the *Survey of Current Business.* The stocks of fixed capital owned by governments include assets owned by government enterprises. Future research will include the compilation of separate estimates of capital stocks owned by government enterprises.

Although this paper deals primarily with the fixed capital portion of total tangible wealth, estimates of stocks of business inventories have also been developed by BEA, and these estimates are given in the Appendix for selected aggregates. The methodology and annual estimates back to 1928 were published in an article in the December 1972 *Survey of Current Business* (Loftus 1972); revised estimates for the years since 1947 were given in part II of the January 1976 *Survey* and are updated in the regular national income and product tables in the *Survey.*

1.1.1 Derivation of the BEA Estimates

The NIPA investment flows used to implement the perpetual inventory method for the years since 1929 are: for fixed business capital—gross private domestic fixed investment; for consumer durables—personal consumption expenditures for durable goods; and for government-owned capital—government purchases of durable goods and structures. These flows are extended back into the nineteenth century using data from public and private sources. The NIPA flows are modified in the case of transfers of secondhand assets among sectors. They are also disaggregated to provide detail by legal form of organization and by major industry group (fixed nonresidential business capital) and tenure group (residential capital).

The service lives used to derive the stock estimates are given in table 1.1. For nonresidential business equipment, the service lives are 85% of the lives specified in the 1942 edition of Bulletin F, issued by the Internal Revenue Service (IRS). The service lives for nonresidential structures are based on 85% of Bulletin F lives for new structures, with an allowance for shorter lives for additions and alterations. The average service life for nonresidential structures including additions and alterations is 20% shorter than that for new structures in manufacturing industries and 7% shorter in nonmanufacturing industries. Alternative estimates of stocks of fixed nonresidential business capital based on service lives equal to 100% of Bulletin F, 75% of Bulletin F, and

Table 1.1 **Service Life Assumptions Used in BEA Capital Stock Study**

Type of Asset	Life (Years)
Fixed nonresidential business capital[a]	
Furniture and fixtures	15
Fabricated metal products	18
Engines and turbines	21
Tractors	8
Agricultural machinery (except tractors)	17
Construction machinery (except tractors)	9
Mining and oil field machinery	10
Metalworking machinery	16
Special-industry machinery, n.e.c.	16
General industrial, including materials handling, equipment	14
Office, computing, and accounting machinery	8
Service-industry machines	10
Electrical machinery	14
Trucks, buses, and truck trailers	9
Autos	10[b]
Aircraft	9
Ships and boats	22
Railroad equipment	25
Instruments	11
Other equipment	11
Industrial buildings	27
Commercial buildings	36
Religious buildings	48
Educational buildings	48
Hospital and institutional buildings	48
Other nonfarm nonresidential buildings	31
Railroad structures	51

Table 1.1 (continued)

Type of Asset	Life (Years)
Fixed nonresidential business capital[a] (continued)	
Telephone and telegraph structures	27
Electric light and power structures	30
Gas structures	30
Other public utility structures	26
Farm nonresidential buildings	38
Petroleum, gas, and other mineral construction and exploration	16
All other private nonresidential structures	31
Residential capital	
1-to-4 unit structures	
New	80
Additions and alterations	40
5-or-more unit structures	
New	65
Additions and alterations	32
Mobile homes	16
Nonhousekeeping	40
Equipment	11
Consumer durables	
Furniture, including mattresses and bedsprings	14
Kitchen and other household appliances	11
China, glassware, tableware, and utensils	10
Other durable house furnishings	10
Radio and television receivers, records, and musical instruments	9
Jewelry and watches	11
Ophthalmic products and orthopedic appliances	6
Books and maps	10
Wheel goods, durable toys, sports equipment, boats, and pleasure aircraft	10
Trucks, trailers, and recreational vehicles, and parts and accessories	8
Autos	10[b]
Fixed nonresidential government-owned capital	
Equipment	15
Industrial buildings	27
Educational buildings	50
Hospital buildings	50
Other nonfarm nonresidential buildings	50
Highways and streets	60
Conservation and development structures	60
Sewer structures	60
Water structures	60
Other nonresidential structures	50

[a]85% of Bulletin F lives.

[b]As explained in the text, the estimation of the gross stocks of autos does not depend on an explicit service life assumption. The unit values used to derive net stocks are depreciated according to a ten-year life, and a nominal net unit value is assigned to autos over ten years old.

100% of Bulletin F through 1940 with a gradual decline to 75% of Bulletin F by 1960 are given in Bureau of Economic Analysis (1976*b*).

For residential structures, the service lives are those used by Goldsmith and Lipsey (1963, chap. 3). For mobile homes, the service life is based on trade association data. For residential equipment, the service life is based on the lives for similar types of nonresidential equipment. For government-owned capital and consumer durables, the service lives are based on expert opinions, evidence from direct measurement of the stock, and comparisons with similar assets in business capital stocks.

The service lives are averages. Underlying the average service life for a given type of asset is a distribution of discards. To take into account that assets of a given type are discarded at different ages, patterns of retirements are used. The patterns of retirements are based on modifications of the following curves developed by Winfrey (1935): fixed nonresidential capital, the Winfrey S-3 modified so that retirements start at 45% and end at 155% of the average life; residential capital, the Winfrey S-3 modified so that retirements start at 5% and end at 195% of the average life; consumer durables, the Winfrey L-2 modified so that retirements start at 25% and end at 215% of the average life. These retirement patterns are given in table 1.2. The S-3 curves are bell-shaped distributions centered on the average service life of the asset. The L-2 curve is an asymmetrical distribution with heavy discards before the average service life is reached and a tapering pattern thereafter. This curve was selected for consumer durables because it appears that many of these goods are discarded after a few years, while others remain in use far beyond the average life.

The BEA capital stock estimates are available in historical, constant, and current cost valuations. Historical cost and constant cost stocks are derived by cumulating current-dollar and constant-dollar investment flows, respectively. Current cost stocks are derived by revaluing the constant cost stocks, using the price indexes employed in the NIPAs to deflate the investment flows.

Assets are carried in gross capital stocks at their undepreciated value during the entire time they remain in the stock. The value of these assets is depreciated to obtain net stocks, which equal the difference between the cumulative value of gross investment and cumulative depreciation. The BEA estimates of net stocks are based on the straight-line depreciation formula, which assumes equal dollar depreciation each year over the life of the asset. Discounting of anticipated future services is not used in computing depreciation and net stocks.

Alternative estimates of depreciation and net stocks based on the double-declining balance formula (which assumes an annual percentage

Table 1.2 **Modified Winfrey Retirement Patterns Used in BEA Capital Stock Study**

Nonresidential S-3		Residential S-3		Consumer Durables L-2	
Percentage of Average Service Life	Percentage of Original Expenditure Discarded	Percentage of Average Service Life	Percentage of Original Expenditure Discarded	Percentage of Average Service Life	Percentage of Original Expenditure Discarded
Less than 45	0	Less than 5	0	Less than 25	0
45	1.2	5	.1	25	1.5
50	1.2	10	.2	35	2.1
55	1.7	15	.2	45	3.6
60	2.4	20	.2	55	6.0
65	3.2	25	.3	65	8.4
70	4.0	30	.3	75	9.8
75	5.0	35	.4	85	10.2
80	5.9	40	.4	95	9.6
85	6.6	45	.6	105	8.6
90	7.2	50	.8	115	7.5
95	7.7	55	1.5	125	6.4
100	7.8	60	2.2	135	5.5
105	7.7	65	3.0	145	4.7
110	7.2	70	3.9	155	4.0
115	6.6	75	4.9	165	3.2
120	5.9	80	5.8	175	2.6
125	5.0	85	6.5	185	2.0
130	4.0	90	7.1	195	1.5
135	3.2	95	7.7	205	1.0
140	2.4	100	7.8	215	1.8
145	1.7	105	7.7	More than 215	0
150	1.2	110	7.1		

Table 1.2 (continued)

Nonresidential S-3		Residential S-3		Consumer Durables L-2	
Percentage of Average Service Life	Percentage of Original Expenditure Discarded	Percentage of Average Service Life	Percentage of Original Expenditure Discarded	Percentage of Average Service Life	Percentage of Original Expenditure Discarded
155	1.2	115	6.5		
More than 155	0	120	5.8		
		125	4.9		
		130	3.9		
		135	3.0		
		140	2.2		
		145	1.5		
		150	.8		
		155	.6		
		160	.4		
		165	.4		
		170	.3		
		175	.3		
		180	.2		
		185	.2		
		190	.2		
		195	.1		
		More than 195	0		

rate of depreciation that is equal to twice the first-year straight-line rate) are given in Bureau of Economic Analysis (1976*b*).

Stocks of autos are an exception to the use of the perpetual inventory procedure described above. The numbers of cars in use, by age of car, are available each year through state registration data tabulated by the R. L. Polk Company. Gross stocks of cars are derived by multiplying the number of cars of each age by the average unit value in the year of original registration. Net stocks are derived similarly by using depreciated unit value figures based on the straight-line formula. Alternative estimates based on the double-declining balance formula are also calculated.

1.1.2 Capital Consumption Allowances in the NIPAs

A major feature of the recently completed benchmark revision of the NIPAs was the introduction of measures of economic depreciation obtained from BEA's capital stock calculations. In the revised NIPAs, capital consumption allowances are based on depreciation computed with the straight-line formula and the service lives for fixed nonresidential and residential business capital shown in table 1.1. The new capital consumption allowances are shown in current and constant dollars.

Previously, capital consumption allowances had included primarily depreciation as tabulated by the IRS from tax returns filed by businesses. The major exceptions were depreciation for the farm sector and for housing that is owned either by owner-occupants or by landlords who file individual tax returns rather than business returns. For the farm sector, BEA used United States Department of Agriculture perpetual inventory estimates valued in current prices. For housing, BEA prepared perpetual inventory estimates valued at historical costs.

Business income in the revised NIPAs is calculated net of capital consumption allowances valued in current prices. The revised presentation shows the new measures of income as the sum of before-tax book income, the inventory valuation adjustment, and a new item, the capital consumption adjustment, which is equal to the tax return–based measure of depreciation less the new measure. The new measure of capital consumption allowances also results in an improved measure in the NIPAs of current-dollar net national product and the introduction of its constant-dollar counterpart.[4]

Capital consumption allowances in the NIPAs are identical to depreciation in the capital stock calculations with a minor exception. Depreciation in the capital stock calculations assumes that accidental damage occurs at the same rate each year. The capital consumption allowances in the NIPAs are adjusted so as to reflect the generally small year-to-year variations in the rate of accidental damage. This refinement has not been carried back into the capital stock calculations.

1.2 Conceptual and Statistical Considerations

1.2.1 Gross Stocks

The concept of capital on which BEA's stock estimates rest is that of capital measured by its cost. Capital defined and measured on this basis is useful in the measurement of productivity. Measured by its cost, capital provides a basis for determining if the use of factors of production is becoming more or less efficient over time. Cost-based measures of capital are not appropriate for determining industrial capacity, or for analyzing the determinants of investment or production, because identical amounts of real capital will represent different capacities to produce goods and services. For such analyses, capital should be measured in terms of its ability to contribute to production. It has been considered difficult to implement such measures statistically. The basic problem is that of measuring the contribution of different types of capital to production. In lieu of such measures, rough allowances for embodied technological change—the costless quality change referred to later—are sometimes added to the cost-based measures.

The concept of capital measured by its cost evolved relatively early in the development of national economic accounting. The standard reference has become a paper by Edward F. Denison (1957) presented at an earlier meeting of this conference. The definition of gross stocks as stated by Denison in that paper is as follows:

> The method, if generalized, leads to the following definitions. The value, in base period prices, of the stock of durable capital goods (before allowance for capital consumption) measures the amount it would have cost in the base period to produce the *actual* stock of capital goods existing in the given year (not its equivalent in ability to contribute to production). Similarly, gross additions to the capital stock and capital consumption are valued in terms of base year costs for the *particular* types of capital goods added or consumed. This must be modified immediately, in the case of durable capital goods not actually produced in the base year, to substitute the amount it would have cost to produce them if they had been known and actually produced. But a similar modification is required in all deflation or index number problems. [p. 222]

Basic to this definition of the quantity of capital is that only cost-associated quality change of capital goods is counted as quantity change. Quality change (e.g., a larger motor) that results in a change in cost is counted as a change in quantity. Quality change that results in no change in cost (e.g., a more efficient motor that costs the same as an older model) is not counted as a change in quantity.

1.2.2 Depreciation

Economists apparently do not fully agree on a single definition of depreciation for allocating the cost of the asset over its service life. Nowadays the field is usually limited to two contenders. We shall refer to these as the NIPA definition and the discounted value definition. The information necessary for implementing either definition is imprecise and incomplete, and simplifying assumptions play major roles. With some oversimplification, we shall describe the two approaches.[5]

The NIPA definition of depreciation, which provides the basis for BEA's net stock estimates and for the estimates of capital consumption allowances and net national product in the NIPAs, can be stated as follows: Depreciation is the cost of the asset allocated over its service life in proportion to its estimated service at each date. The services are net of maintenance and repair expenses. In theory, the service life used in determining the allocation is the physical life—the length of time it is physically possible to use the asset. In some instances this is longer than the economic life—the length of time it is economically feasible to use the asset. The services are not discounted and they do not reflect the effect of obsolescence. Obsolescence is charged when the asset is retired. The reason for this treatment is that obsolescence has little if any effect on the time pattern of services provided by the asset before retirement, even though it is a determinant of the timing of retirement. The charge for obsolescence at retirement writes off the remainder of the asset as a component of capital consumption and in effect replaces the physical life with the economic service life.

Given the available information, the depreciation curve that best implements the definition cannot be determined precisely. In the BEA estimates, the asset is written off by straight-line depreciation over its estimated economic life. BEA's judgment is that straight-line depreciation provides a close approximation to the desired measure. For a single asset, the straight-line formulation has the following properties:

1. If services are constant over the service life and no obsolescence occurs, straight-line depreciation is the correct measure.

2. If services decline over the service life and no obsolescence occurs, straight-line depreciation is too low in the early years of the service life and too high in the later years.

3. If services are constant over the service life and obsolescence occurs, straight-line depreciation is too high in all years of the service life except in the last year, when it is too low.

4. If services decline over the service life and obsolescence occurs, the types of errors in properties 2 and 3 arising from straight-line depreciation tend to be offsetting, depending on the amount and pattern of the decline in services and the amount of obsolescence.

Figure 1.1 compares the pattern of depreciation in each of the four cases enumerated above with that which results from the straight-line formulation. In each case, the original cost of the asset is 100 and the economic service life is ten years. In cases 1 and 2, the physical service life is equal to the economic service life; in cases 3 and 4, the physical life is fifteen years, but the asset is retired after ten years because of obsolescence. In cases 1 and 3, services are constant; in cases 2 and 4, services decline linearly to zero at the end of the physical life. It should be noted that when the depreciation pattern with the parameters specified in case 4 is applied against an increasing or decreasing investment stream, the errors would be further offsetting.

We do not know the relative weights to assign to the four cases. In addition, the illustrations suggest that the effect of obsolescence on the retirement of an asset from the stock is sudden and complete. In practice, retirement is often not well defined and sometimes is viewed as occurring more gradually than in the example. Nevertheless, the four cases point up the general applicability of the straight-line formulation as an approximation to the NIPA definition.

The discounted value definition of depreciation can be stated as follows: Depreciation is the decline in the value of the sum of the remaining anticipated services discounted to the present. The anticipated services are net of maintenance and repair expenses and net of the reduction in value occasioned by obsolescence. The effect of obsolescence is probably best viewed as occurring at a constant rate. The total of the depreciation charges under the discounted value definition, as with the NIPA definition, equals the cost of the asset. The time path of the charges, however, can vary from that based on the NIPA definition.

Depreciation based on the discounted value definition can be either more or less than straight-line depreciation in the early years of an asset's service life, with the reverse occurring in later years. A decline over time in the services provided by an asset because of either deterioration or constant-rate obsolescence contributes to a more rapid write-off than straight-line depreciation. The effect of discounting works in the opposite direction.

The NIPA definition arises from the view that depreciation represents the quantity of capital, as measured by its cost, that is expended in production and that net national product represents output after allowance for this quantity. Also, the view is that such flows for the year in question do not reflect past or present expectations of future returns. This approach is consistent with the basic design of the NIPAs, which

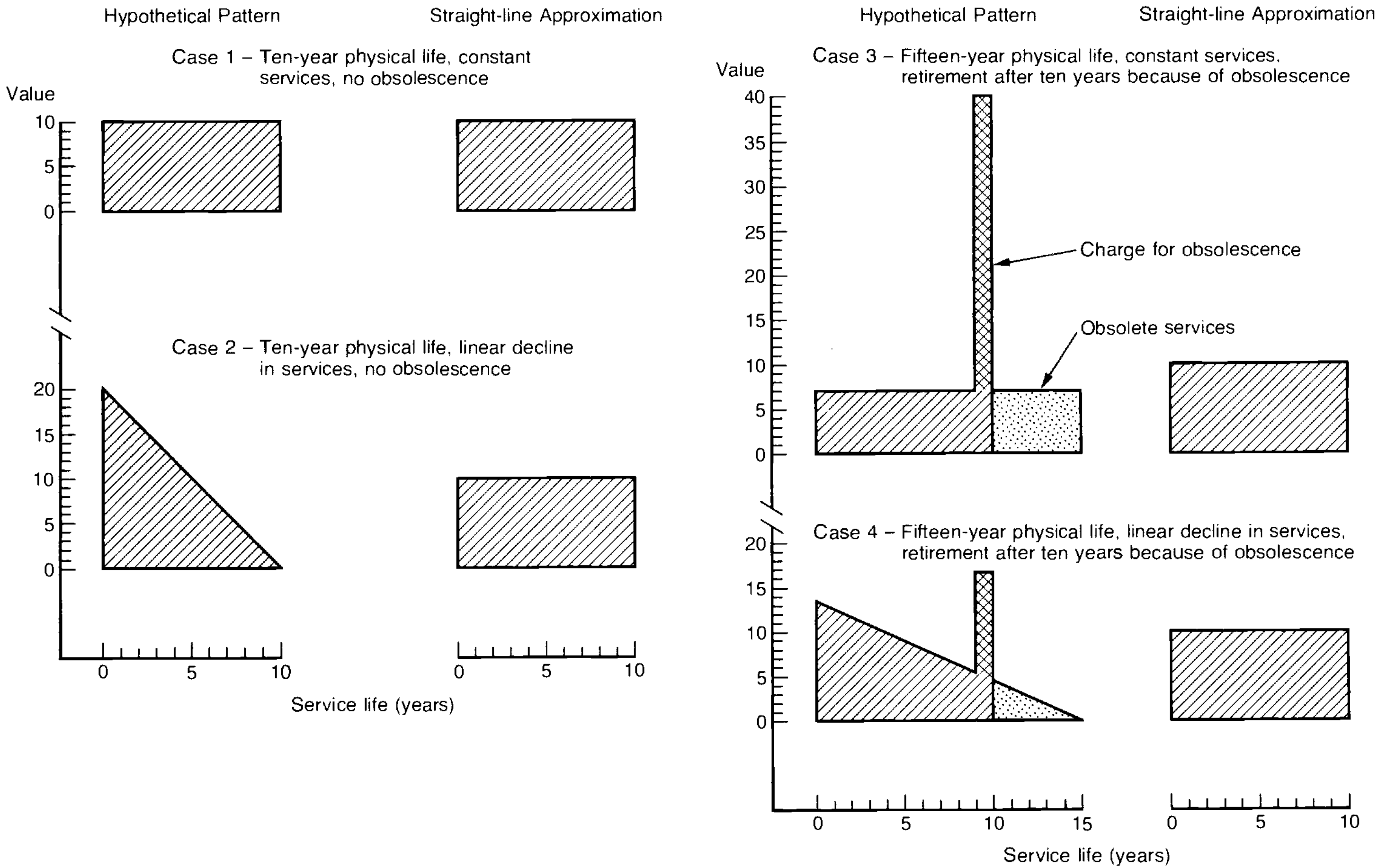

Fig. 1.1 Hypothetical depreciation patterns and straight-line approximation.

measure flows of goods and services—including the services of the factors of production—and with the use of the NIPAs to analyze production and productivity.

Does the discounted valued definition also have a place within the context of national economic accounting? In the most general terms, this question amounts to whether the definition is useful in defining or analyzing aggregate flows of business income. The discounted value definition is frequently described as appropriate for accounting for profits by the individual firm and in studies carried out at the aggregate level that are concerned with the behavior of the firm. Examples of such studies are the examination of the basis for investment decisions and the assessment of the adequacy of depreciation taken on tax returns. For these types of studies, it seems that national economic accounts based on the discounted value definition would be useful. Some investigators apparently go beyond this position and consider the discounted value definition to be the only appropriate measure (for example, Christensen and Jorgenson 1973; Mendelowitz 1971). To some extent the question is academic, however, if the difference between the two statistical measures is small. This is the subject we shall now take up.

Taubman and Rasche (1969) estimated that the decline in the value of discounted future services of office buildings is less rapid than straight-line depreciation in the early years of the service life. They believe this finding can be extended to apartment buildings and factories. The depreciation curve obtained by Taubman and Rasche shows a somewhat more rapid write-off than straight-line depreciation when the discounting calculation is removed. An allowance for some degree of obsolescence, which is called for with the NIPA definition, would move the curve back toward straight-line depreciation. Various evidence suggests that housing is also approximated by the straight-line formulation.

There are several studies of depreciation patterns for equipment (for example, Wykoff 1970; Terborgh 1954). They almost all show that the decline in the value of discounted future services is more rapid than straight-line depreciation in the early years of the service life. However, most of these studies are of motor vehicles and are based on prices observed in secondhand markets. Such studies probably understate the services provided by assets that are retained by their original owners and therefore indicate too rapid a decline in value.[6]

Other than secondhand market prices, there is evidence for some types of equipment, such as that in Terborgh's studies, that indicates decreasing services over the life of the asset because of increasing maintenance and repair expense and changes in the intensity of use. It seems reasonable to conclude that for some types of equipment the effect of maintenance and repair coupled with obsolescence outweighs the effect of discounting, and consequently the decline in the value of discounted future services is more rapid than straight-line depreciation in the early years of the service life. (Such findings probably should not be extrapolated, however, to all types of equipment. For example, furniture may have a pattern similar to that of buildings.)

A study by Coen (1975) estimated the decline in service provided over the service life by plant and by equipment separately for twenty-one two-digit SIC manufacturing industries. Discounting was not reflected in the pattern of decline. However, obsolescence was taken as occurring at a constant rate. In this respect the specification was not consistent with the NIPA definition. Because of the treatment of obsolescence, the service declines estimated by Coen are overstated in terms of the NIPA definition. It is possible that they are also overstated because Coen preselected only a few patterns of decline with no graduation between the one-horse-shay pattern and the pattern showing a linear decline to zero over the service life.

Coen's results indicate that services provided by about 50% of plant and 12% of equipment in manufacturing resemble those of a one-horse shay.[7] Services of another 28% of plant and 44% of equipment decline linearly to zero over the service life. With respect to the NIPA definition, a revised treatment of obsolescence and a finer graduation might provide a pattern of services for assets in this latter category that would be roughly consistent with straight-line depreciation. With respect to the discounted value definition, the introduction of discounting would also shift Coen's results toward less rapid write-offs.

Mendelowitz (1971) estimated that the decline in value of discounted future services for the aggregate of plant and equipment owned by manufacturers was less rapid than straight-line depreciation in the early years of the service life. His estimate of depreciation was less than that provided by the straight-line formula for 1962 to 1969.

The empirical results are imprecise, and one hopes they can be improved in the future. In particular it may be worthwhile to conduct empirical studies that take explicit account of the NIPA definition.

Our reading of the empirical results is as follows: (1) For broad aggregates, straight-line depreciation comes reasonably close to the measure called for by either definition. (2) This judgment relies partly on the presence of offsetting errors. For the discounted value definition, straight-line depreciation may provide too slow a write-off for certain types of equipment. However, such understatement tends to be offset by the use of straight-line depreciation for buildings. For the NIPA definition, errors arising from the use of straight-line depreciation for types of equipment where services decline over the service life tend to be offset by errors arising from the treatment of obsolescence. (3) For the discounted value definition, the offsets between structures and equipment noted in point 2 do not apply to separate estimates for housing (virtually all structures) or consumer durables (all equipment).

1.2.3 Net Stocks

Given the NIPA definition of depreciation, net stocks are the sum of unused capital as measured by its cost. The discounted value definition of depreciation ties into a definition of net stocks measured by their market values. It is this latter definition that is consistent with a market valuation of balance sheets and wealth accounts. To the extent that the two definitions of depreciation can be distinguished statistically, investigators who construct balance sheets and wealth accounts based on market valuations can achieve consistently between net stocks in these accounts and the stock-related flows in the NIPAs with an adjustment item in the revaluation account.

1.2.4 Capital Services

The state of the art is such that many economists do not use the estimates of gross or net stocks as a measure of capital services without some modification. We will touch on some of the major aspects of this subject here.

Estimates of capital services have typically involved one or two modifications to aggregate gross stocks. One modification is the weighting by rates of return of the detailed gross stock estimates by sector and legal form of organization and also sometimes by industry. The other modification is that the one-horse-shay assumption of capital services inherent in BEA's gross stocks is not always considered to provide an appropriate measure of capital services. For example, in his recent work, Denison weights gross and net stocks in the ratio of three to one to obtain a rough allowance for declining services over an asset's service life. Other investigators have used a rapid geometric decline to describe the write-off in services (for example, Jorgenson and Griliches 1967).

With more evidence concerning the pattern of capital services provided by an asset over its service life, some investigators think it would be appropriate for BEA to introduce indexes of capital services by sector, legal form of organization, and industry. Such evidence would also improve the basis for the depreciation estimates, although for the reasons noted previously the straight-line formulation might very well remain the appropriate choice for an aggregate measure.

1.2.5 Gross Fixed Investment

For the estimation of the capital stocks presented in this paper, gross fixed investment is defined as the value of acquisitions of fixed capital assets by private business and nonprofit institutions, government (including government enterprises), and households. This definition is more inclusive than that used in the NIPAs, where fixed investment is limited to fixed capital assets purchased by private business and nonprofit institutions. Fixed capital assets include equipment and structures located in the United States. Land is excluded. Military assets are also excluded. For business and government, equipment is defined as durable goods with an average service life of more than one year. For households, equipment (consumer durables) is defined as durable goods having an average service life of at least three years. In practice, the effect of the difference in the average service lives is small.

Gross fixed investment consists of both the acquisition of new assets and the net acquisition (purchases less sales) of used assets. It includes costs of installation and margins and commissions of dealers and brokers on transactions in both new and used assets. Also included in investment are additions, alterations, and major replacements of parts of assets such as a new furnace installed in a building or an engine in an airplane.

Replacements of small parts and repairs are not included in investment, and it is necessary to establish a boundary between these items and major replacements. For business, the boundary is based on whether the item is capitalized under IRS regulations. For government, the boundary is based on that established for business. An examination currently under way at BEA indicates that a substantial proportion of major replacements in private structures is probably being missed in the present NIPA estimates. We expect this investigation to result in an upward revision in gross fixed business investment in the next benchmark revision of GNP.

Fixed investment by the business sector in the NIPAs differs in several respects from that capitalized under IRS regulations. The major difference is the inclusion of owner-occupied housing in fixed investment in the NIPAs. Other items included in the NIPA measure but not capitalized under IRS regulations include assets owned by nonprofit institutions, expenditures for mining exploration, mine shafts and petroleum and natural gas wells, and autos of employees reimbursed for travel expenses.

For the total of the business, government, and household sectors, the net acquisition of used assets is a minor item in gross fixed investment. It consists of the net flow of used equipment to the rest of the world and the net flow of used equipment to dealers' inventories. All other flows of used assets are among the three sectors and sum to zero. When the total is disaggregated into the three sectors, especially when these sectors are further disaggregated, the net acquisition of used assets becomes an important aspect of the definition of investment. Not only are there transactions among sectors or more detailed groupings of transactors, but there are transfers of used assets that result from changes in the classification of transactors. For example, the incorporation of an unincorporated business firm moves capital from the noncorporate stock to the corporate stock.

The largest intersector flows of used assets in the NIPAs are the sales of used plant and equipment by the federal government to other sectors after World Wars I and II and the sale of used autos by business to households. Another flow of some size is the acquisition of private structures by state and local governments for demolition in conjunction with highway construction and urban renewal. Since these structures are purchased for demolition, they are treated as discards from total stocks. There are two important flows that are inadequately accounted for in the NIPAs because of lack of information—takeovers of privately owned transit systems and other public utilities by state and local governments, and donations of streets and other improvements to municipalities by developers.

In general, an accounting of transfers of used assets at more disaggregated levels than the three sectors mentioned above is not necessary in the NIPAs. Such an accounting, however, is necessary for detailed estimates of stocks. Unfortunately, it is missing in the detailed stock estimates, with the exception of the disaggregation by legal form of organization and industry of the flows of used assets between business and the other two sectors, which are available in the NIPAs. Probably the most important flows not explicitly accounted for in the detailed estimates are those between corporate and noncorporate business. The lack of explicit estimates implies that increases in corporate stock due to incorporations of unincorporated businesses are offset by sales of used assets by corporations to unincorporated business.

The transfers of used assets among sectors in the NIPAs are valued at the market price at the time of transfer. In estimating gross and net stocks it is necessary to modify the market valuation. The modification consists of valuing the asset at its original acquisition (when new) price for purposes of moving it from the gross stock of the seller to the gross stock of the buyer. For net stocks the modification consists of valuing the asset at the straight-line depreciated value of the original acquisition price. An exception to these procedures is for assets purchased new by the government during periods of war and subsequently sold secondhand to business that contained characteristics of no use to their postwar business purchaser. The valuation of these transfers is based on an estimate of the value that business would have paid for new assets of equal productivity.

The procedure for valuing transfers of used assets requires information on the length of time the asset is held by its original owner and its original acquisition price. Reasonably good estimates of such information are available to value the intersector flows described above. It is apparent that the lack of this type of information is a serious limitation on the use of the perpetual inventory method to obtain estimates for more detailed groups of transactors.

Margins and commissions include those on transactions among sectors and within sectors. The inclusion of margins and commissions in investment is based largely on their treatment in IRS regulations that require that these items be capitalized. For purposes of estimating capital stock, it is not clear that it is desirable to treat margins and commissions on used assets as investment, since this implies an increase in the stock when a used asset is tranferred between owners and a margin or commission is earned by a broker. This seems inconsistent with the treatment of assets that do not change ownership during their lives. If an alternative procedure were adopted that treated margins and commissions on used assets as a business expense, capital consumption allowances and profits in the NIPAs would also be affected. In 1975, margins and commissions on used assets accounted for about $5.6 billion in business investment, mostly on housing, and $6.0 billion in purchases of consumer durables, mostly on autos.)

1.2.6 Deflation and Price Indexes

Constant-dollar investment in the NIPAs is generally derived by deflating current-dollar investment flows by price indexes. Thus, implementation of the NIPA definition of real capital depends crucially on the treatment of quality change in the price indexes BEA uses to separate current-dollar flows into prices and quantities. The approach taken by the Bureau of Labor Statistics (BLS) and other compilers of the price indexes is essentially to attempt to remove from the reported price change the change in costs associated with quality change. Deflation of gross fixed investment by the resulting price indexes counts only cost-associated quality change as a change in real capital.

Deflation is particularly difficult when new products are introduced, since there is no obvious way to value these products at base period prices if they did not exist in the base period. The method generally used considers the new product equivalent to one unit of the old product multiplied by the ratio of the cost of the new product to that of the old product in an overlap period. If an overlap period does not exist, a hypothetical comparison must be undertaken by estimating what it would have cost to produce the new product in a period when the old one still existed.

Many presume that the compiled price indexes overstate the amount of price increase. If so, the growth in constant-dollar capital stock is understated. However, a recent review by Jack Triplett (1975) of several components of the consumer and wholesale price indexes suggests that one should not jump to conclusions on this subject. He indicates that editing procedures designed to detect and adjust for quality change could introduce biases in either direction and that findings of several emprical studies are mixed as to the direction of bias.

In the recently completed benchmark revision of GNP, improved deflation procedures were adopted for structures (see Bureau of Economic Analysis 1974). These improvements came as a result of an extensive review of available price data by BEA and the Bureau of the Census and resulted in a significant reduction in the dollar value of structures deflated by the prices of construction inputs. In the present deflation of structures, price indexes based on construction outputs are available for housing, office buildings, road building, petroleum pipelines, and dams and reclamation projects. Price indexes based on construction outputs are not available for other types of structures. These latter types of structure are deflated either by price indexes of construction inputs or by weighted averages of the available price indexes of construction outputs. For example, all expenditures on construction of nonresidential buildings are deflated by an average of the price indexes for housing, office buildings, and highway structures. This procedure is considered reasonably accurate, although it is difficult to judge the extent of any bias until additional price indexes for specific types of nonresidential structures are available.

As has been discussed many times at this conference, much else remains to be done on the price front. We single out three areas where more work is needed: (1) Further assessment of the statistical treatment of quality change in the BLS-compiled and other price indexes is needed. (2) The pricing coverage by BLS is deficient or nonexistent for certain types of equipment and should be extended, particularly for ships, aircraft, and computers; (3) Price information is needed for new types of capital assets entering the stock. One such type of asset that is increasing in importance is nuclear generating plant and equipment.

1.2.7 Service Lives and Retirement Patterns

The success of the perpetual inventory method in measuring the stock of fixed capital depends, to a large extent, on the accuracy of the service lives assigned to different types of assets. Unfortunately, only fragmentary information is available on actual or economic service lives of assets.

Service lives on which depreciation of fixed nonresidential business capital is computed for tax purposes declined substantially between the issuance of IRS Bulletin F in 1942 and the adoption of the asset depreciation range (ADR) in 1971.[8] Studies conducted by IRS showed that tax service lives for new investment in 1954–59 were approximately

75% of Bulletin F lives (0.75F). The 1962 IRS guidelines permitted a reduction in tax service lives for new and existing equipment to about 0.6F or 0.7F. The 1971 ADR allowed businesses to depreciate new equipment with lives up to 20% shorter than the guideline lives. However, the actual service lives probably were not as long as Bulletin F lives during the 1940s, and the decline, if any, in actual lives has not matched by change in tax service lives. Thus the BEA estimates for fixed nonresidential business capital are based on the assumption that actual lives are about 15% shorter than Bulletin F lives over the entire period of the stock calculations. For housing, the service lives used for tax purposes are forty years for apartments and forty-five years for houses. The service lives for residential capital given in table 1.1 are considerably longer than these, since evidence from the census of housing and other studies of the housing stock indicates that actual lives are longer than tax lives.

Several studies have provided indirect evidence of actual service lives for fixed nonresidential business capital. The Jack Faucett Associates studies cited later in this paper suggested that actual service lives for manufacturing industries were equal to or longer than Bulletin F lives. Studies by Coen (1975) indicated that actual service lives for equipment for the period 1947–66 were in the same range as the 1962 guideline lives. Because of data limitations, it is difficult to attach much precision to these empirical studies. Surveys of actual service lives used by businesses are needed for assessing the accuracy of the service lives used in the BEA study.

With the exception of automobiles, the Winfrey retirement patterns given in table 1.2 are applied uniformly to all types of investment. While this undoubtedly introduces an artificial smoothness into the stock numbers, it seems to be the best procedure available considering the lack of information on actual retirements. The Winfrey patterns may be viewed as representing two different phenomena: within each asset group in the study, there are a number of different types of assets with different service lives; for each type of asset, there is a distribution of retirements about the average service life.

1.2.8 Direct Measurement

As noted earlier, stocks of autos are the only type of asset for which the BEA estimates are based on direct measurement. Because capital stock estimates based on the perpetual inventory method are subject to considerable error if the investment data and service lives used are not accurate, there is a need for estimates based on direct measurement to supplement and serve as a check on the perpetual inventory estimates.

In 1964, the Wealth Inventory Planning Study (WIPS) (see Kendrick 1964) reviewed the available data and made a detailed series of recommendations for developing estimates of wealth in the United States by sector and industry. An important part of the WIPS recommendations centered on the need for detailed, periodic censuses of tangible wealth. These recommendations have not been implemented in the federal statistical program. If implemented, they could provide the same sort of benchmark check on the levels of national wealth that are now provided by the sources used to benchmark the NIPAs.

The WIPS sector recommendations call for two basic types of data: census and survey data where data on physical units are available; and balance sheet data where data on physical units are generally not available.

The census and survey method involves a periodic counting and valuing of all assets in the stock, updated by sample surveys. Some data of this type are already available, and the WIPS proposals call for upgrading and expanding such data. Housing is an example of an asset where a periodic census type of data is available (every ten years), updated with survey data.[9] However, for stock estimation the problem is valuation. Homeowners are asked to estimate the present value of their house and lot, which may be difficult for those who have not bought or sold a house recently. Also, there are problems in separating the value of the land from that of the structure. These problems are not insurmountable, but careful attention needs to be paid to correct valuation in such estimates.

Other types of assets for which stock estimates based on census and survey information may be feasible are trucks and other types of transportation equipment. It may be possible to derive stocks of trucks by utilizing registration data as is done for autos. Stocks of buses, ships, aircraft, and railroad equipment might be developed from data contained in the periodic reports to federal regulatory agencies. Here again the valuation of the assets may prove difficult.

Balance sheet data on gross book value of depreciable assets are available for some industries at five-year intervals from the Census Bureau's economic censuses (establishment-based) and annually from IRS Statistics of Income (company-based). A considerable upgrading of this type of data is proposed by the WIPS, with more detail by type of asset, industry, and geographic area. The WIPS also proposes collecting more data on accounting practices, age distributions, and actual service lives of assets. Balance sheet data, expressed at historical costs, can be converted to constant or current costs if data on the age of the assets in the stock are known. Historical cost balance sheet data can also be used to derive benchmarks for perpetual inventory estimates.[10]

One important aspect of balance sheet data is the valuation of used assets acquired by an establishment. These assets are carried on the books at their secondhand purchase prices, and a revaluation is necessary to derive estimates of their acquisition prices when new. This would require collection of information that would permit the estimation of the dates when these assets were acquired new and their original acquisition prices.

An area where balance sheet data would be particularly useful is rented capital. The BEA stock estimates are based on ownership rather than on use. Alternative estimates classified by user would clearly be desirable and could be made possible by collecting a balance sheet type of data on the value and age of rented capital.

In summary, implementation of the WIPS proposals could provide the basis for substantially upgrading the accuracy and available detail of estimates of capital stock in the United States.

1.2.9 Other Estimates

Several studies have produced estimates of capital stock in the United States other than those prepared by BEA. Some of these include industry detail not available in the BEA study. In some cases the industry detail is controlled to the BEA aggregates. There also are cases where the researcher utilized some aspects of BEA's work, particularly the investment flows and service lives, and chose to measure or define other aspects differently. A partial list follows. Consult the reference list for full facts of publication.

Raford Boddy and Michael Gort, "The Estimation of Capital Stocks by Industry, 1947–63" (1968); and their "Obsolescence, Embodiment, and the Explanation of Productivity Change" (1974). Boddy and Gort derived estimates of gross and net fixed capital stocks for thirty industries using the perpetual inventory method, with investment flows developed from IRS tabulations of balance sheets by taking changes in year-end net assets and adding depreciation charges.

Laurits R. Christensen and Dale W. Jorgenson, "Measuring Economic Performance in the Private Sector" (1973). Christensen and Jorgenson used the perpetual inventory method and the BEA investment data to develop annual estimates of capital input for three sectors (corporate business, noncorporate business, households and institutions) for the years since 1929. The decline in services provided by an asset was assumed to follow the pattern provided by the double-declining balance depreciation formula.

Daniel Creamer, *Capital Expansion and Capacity in Postwar Manufacturing* (1961). Creamer's estimates of gross fixed capital stocks for twenty-three manufacturing industries were developed by revaluing book value stocks from IRS tabulations of balance sheets, using assumptions on the average age of capital for each industry. His work also includes separate estimates of the value of rented capital.

Edward F. Denison, *Accounting for United States Economic Growth 1929–1969* (1974). Denison used the BEA estimates of gross and net fixed capital stocks based on Bulletin F service lives to derive measures of capital input. Gross and net stocks were weighted three to one as an allowance for the decline in capital services over the service life.

Jack Faucett Associates, Inc. (JFA), *Development of Capital Stock Series by Industry Sector* (1973); and their *Fixed Capital Stocks by Industry Sector, 1947–70 (71)* (1975). The JFA studies derived estimates of gross and net fixed capital stocks for about 170 industry groups, with separate estimates of government-owned, contractor-operated stocks. These estimates were derived by the perpetual inventory method, utilizing detailed investment flows back to 1890 that JFA dveloped using data from the economic census where available and the Boddy/Gort approach for most other industries, and controlling to aggregate investment flows in the BEA capital stock study.

Raymond W. Goldsmith, *The National Wealth of the United States in the Postwar Period* (1962); and his *Institutional Investors and Corporate Stock: A Background Study* (1973). The Goldsmith studies derived estimates of total gross and net wealth by sector. The fixed capital estimates were derived by the perpetual inventory method. The 1973 study used BEA stock estimates where available. These are updatings of Goldsmith's earlier pioneering studies in the estimation of capital stock by the perpetual inventory method.

Frank Gollop and Dale W. Jorgenson, "U.S. Total Factor Productivity by Industry, 1947–1973" (1975). Gollop and Jorgenson derived capital input estimates for sixty-seven industries using the perpetual inventory method and the JFA industry investment series controlled to the BEA structures and equipment totals. The decline in services provided by an asset was assumed to follow the pattern provided by the double-declining balance depreciation formula.

Bert G. Hickman, *Investment Demand and U.S. Economic Growth* (1965). Hickman derived annual estimates of net capital stocks for the years 1945–62 for twenty-one industry groups, using the perpetual inventory method and industry investment series from the BEA Plant and Equipment Expenditures Survey, supplemented by data from trade associations and other researchers. Declining balance depreciation rates were assigned by industry, ranging from 1.5 to 2.0 times the straight-line rate.

John W. Kendrick, with Kyu Sik Lee and Jean Lomask, *The National Wealth of the United States by Major Sector and Industry* (1976); and John W. Kendrick, assisted by Yvonne Lethem and Jennifer Rowley, *The Formation and Stocks of Total Capital* (1976). Kendrick derived annual and quarterly estimates of total capital stocks and total wealth in the United States. He also derived annual and quarterly estimates of gross and net fixed capital stocks for thirty-two industry groups, based primarily on the perpetual inventory method and utilizing the work of Boddy and Gort, Creamer, and JFA, and controlling to the BEA stock estimates for the farm, manufacturing, and nonfarm nonmanufacturing totals.

Helen Stone Tice, "Depreciation, Obsolescence, and the Measurement of the Aggregate Capital Stock of the United States, 1900–1961" (1967). Tice developed annual estimates of gross and net stocks of residential structures, nonresidential structures, producers' durable equipment, and consumer durables, using the investment flows from Goldsmith's earlier work and assumptions about embodied technological change.

Also of interest is another BEA study concerned with projections of capital stock and investment: United States Bureau of Economic Analysis, *A Study of Fixed Capital Requirements in the U.S. Business Economy 1971–1980* (1975). This study derived estimates of gross fixed capital stock for eighty-five industry groups in 1980, implied by projected estimates of output and projected capital-output ratios in 1980, and also provided estimates of the investment by industry for 1971–80 necessary to derive these stocks. The 1970 capital stock estimates that served as a starting point for these projections were based on the JFA stocks by industry, controlled separately for equipment and structures to the BEA industry totals for farm, manufacturing, and nonfarm nonmanufacturing.

Appendix

Estimates of constant-dollar gross and net stocks of reproducible tangible capital for selected years in the period 1925–75 are presented in the following tables:

Totals, by sector and legal form of organization, Table 1.A.1
Business, by type of capital, 1.A.2
  Corporate, 1.A.3
    Nonfinancial, 1.A.4
  Noncorporate, 1.A.5
Government, by type of capital, 1.A.6
  Federal, 1.A.7
  State and local, 1.A.8

Sectors consist of business, government, and households. Within the business sector, legal forms of organization are corporate and noncorporate, with estimates also presented for nonfinancial corporations. Types of capital consist of nonresidential equipment, nonresidential structures, residential, and business inventories. Estimates for the government sector exclude inventories and military assets.

Table 1.A.1 Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, by Sector and Legal Form of Organization, Selected Years, 1925–75 (Billions of 1972 Dollars)

	Gross Stocks							
		Business			Government[a]			
End of Year	Total	Total	Corporate	Noncorporate	Total	Federal	State and Local	Households[b]
1925	1,326.2[c]	1,052.0[c]	445.2[c]	606.8[c]	143.3	14.3	129.1	130.8
1930	1,646.6	1,286.1	557.9	728.2	189.8	15.8	174.0	170.7
1935	1,626.4	1,233.6	512.7	720.9	228.5	23.2	205.2	164.3
1940	1,717.0	1,261.7	510.0	751.7	281.6	38.8	242.8	173.7
1945	1,828.9	1,265.5	503.0	762.5	384.8	135.0	249.7	178.7
1950	2,192.9	1,517.3	614.2	903.1	420.9	132.7	288.2	254.7
1955	2,634.4	1,795.4	729.5	1,065.8	491.8	139.8	352.0	347.2
1960	3,068.0	2,075.2	841.6	1,233.6	564.3	122.9	441.4	428.6
1965	3,652.7	2,441.4	1,006.6	1,434.8	683.5	127.1	556.4	527.8
1970	4,469.2	2,932.8	1,284.6	1,648.2	837.6	138.2	699.5	698.8
1975	5,350.8	3,434.7	1,544.2	1,890.4	962.6	144.3	818.3	953.6
	Net Stocks							
		Business			Government[a]			
End of Year	Total	Total	Corporate	Noncorporate	Total	Federal	State and Local	Households[b]
1925	784.5[c]	612.3[c]	235.9[c]	376.4[c]	100.4	9.1	91.4	71.8
1930	1,020.1	792.0	326.9	465.1	134.6	9.6	125.0	93.5
1935	935.7	699.4	270.2	429.2	157.2	16.0	141.3	79.1
1940	990.8	710.1	271.8	438.3	190.9	28.3	162.6	89.7
1945	1,034.4	694.7	268.2	426.6	259.9	106.6	153.3	79.7
1950	1,283.3	900.1	361.1	539.0	253.0	77.8	175.2	130.3
1955	1,564.5	1,098.1	439.9	658.2	292.8	73.5	219.4	173.6
1960	1,844.1	1,292.1	510.7	781.5	351.1	67.9	283.1	200.9
1965	2,260.0	1,558.8	630.1	928.7	445.4	79.1	366.3	255.8
1970	2,803.5	1,900.5	831.9	1,068.6	554.2	84.6	469.5	348.9
1975	3,286.7	2,206.0	986.8	1,219.2	623.4	83.9	539.5	457.4

[a]Government sector stocks exclude inventories and military assets.
[b]Household sector stocks consist of durable goods owned by consumers.
[c]Excludes business inventories.

Table 1.A.2 **Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, Business, by Type of Capital, Selected Years, 1925–75 (Billions of 1972 Dollars)**

End of Year	Gross Stocks					Net Stocks				
		Nonresidential					Nonresidential			
	Total	Equipment	Structures	Residential	Inventories	Total	Equipment	Structures	Residential	Inventories
1925	1,052.0[a]	169.3	395.4	487.2	n.a.[b]	612.3[a]	89.7	209.0	313.6	n.a.[b]
1930	1,286.1	188.8	444.4	557.5	95.4	792.0	97.3	241.3	358.0	95.4
1935	1,233.6	166.1	424.4	563.1	80.0	699.4	71.5	209.6	338.4	80.0
1940	1,261.7	164.9	411.5	589.9	95.3	710.1	79.3	193.2	342.2	95.3
1945	1,265.5	174.9	386.3	597.6	106.7	694.7	89.2	170.6	328.2	106.7
1950	1,517.3	274.0	419.6	693.5	130.2	900.1	162.1	205.4	402.4	130.2
1955	1,795.4	363.4	466.8	810.0	155.3	1,098.1	201.7	249.6	491.6	155.3
1960	2,075.2	426.0	537.9	939.7	171.6	1,292.1	225.9	307.1	587.6	171.6
1965	2,441.4	500.6	634.6	1,097.3	209.0	1,558.8	269.7	376.2	703.9	209.0
1970	2,932.8	651.4	770.1	1,249.9	261.3	1,900.5	364.4	469.3	805.5	261.3
1975	3,434.7	805.5	895.7	1,443.2	290.3	2,206.0	440.9	540.0	934.8	290.3

[a]Excludes inventories.
[b]n.a. = not available.

Table 1.A.3 **Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, Corporate Business, by Type of Capital, Selected Years, 1925–75 (Billions of 1972 Dollars)**

	Gross Stocks					Net Stocks				
		Nonresidential					Nonresidential			
End of Year	Total	Equipment	Structures	Residential	Inventories	Total	Equipment	Structures	Residential	Inventories
1925	445.2[a]	128.1	304.9	12.2	n.a.[b]	235.9[a]	67.8	159.4	8.6	n.a.[b]
1930	557.9	138.8	339.9	16.8	62.4	326.9	70.7	181.8	12.0	62.4
1935	512.7	121.7	322.9	17.1	51.0	270.2	52.0	156.1	11.0	51.0
1940	510.0	118.3	311.8	17.9	61.9	271.8	55.8	143.4	10.7	61.9
1945	503.0	125.6	292.9	17.7	66.8	268.2	64.4	127.5	9.5	66.8
1950	614.2	194.2	314.8	18.4	86.8	361.1	113.9	151.0	9.4	86.8
1955	729.6	262.1	341.9	18.9	106.8	439.9	147.0	176.7	9.5	106.8
1960	841.6	318.8	380.4	21.8	120.5	510.7	171.4	206.9	11.9	120.5
1965	1,006.6	385.0	434.1	31.9	155.6	630.1	209.8	243.6	21.0	155.6
1970	1,284.6	514.1	520.6	42.8	207.0	831.9	290.6	304.5	29.9	207.0
1975	1,544.2	653.4	604.6	53.9	232.3	986.8	361.1	355.4	38.0	232.3

[a]Excludes inventories.
[b]n.a. = not available.

Table 1.A.4 **Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, Nonfinancial Corporate Business, by Type of Capital, Selected Years, 1925–75 (Billions of 1972 Dollars)**

End of Year	Gross Stocks					Net Stocks				
		Nonresidential					Nonresidential			
	Total	Equipment	Structures	Residential	Inventories	Total	Equipment	Structures	Residential	Inventories
1925	436.5[a]	126.8	298.2	11.5	n.a.[b]	230.7[a]	67.2	155.4	8.1	n.a.[b]
1930	547.3	137.3	331.7	16.0	62.4	320.4	69.9	176.7	11.4	62.4
1935	502.3	120.3	314.7	16.3	51.0	264.6	51.4	151.7	10.5	51.0
1940	500.0	116.8	304.2	17.0	61.9	267.0	55.1	139.9	10.2	61.9
1945	494.3	124.5	286.2	16.8	66.8	264.7	64.0	124.9	9.0	66.8
1950	605.0	192.2	308.5	17.4	86.8	357.0	112.6	148.6	8.9	86.8
1955	718.5	258.9	334.8	17.9	106.8	434.1	145.1	173.3	8.9	106.8
1960	827.7	314.4	372.1	20.7	120.5	502.6	168.8	201.9	11.3	120.5
1965	987.0	378.2	422.7	30.5	155.6	617.2	205.7	235.7	20.1	155.6
1970	1,248.1	499.4	500.6	41.1	207.0	806.0	281.1	289.3	28.7	207.0
1975	1,486.6	628.6	573.9	51.9	232.3	947.6	346.2	332.4	36.7	232.3

[a]Excludes inventories.
[b]n.a. = not available.

Table 1.A.5 **Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, Noncorporate Business, by Type of Capital, Selected Years, 1925–75 (Billions of 1972 Dollars)**

End of Year	Gross Stocks					Net Stocks				
		Nonresidential					Nonresidential			
	Total	Equipment	Structures	Residential	Inventories	Total	Equipment	Structures	Residential	Inventories
1925	606.8[a]	41.2	90.6	475.0	n.a.[b]	376.4[a]	21.9	49.6	305.0	n.a.[b]
1930	728.2	50.0	104.4	540.7	33.0	465.1	26.6	59.5	346.0	33.0
1935	720.9	44.4	101.6	545.9	29.0	429.2	19.5	53.4	327.3	29.0
1940	751.7	46.6	99.8	571.9	33.4	438.3	23.5	49.8	331.5	33.4
1945	762.5	49.4	93.4	579.8	39.9	426.6	24.9	43.1	318.7	39.9
1950	903.1	79.8	104.8	675.2	43.4	539.0	48.2	54.4	393.0	43.4
1955	1,065.8	101.3	125.0	791.0	48.5	658.2	54.7	72.9	482.1	48.5
1960	1,233.6	107.1	157.5	917.9	51.1	781.5	54.5	100.2	575.7	51.1
1965	1,434.8	115.6	200.4	1,065.4	53.3	928.7	59.9	132.6	682.9	53.3
1970	1,648.2	137.3	249.5	1,207.1	54.3	1,068.6	73.7	164.8	775.7	54.3
1975	1,890.4	152.1	291.1	1,389.2	58.0	1,219.2	79.8	184.6	896.8	58.0

[a]Excludes inventories.
[b]n.a. = not available.

Table 1.A.6 **Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, Government, by Type of Capital, Selected Years, 1925–75 (Billions of 1972 Dollars)**

End of Year	Gross Stocks				Net Stocks			
		Nonresidential				Nonresidential		
	Total	Equipment	Structures	Residential	Total	Equipment	Structures	Residential
1925	143.3	4.3	138.8	.2	100.4	2.6	97.6	.2
1930	189.8	6.7	182.9	.2	134.6	4.4	130.1	.1
1935	228.5	9.9	218.3	.3	157.2	6.1	150.9	.2
1940	281.6	18.8	259.5	3.3	190.9	12.3	175.6	3.0
1945	384.8	84.0	292.6	8.2	259.9	63.9	188.6	7.4
1950	420.9	87.5	324.8	8.5	253.0	43.9	201.8	7.3
1955	491.8	83.7	396.3	11.8	292.8	32.8	250.3	9.7
1960	564.3	62.5	485.0	16.8	351.1	26.4	311.1	13.6
1965	683.5	59.5	601.6	22.3	445.4	32.2	395.7	17.5
1970	837.6	69.7	740.4	27.5	554.2	38.9	494.5	20.7
1975	962.6	78.0	851.6	33.0	623.4	41.1	558.5	23.8

Note: Excludes inventories and military assets.

Table 1.A.7 Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, Federal Government, by Type of Capital, Selected Years, 1925–75 (Billions of 1972 Dollars)

	Gross Stocks				Net Stocks			
		Nonresidential				Nonresidential		
End of Year	Total	Equipment	Structures	Residential	Total	Equipment	Structures	Residential
1925	14.3	1.3	12.8	.2	9.1	.7	8.2	.2
1930	15.8	1.2	14.4	.2	9.6	.5	9.0	.1
1935	23.2	1.7	21.3	.3	16.0	1.1	14.7	.2
1940	38.8	8.1	28.3	2.4	28.3	6.1	20.1	2.1
1945	135.0	74.4	54.9	5.7	106.6	59.4	42.1	5.2
1950	132.7	74.2	54.4	4.1	77.8	36.2	38.2	3.4
1955	139.8	64.0	72.1	3.8	73.5	20.7	50.0	2.7
1960	122.9	34.7	82.4	5.8	67.9	10.4	53.1	4.5
1965	127.1	22.3	97.0	7.7	79.1	11.3	62.1	5.8
1970	138.2	22.9	107.0	8.3	84.6	12.3	66.6	5.7
1975	144.3	18.4	115.8	10.0	83.9	7.2	70.0	6.7

Note: Excludes inventories and military assets.

Table 1.A.8 **Constant-Dollar Gross and Net Stocks of Reproducible Tangible Capital, State and Local Government, by Type of Capital, Selected Years, 1925–75 (Billions of 1972 Dollars)**

	Gross Stocks				Net Stocks			
		Nonresidential				Nonresidential		
End of Year	Total	Equipment	Structures	Residential	Total	Equipment	Structures	Residential
1925	129.1	3.0	126.0	0	91.4	2.0	89.4	0
1930	174.0	5.5	168.5	0	125.0	3.9	121.1	0
1935	205.2	8.3	197.0	0	141.3	5.0	136.3	0
1940	242.8	10.7	231.1	1.0	162.6	6.2	155.5	1.0
1945	249.7	9.6	237.7	2.4	153.3	4.5	146.6	2.2
1950	288.2	13.3	270.5	4.4	175.2	7.7	163.5	3.9
1955	352.0	19.7	324.2	8.0	219.4	12.1	200.3	7.0
1960	441.4	27.9	402.6	10.9	283.1	16.0	258.0	9.1
1965	556.4	37.3	504.6	14.6	366.3	20.9	333.6	11.7
1970	699.5	46.9	633.4	19.2	469.5	26.6	427.8	15.1
1975	818.3	59.6	735.8	23.0	539.5	33.9	488.5	17.1

Note: Excludes inventories.

Notes

1. Bureau of Economic Analysis (1976*b*). A summary of the tabulations and method in this volume is given in Musgrave (1976*a*). Revised estimates for 1973–75 are given in Musgrave (1976*b*).

2. Earlier estimates of stocks of consumer durables were given in Shavell (1971).

3. Estimates of the value of capital owned by the federal government and operated by private contractors are given in Bureau of Economic Analysis (1976*b*).

4. The revised NIPAs are described in Bureau of Economic Analysis (1976*a*).

5. In the first approach, there is room for some latitude in the treatment of obsolescence depending on one's view of whether foreseen obsolescence should be treated differently from unforeseen obsolescence. What we are calling the NIPA definition represents the view that the two types of obsolescence should be treated in the same manner. The most complete discussion of the NIPA definition and the discounted value definition of which we are aware is that by Denison (1972, pp. 101–8).

6. We like the way Eisner states one aspect of this point. "In the case of automobiles there is as well a substantial element of 'moral hazard.' A disproportionate number of cars put on the market may be offered for sale because they have proved to be 'lemons.' " See his "Comment" on Christensen and Jorgenson (1973).

7. The percentages were obtained by combining Coen's industry results with weights based on book values of fixed assets from the 1970 Annual Survey of Manufactures.

8. For a review of the tax service lives, see Young (1975).

9. For estimates of housing stocks based on the census and survey techniques, see Young, Musgrave, and Harkins (1971).

10. Examples of these uses of balance sheet data are given in the works by Creamer and Jack Faucett Associates cited in the next section.

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Comment Thomas K. Rymes

Though it has been some time since I "measured capital" by the perpetual inventory method,[1] I recognize a job well done, and I congratulate the authors of this paper. They not only present some of the latest BEA estimates of the gross and net stock of capital and capital consumption allowances in current, constant, and historical dollars at various sectoral levels, but they also survey a number of alternative estimates with clarity and succinctness. At this conference one need not recite the usual litany of problems associated with the perpetual inventory method, but it is useful, as the authors commendably do, to remind ourselves how limited is our knowledge of intersectoral transactions in existing fixed capital, survival and depreciation functions, average economic lives, and biases in capital good price indexes. As the authors say, some of these questions are academic, since trends and cyclical swings in gross capital formation data may swamp the effects of even substantial variations in life estimates and in survival and depreciation functions on the resulting gross and net stock and capital consumption allowance estimates.

Academic or not, though, I confess I am somewhat puzzled by the conceptual discussion. It has always been my understanding that, while recognizing that "chops and changes" of non–steady-state real economic life prevent one from attaching precision to capital flow and stock estimates, however produced, one wants those estimates to come as close as possible to those the price system would generate. Thus, in case 1 of Young and Musgrave's paper, where a single capital good lasts a number of years with its stream of services (its gross marginal product) remaining intact, and where there is no obsolescence, the authors state that straight-line depreciation is the correct answer—correct, I presume, in relation to what they call the discounted value definition of depreciation. Yet in such a case, so long as some positive rate of profit is being earned by such assets, surely the discounted value definition is different and correct. A single asset, halfway through its life, under straight-line depreciation, would have a net stock value half that of its gross stock value, while under the discounted value definition its net

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stock value would stand at more than half its gross stock value. The time pattern of the value of the net stock of the asset generated by the discounted value definition, with its correspondingly different time pattern of depreciation, would be that generated by the market value of the asset—assuming, of course, that the usual tranquillity conditions hold. That, it seems to me, is what we want, and so I strongly support the discounted value definition. Of course, for a balanced stationary stock of such assets the net stock estimates will differ while the estimates of capital consumption allowances will be the same, but for a growing stock they will not.[2] For total factor productivity calculations this will be important, since a *partial* component of such calculations will be $\ldots \beta k_n + \gamma k_d \ldots$, where β is the share of the net returns to capital, k_n is the growth rate of the net stock of capital, and γ is the share and k_d is the growth rate of capital consumption allowances; and it will evidently matter, conceptually at least, particularly for estimated shares, whether the net stock and capital consumption allowances estimates are calculated in the manner the authors suggest or by adherence to the discounted value or economic criterion.

Similarly, if one deflated current-dollar *net* returns to the asset in question by a capital services price index to obtain constant-dollar *net* services estimates (or constant-dollar value of the *net* marginal product of the asset), it would be the discounted value criterion one would want.[3] Thus, whether we measure capital inputs in terms of constant-dollar net stocks and capital consumption allowances, constant-dollar gross service flows, constant-dollar net service flows and capital consumption allowances, it is the economic or discounted value definition of capital consumption allowances that is desired.[4]

The same considerations apply, with much elaboration required, to the authors' position on the measurement of "depreciation by obsolescence." I do not see any theoretical force to the argument of excluding obsolescence from measures of depreciation. A capital good, requiring a fixed amount of labor throughout its life, may continue to produce an unchanging flow of gross services (their third case) until its associated wages bill rises to snuff out any positive net returns to capital. Once again, the price of the *net* marginal product will decline by the economic or discounted value definition.

All this seems to me to follow from the obvious fact that when the capital good first enters the stock it appears at its new economic or discounted or gross stock value. I do not see why the same concept is not applied when estimating its net stock value (and associated capital consumption allowances) simply because it has aged or has become by obsolescence closer to the end of its economic life.[5]

Of course I realize that in the case of "depreciation by obsolescence" I am touching upon the vexed question of how one constructs a price index of capital goods subject to "depreciation by obsolescence" or "embodied technical progress" or "quality improvements," but I would observe that where (*a*) price-relative overlap information for new capital goods exists and is used, the discounted value criterion is in fact being employed; where (*b*) price-relative overlap information is constructed by the "characteristics price" approach, once again the discounted value criterion is being employed; and where (*c*) the "characteristics price" approach is given up because a new characteristic is involved without overlap and the comparative cost construction is used, then once again it seems to me that the discounted value criterion is being used—*unless* it is assumed that the ex ante rate of return on capital involved in producing the new good is higher than on the old so that all advances in knowledge are embedded in costly additions to constant-dollar outputs and inputs and, with respect to total factor productivity, we can all go home, since it is definitionally always unity.

(Parenthetically, I agree with the authors when they refer to evidence, and the need for more careful empirical work, that suggests that price indexes may not be so badly biased upward as is commonly assumed because of their supposed failure to account adequately for "quality improvements," and I would note the existence of similar evidence in Canada [Asimakopolos 1962].)

My argument applies, I think, with much force when one takes into account "intersectoral transactions" in existing fixed capital goods. Consider, for example, a case where the capital stock of an unincorporated enterprise is sold to an incorporated enterprise. I recognize, of course, that some "backtracking" of data will be necessary to adjust the gross stocks, and, assuming that the authors' remarks about revaluation are not just related to general inflation, I think it would be a mistake if the net stock estimates of the unincorporated enterprise were constructed so as not to be the market value of the capital stock sold to the corporate enterprise sector. In short, use of the discounted value criterion would, ceteris paribus, obviate the necessity of a formidable number of adjustments associated with intersectoral transactions in existing fixed capital goods. There appears to me, then, to be a very practical objection to the valuation procedures the authors advocate at least conceptually. In addition, the position I advocate would support the authors' inclusion of the costs of transactions in existing capital goods in gross fixed capital formation and would resolve the difficulties they see involved.

If one accepts my argument, it seems that, with respect to rented capital goods, the fact that the BEA estimates are based on ownership rather than on user is a strength, not a weakness to be corrected by alternative estimates. Rents paid by the user sector should be treated as intermediate inputs of the using sector and as gross outputs of the owning sector.

The price indexes needed for expressing such flows in constant dollars will be approximated by the gross rental prices discussed above and in the Appendix and, for total factor productivity estimates, the net stocks and capital consumption allowances are hence correctly allocated to the sector in which the net returns and depreciation on the discounted value criterion are originating.

Finally, while I believe the discount value criterion is correct, particularly in the preparation of capital input data for total factor productivity estimates, I hasten to note that, for such estimates, one must also remember that capital goods (or capital goods services—no issue of substance is really involved in this distinction) are reproducible inputs; and I am pleased to say that Denison (1974) and Hulten (1975) at least begin to see the point. That capital inputs are reproducible is clear, and the point has nothing to do with "aggregation and all that."[6] One needs nonetheless to obtain estimates of capital outputs and inputs in constant dollars and their respective prices that are as meaningful as possible, and this is why I am puzzled by the conceptual discussion in this otherwise workmanlike and informative paper.

Appendix

In this appendix, the relationships between gross and net stocks of capital, capital consumption allowances, and gross and net market rentals for capital goods are set out in a world of tranquillity and lucidity (Robinson 1969, p. 59)—a world of long-period competitive semistationary equilibrium where expectations and outcomes are such that "today" is exactly like "yesterday," and "tomorrow" is confidently expected to be exactly like "today." The devices of tranquillity and lucidity are used simply to isolate the logic of the problems; the analysis says nothing about events in historical time; and, in particular, though money is used as a numeraire, the monetary aspect of the economy is completely without significance. I wish to reiterate that nothing substantive is involved in this appendix—in particular, it does not tell us what are the best empirical approximations to average economic lives and patterns of depreciation for capital goods. It merely indicates the logical relationships between stocks and flows of capital goods and their services and the corresponding prices when it is assumed that lives and depreciation rates are known.[7]

Consider, then, a capital good where gross marginal product is constant over its economic life. The ith vintage of such a capital good will have a value equal to

$$Pk_i = \int_{t=0}^{t=(T-i)} \overline{P}\,\frac{\partial \overline{Q}}{\partial K}\, e^{-Rt}dt = \frac{\overline{P}}{R}\frac{\partial \overline{Q}}{\partial K}\left[1 - \frac{1}{e^{R(T-i)}}\right],$$

where $\frac{\partial \overline{Q}}{\partial K}$ is the constant gross marginal physical product of the capital good, $\overline{P}$ is the price of the product produced by the capital good, T is the economic life, and R is the ruling equilibrium net rate of return or rate of profit on capital.

If the capital good is new, $i =$ zero, P_{K_0} is the gross price, whereas P_{K_i} $(T \geq i > 0)$ is the net price of the ith vintage.

For the ith vintage, its value declines as it ages by

$$\frac{\partial P_{K_i}}{\partial i} = -\overline{P}\frac{\partial \overline{Q}}{\partial K} \cdot \frac{1}{e^{R(T-i)}}$$

and by the proportionate rate

$$\frac{1}{P_{K_i}} \cdot \frac{\partial P_{K_i}}{\partial i} = \frac{-R}{e^{R(T-i)} - 1},$$

where $\frac{\partial P_{K_i}}{\partial i}$ is the value of the depreciation experienced by the ith vintage

and $\frac{1}{P_{K_i}} \frac{\partial P_{K_i}}{\partial i}$ is the proportionate rate of depreciation.[8]

What are the prices of the services of such capital goods? The gross rental for a capital good of the ith vintage will be the gross rate of return on the vintage multiplied by the net price of the vintage. The gross rate of return is the prevailing net rate of return or rate of profit plus the rate of depreciation (or the rate of profit minus the proportionate rate of change in the price of the vintage). Thus,

$$\begin{aligned} GV_i &= \left(R - \frac{1}{P_{K_i}} \frac{\partial P_{K_i}}{\partial i}\right) P_{K_i} \\ &= \left(\mathrm{R} - \frac{-R}{e^{R(T-i)} - 1}\right) \frac{\overline{P}}{R} \frac{\partial \overline{Q}}{\partial K} \left(1 - \frac{1}{e^{R(T-i)}}\right) \\ &= \left(\frac{Re^{R(T-i)}}{e^{R(T-i)} - 1}\right) \frac{\overline{P}}{R} \frac{\partial \overline{Q}}{\partial K} \left(\frac{e^{R(T-i)} - 1}{e^{R(T-i)}}\right) \end{aligned}$$

Cancelation yields

$$GV_i = \overline{P} \cdot \frac{\partial \overline{Q}}{\partial K}.$$

Thus the gross rental for a capital good of the ith vintage, GV_i, whose gross marginal product is constant over its life will be also unchanged over its life—as a competitively determined rental would indicate. The net rental for the ith vintage, NV_i will be

$$NV_i = RP_{K_i} = \bar{P}\frac{\partial Q}{\partial K}\left[1 - \frac{1}{e^{R(T-i)}}\right],$$

which will, of course, be affected by its vintage. Thus the net rental for a capital good will reflect the fact that the value of its net marginal product will be lower the greater its age. For *new* capital goods with very long economic lives, the net rental will approximate the gross rental.

If the gross marginal product of a capital good declines as it ages, then the formulas are adjusted to that the net price of the *i*th vintage will be

$$P_{K_i} = \int_0^{T-i} \bar{P}\frac{\partial Q}{\partial K_0} e^{-(R+\delta)}\, dt = \frac{\bar{P}}{R+\delta}\frac{\partial Q}{\partial K_0} \times \left[1 - \frac{1}{e^{(R+\delta)\,(T-i)}}\right],$$

where δ is the proportionate rate at which the gross marginal physical product of the capital good declines as it ages. Other functions depicting the decline of the gross marginal physical product of the capital good could, of course, be considered. Again, if the capital good is new, $i = 0$, P_{K_0} is the gross price, whereas P_{K_i} is the net price of the *i*th vintage. For that vintage, its net price declines as it ages by

$$\frac{\partial P_{K_i}}{\partial i} = -\bar{P}\frac{\partial Q}{\partial K_0}\frac{1}{e^{(R+\delta)\,(T-i)}}$$

and by the proportionate rate

$$\frac{1}{P_{K_i}}\frac{\partial P_{K_i}}{\partial i} = \frac{-(\mathrm{R}+\delta)}{e^{(R+\delta)\,(T-i)} - 1}.$$

The gross rental of the *i*th vintage would be

$$GV_i = \left(R - \frac{1}{P_{K_i}}\frac{\partial P_{K_i}}{\partial i}\right) P_{K_i}$$

$$= \left\{\frac{R}{R+\delta} + \frac{\delta}{(R+\delta)\, e^{(R+\delta)\,(T-i)}}\right\}\bar{P}\frac{\partial Q}{\partial K_0}.$$

In this case the gross rental is lower the older the capital good, reflecting the decline in its gross marginal physical product as it ages. The net rental of the *i*th vintage would be

$$NV_i = RP_{K_i} = \frac{R}{R+\delta}\bar{P}\frac{\partial Q}{\partial K_0}\left[1 - \frac{1}{e^{R+\delta)\,(T-i)}}\right].$$

As a third case to consider, one might think of a capital good whose gross marginal physical product is maintained over its economic life only by rising expenditures on labor for maintenance purposes. In this case, while the gross *gross* rental of the capital good would be constant over its life (gross, that is, of the wage payments associated with maintenance), its net price and gross and net rentals would have the time profiles exhibited by the second case, with δ being interpreted as the proportionate rate of increase in wage payments associated with the capital good for maintenance purposes.

Consider now "depreciation by obsolescence." As a fourth case, then, one might consider a captial good requiring for its operation a fixed amount of labor that, in a world where newer capital goods require steadily less labor to produce the same output and consequently steadily rising own-product real wage rates, has an economic life determined by the length of time the net rentals remain positive.[9] In such a fixed coefficients case, one has for the *i*th vintage

$$P_{K_i} = \int_0^{T^*-i} (\overline{PQ} - W_0 e^{\delta t}\overline{L}) e^{-Rt} dt,$$

where δ is the rate at which money wage rates are confidently expected to rise relative to the prices of the products and T^* is the economic life of the capital good determined by the number of periods required to reduce $(PQ - W_0 e^{\ t} \mathrm{L})$ to zero. If $R \geq \delta$ (the rate of return exceeds or equals the rate of technical progress), then

$$P_{K_i} = \frac{\overline{PQ}}{R}\left[1 - \frac{1}{e^{R(T^*-1)}}\right] - \frac{W_0 L}{\mathrm{R} - \delta} \times \left[1 - \frac{1}{e^{(R-\delta)(T^*-i)}}\right],$$

where the first term on the right-hand side depicts the present value of the stream of gross rentals $\overline{PQ}$ and the second term the present value of the stream of wage payments with money wage rates rising at the rate δ, the rate of technical progress.

Then,

$$\frac{\partial P_{K_i}}{\partial i} = -\left[\frac{\overline{PQ} e^{(R-\delta)(T^*-1)} - W_0 \overline{L} e^{R(T^*-i)}}{e^{R(T^*-1)} e^{(R-\delta)(T^*-i)}}\right]$$

and

$$\frac{1}{P_{K_i}} \frac{\partial P_{K_i}}{\partial^i} =$$

$$\frac{-R(R-\delta)[\overline{PQ} e^{(R-\delta)(T^*-i)} - W_0 \overline{L} e^{R(T^*-i)}]}{(e^{R(T^*-1)} - 1)[\overline{PQ}(R-\delta) e^{(R-\delta)(T^*-1)} - W_0 \overline{L} \cdot R \cdot e^{R(T^*-1)}]}$$

A fifth case, "depreciation by obsolescence" with variable coefficients, would take into account the reduction in labor because of rising own-product wage rates associated with this ith vintage capital good as it aged and the consequent diminution in the gross marginal physical product associated with any ith vintage capital good as it aged. In the fourth case, it is clear that the gross gross rental on the capital good, as it ages, remains unchanged, its gross rental declines as the associated wages bill rises, and its net rental declines more rapidly because a diminishing stream of gross rentals is being discounted. In the fifth case even the gross gross rental is declining as the ith vintage ages. Cases 4 and 5, then, are seen as similar to cases 1 and 2.

Return to case 1. If one had steadily growing gross capital formation in such capital goods, then, at any moment of time t_0, the value of the gross stock of capital at t_0 in t_0 dollars would be

$$K_G = \frac{\overline{P}}{R}\frac{\partial\overline{Q}}{\partial K}\overline{K}\left(1-\frac{1}{e^{RT}}\right)\frac{1}{g}\left(1-\frac{1}{e^{gT}}\right),$$

where K is the number of new capital goods installed at t_0 and g is the rate of growth of gross capital formation. The total gross rentals accruing to such a stock would be $\overline{P}\dfrac{\partial\overline{Q}}{\partial K}\dfrac{\overline{K}}{g}\left[1-\dfrac{1}{e^{gt}}\right]$, so that the ratio of the total gross rentals to the total gross stock would be

$$\frac{R}{\left(1-\frac{1}{e^{RT}}\right)}.$$

The value of the net stock of capital would be

$$K_N = \frac{\overline{P}}{R}\frac{\partial\overline{Q}}{\partial K}\overline{K}\left\{\frac{1}{g}\left[1-\frac{1}{e^{gT}}\right]\right.$$
$$\left.+\frac{1}{e^{RT}(R-g)}\left[1-\frac{1}{e^{-(R-g)T}}\right]\right\}.$$

The total value of capital consumption allowances, or depreciation, would be

$$-\overline{P}\frac{\partial\overline{Q}}{\partial K}\overline{K}\frac{1}{e^{RT}(R-g)}\left[1-\frac{1}{e^{-(R-g)T}}\right].$$

The total net returns to the net capital stock would then be

$$\overline{P}\frac{\partial\overline{Q}}{\partial K}\overline{K}\left\{\frac{1}{g}\left[1-\frac{1}{e^{gT}}\right]\right.$$
$$\left.+\frac{1}{e^{RT}(R-g)}\left[1-\frac{1}{e^{-(R-g)T}}\right]\right\},$$

and the ratio of the net returns to the net capital stock would then be R as desired. In the first case, only if capital consumption allowances or depreciation were calculated on the economic or discounted value definition would the ratio of capital consumption allowances to the net value of the stock of capital reflect the unchanging net rate of return to capital and would the weights attached to the steadily growing net stock of capital and capital consumption allowances in constant prices in total factor productivity measurement be correct. Similarly, if a current-dollar flow of gross rentals were deflated by a gross rental price index, then only if the gross rental price index were calculated on the basis outlined in this appendix would the constant-dollar gross service flows be obtained correctly. For the gross rental price relative for the ith vintage would be

$$GV_{\underset{01}{i}} = \frac{R_1 - \left(\frac{1}{P_{K_{i1}}} \frac{\partial P_{K_{i1}}}{\partial i}\right) P_{K_{i1}}}{R_0 - \left(\frac{1}{P_{K_{i0}}} \frac{\partial P_{K_{i0}}}{\partial i}\right) P_{K_{i0}}},$$

which, when summed over all vintages with correct vintage weights derived from the foregoing analysis, yields a price index of gross rentals. Such an index, when divided into an index of the value of gross rentals, would show constant-dollar gross services flows growing at the rate g.

Furthermore, if current-dollar net rentals and capital consumption allowances were deflated by price indexes to obtain constant-dollar net service flows and capital consumption allowances, then the price indexes would have to be derived from the price relatives based on the formulas outlined here to get the correct results. The price relative for the net rentals on the ith vintage would be

$$\frac{R_1 P_{K_{i1}}}{R_0 P_{K_{i0}}},$$

and for capital consumption on the ith vintage would be

$$\frac{\frac{1}{P_{K_{i1}}} \frac{\partial P_{K_{i1}}}{\partial i} \cdot P_{K_{i1}}}{\frac{1}{P_{K_{i0}}} \frac{\partial P_{K_{i0}}}{\partial i} \cdot P_{K_{i0}}},$$

which would be combined with the appropriate vintage weights and based on the economic or discounted value definition of depreciation.

Thus, in case one, concepts such as the constant-dollar gross and net stocks of capital and capital consumption allowance, constant-dollar gross and net service flows, and their various current-dollar counterparts and weights in the national accounts and total factor productivity measurement are seen to be cogently related only when the economic or discounted value definition of depreciation is employed.

Since the same arguments can be made with respect to the other cases covered in this appendix, it can be seen that, if economic lives and depreciation functions of capital goods are known, such arbitrary variants of depreciation measures as straight-line or double-declining balance methods are at least conceptually seen to be unsatisfactory as compared with the economic or discounted value definitions. Again, it is always recognized that such arbitrary measures are merely least-cost approximations to what is desired in the real world of non–steady-state accumulation; but, as this appendix shows, there is no a priori reason to expect such arbitrary variants to be satisfactory from a conceptual point of view. How close such variants come to what would be conceptually desired in a world where precision of measurement is not possible is a moot question. Only much additional empirical research can shed light on it.

Notes

1. See Statistics Canada, *Fixed Capital Flows and Stocks, Manufacturing, Canada, 1926–1960: Methodology*. My early estimates are, of course, now replaced by Statistics Canada, *Fixed Capital Flows and Stocks 1926–1973* and *1970–1974*, and experimental work is being carried on with alternate survival and depreciation functions and regional estimates. (cf. P. Koumanakos, Statistics Canada, "Alternative Estimates of Nonresidential Capital in Canada, 1926–1975" and "Provincial Capital Stocks in Manufacturing [1947–1971] and Non-Manufacturing sectors [1959–1971]").

2. The formulas underlying these cases are well known. See, for example, Robinson (1960*a*, *b*) and Rymes (1971), especially chapter 4.

3. The gross service price of the asset would be $(R - \Delta P_k/P_k)P_k$ (where R is the prevailing rate of profit, $\Delta P_k/P_k$ is the decline of the value of the asset owing to "depreciation by sudden death," and P_k is the market or discounted value measure of its remaining stream of services) and though (ignoring general inflation), older assets would have a lowerP_k, the higher rates of depreciation on the economic criterion would result in offsettingly larger negative values of $\Delta P_k/P_k$ so that gross rental prices would be unchanged over the life of any asset. These gross service prices would exactly measure the unchanging gross marginal product of the asset in question. The *net* service price of the asset would be RP_k, and older assets would have, of course, a lower service price, reflecting the fact that older assets, though yielding the same *gross* marginal product, would not be yielding the same *net* marginal product. On all this, see the Appendix to these comments.

4. The same arguments apply, mutatis matandis, to the author's second case.

5. H. Barger, in his comments from the floor, made the same points, and my Appendix covers much the same ground as an unpublished note he has written—

a copy of which Barger was kind enough to give me. As his oral and written comments, and mine as well, indicate, it seems that the arguments are common and well known. Thus it is difficult to understand the opposition to the discounted value or economic definition of depreciation.

6. In my *On Concepts of Capital and Technical Change* (Rymes 1971), I pointed out that aggregation problems, reswitching debates, and so forth, were not central to criticisms I advanced against standard measures of total factor productivity. Cambridge criticisms of traditional theory run deeper than aggregation difficulties.

7. More substantive issues *may* be involved. See Denison (1972).

8. This is the "depreciation by sudden death" case.

9. The case mentioned under "depreciation by obsolescence" in the comments.

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Comment Jack G. Faucett

We are indebted to Allan Young and John Musgrave for giving us a good description of the procedures employed in constructing the BEA capital stock series and for pointing out the weaknesses and limitations of the data. The procedures used are probably the best available in view of the data limitations. I wish, however, to discuss some of the issues involved in capital stocks measurement and particularly the problems with measures for more disaggregated sectors. In addition, I agree with those who contend that a discount factor should be applied in the calculation of economic depreciation.

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I wish to discuss the four following issues and problems in current measures of capital stocks:

(1) perpetual inventory method versus deflation of book value measures; (2) accounting for assets furnished to private business by the government; (3) owned versus rented assets; and (4) economic depreciation.

Perpetual Inventory Method versus Deflation of Book Value Measures

The perpetual inventory method involves the accumulation of measures of prior investment by year (adjusted to prices of a common year). Each yearly investment stream is depreciated over time and is finally reduced to zero at the estimated end of the useful life of the asset. The measures of stocks for each year are obtained by summing the remaining values of past investment streams—either the gross as undepreciated values to derive gross stock measures or the depreciated values to derive net stock measures.

There are several major problems with this procedure:

1. There are no good estimates of lives of plant and equipment.
2. There is shifting over time of the industrial classification of establishments holding the stocks.
3. The investment data are weak before 1947 and are woefully lacking in the early years needed to establish stock measures beginning with 1925.
4. Transfers of assets between industries, between industry and government, and exports of used equipment are extremely difficult to identify and properly value.

Estimates of lives are generally based on lives used by companies for tax depreciation, adjusted by estimate to reflect best guesses on actual lives. The adjustments are based on fragmentary evidence and observation of actual lives. No comprehensive measures of actual lives exist. This lack of data on actual lives can introduce substantial error in the stock estimates.

The industrial classification of establishments changes when the major production of a establishment shifts to products classified in other industries. This is a major problem at the three- and four-digit SIC classification levels for manufacturing industries, and, to some extent, at the two-digit level. It is a much small problem at the three-sector economy levels at which the BEA stock measures are tabulated.

The shifting of assets between industries owing to the reclassification of establishments cannot be accommodated in the perpetual inventory method. As a result, the time series of stock measures are not consistent with output measures, which are tabulated on the current classification of establishments. This is a serious problem in most applications of stocks data for disaggregated sector detail.

In view of these problems, it appears that some way must be found to use book value measures to serve the need for stocks data at the detailed industry level, as well as to avoid measurement error resulting from poor data on asset lives. Book value is not subject to the limitations and problems discussed above. Unfortunately book values have not been available generally except at the company level and, further, unknown vintage distribution in these values has made accurate deflation impossible.

Book value data on stocks held by manufacturing establishments are now reported by the census, first in 1957 and annually beginning in 1962, with the exception of one or two years that were missed. However, separate data on plant and equipment were collected starting only in 1967. Within a few years these series should provide enough observations for use in econometric analysis.

For nonmanufacturing industries, book value data are available generally only by company from the IRS *Statistics of Income* and from regulatory agency reports for regulated industries. In nonmanufacturing, company data may be satisfactory since there is less diversity in the operations of companies than in manufacturing, except for financial conglomerates, which generally file separate IRS returns by type of business through their subsidiary companies. Also, the IRS data represent a principal source for sales or output measures for these industries in lieu of other census-type sources, and therefore consistency is maintained between the stock measures and associated output measures.

I propose that the two approaches—perpetual inventory and book value deflation—be combined to provide better measures than are now available. The perpetual inventory method would be used to develop reasonably good stock deflators, and these deflators would be applied to book values to derive stock measures in constant dollars. The deflators are subject to some error, of course, owing to the same problems inherent in the perpetual inventory method. However, the distortion effect is much less on a deflator series, since the error only affects the weights in the development of the deflators.

Accounting for Assets Furnished to Private Business by the Government

These assets account for 6 to 8% of stocks used by the private business sector but are concentrated in a relatively few industries, mainly in defense production. They contribute to the output of these sectors, but the value of this contribution is not reflected in sales measures, since the equipment is furnished without charge by the government and contract prices for the output, sold to the government, are negotiated to reflect this.

This situation creates a problem in use of the stock measures, since the output measures are not consistent with stock input measures when these stocks are added to contractor-owned stocks; on the other hand, if these stocks are not included, the production function relationship (e.g., the capital/labor ratio) is distorted for the industries that use these government-furnished stocks.

One way to resolve the problem would be to adjust the output measures to reflect the contribution of this capital. This of course would be difficult to do, and the adjustment would necessarily be made on the basis of the value of the capital input, rather than on any direct measure of its contribution to output, and therefore would in fact specify productivity change. This specification of productivity change would considerably reduce the value of the data for productivity measurement.

There appears to be no satisfactory solution to this problem. However, its importance is small when one considers the general problem of assets used but not owned by the industry—that is, the large amounts of rented and leased equipment and structures.

Owned versus Rented Assets

Young and Musgrave contend that there is a need to develop capital stocks data by using industry rather than by owning industries. The ultimate in this procedure would lead to trying to impute the value of a vast amount of rented and leased equipment and buildings to the using industries, probably an impossible and frustrating task. Extending this concept could conceivably imply the imputation of capital owned by industries supplying services to each industry; the differing degrees of vertical integration among plants in each industry would require this to make the stocks/output ratios comparable.

Rather than adjusting the stocks data, perhaps an easier way is to make the adjustment in the cost of capital services, the proper measure for the capital input in production function analyses. If the capital input is measured by the cost of its services (explicit or implicit), then the measurement problem is reduced. The values of owned assets are converted to implicit rental costs, and the rental costs for rented or leased assets are added to derive the total capital costs, after subtracting the value of rental receipts.

For this procedure, data are needed on rental payments and receipts. Some data are now collected by the Bureau of the Census and the Internal Revenue Service. I suggest that efforts to collect better and more complete data on rental payments and receipts are of high priority in improving the measurement of real capital input by detailed sectors of the economy.

Economic Depreciation

I agree with those who contend that economic depreciation should be calculated with a discount factor; that is, it should involve a calculation of the present value of the future stream of services from the capital assets. The discussion on economic depreciation below is taken from some work I did a few years ago, and I believe it sheds some further light on the proper method for calculating economic depreciation and its use in capital analysis.

Differences between accounting and economic depreciation cause a divergence between book values of stocks (after adjustment for price change) and market values. Market values reflect economic depreciation, whereas book values reflect accounting depreciation methods that are often arbitrary and are not good approximations to economic depreciation. Economic depreciation reflects the loss in the current and future service value of the stock, which, by definition, affects the price a purchaser is willing to pay for the stock—the market value. As a stock increases in age, its current service value may decrease because of physical deterioration, which renders it less efficient in production. Its future service value also declines with age because its remaining life or stored-up value is reduced. There is no reason the sum of these two effects should be linear (straight-line depreciation) or exponential (declining-balance depreciation). Under the assumption of no less in efficiency over the life of the stock, the shape is quite different from either of these methods as shown in figure C1.1.

Economic depreciation is calculated as the loss in the value of the stock during a specified period of time, usually calculated annually. The value of the stock by definition is the sum of the time-discounted values of its future flow of services. Thus, each year it loses one year of remaining life; that is, the final year, which is distant and therefore worth less than the current year's service because of the discount factor. (Economic depreciation increases steadily over the life of the stock under the assumption of no decline in productive services over its life.) The calculation for depreciation in time period, a to $a + 1$, is:

$$a^d a + 1 = \sum_{t=1}^{n-a} [1 + r]^{-t}\, CS_t - \sum_{t=1}^{n-(a+1)} [1 + r]^{-t}\, CS_t,$$

where $a =$ age of stock
$n =$ expected economic life of stock
$r =$ discount factor
$CS_t =$ index of capital services at time t normalized so that $\sum_{t=1}^{n} [1 + r]^{-t}\, CS_t =$ original cost of the stock.

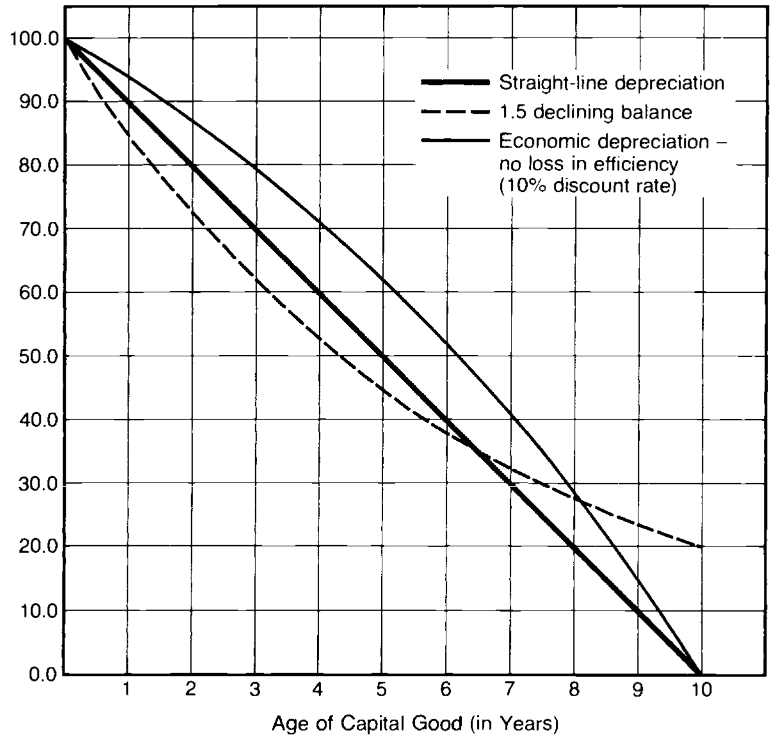

Fig. C1.1 Asset value under different depreciation methods, ten-year life, in percentage of original cost.

To explain further, depreciation in any period is equal to the change during that period in the value of discounted future services of the stock over its remaining life. *CS* is an abstract measure of the flow of those services, the discounted sum of which is equal to the original cost of the stock.

Straight-line and declining-balance depreciation are contrasted with economic depreciation in table C1.1. Economic depreciation is calculated under two different assumptions: no loss in productivity (efficiency) over the life of the asset; and productivity decline according to the formula

Table C1.1 **Depreciation, Depreciated Value, and Cost of Capital Services**

$10,000 Original Cost
Ten-year Life
10% Discount Factor

	Straight-line Depreciation		1.5 Declining Balance Depreciation		Economic Depreciation				Cost of Capital Services					
					No Decline in Productivity		Decline in Productivity		No Decline in Productivity			Decline in Productivity		
Year[a]	Depr.	Value	Depr.	Value	Depr.	Value	Depr.	Value	Depr.	Int.	Total	Depr.	Int.	Total
1	1,000	9,000	1,500	8,500	627	9,373	804	9,196	627	1,000	1,627	804	1,000	1,804
2	1,000	8,000	1,275	7,225	691	8,682	867	8,329	691	937	1,628	867	920	1,787
3	1,000	7,000	1,084	6,141	759	7,923	929	7,400	759	868	1,627	929	833	1,762
4	1,000	6,000	921	5,220	835	7,088	992	6,408	835	792	1,627	992	740	1,732
5	1,000	5,000	783	4,437	919	6,169	1,051	5,357	919	709	1,628	1,051	641	1,692
6	1,000	4,000	666	3,771	1,011	5,158	1,104	4,253	1,011	617	1,628	1,104	536	1,640
7	1,000	3,000	565	3,206	1,111	4,047	1,147	3,106	1,111	516	1,627	1,147	425	1,572
8	1,000	2,000	481	2,725	1,222	2,825	1,153	1,953	1,222	405	1,627	1,153	311	1,464
9	1,000	1,000	409	2,316	1,345	1,480	1,091	862	1,345	283	1,628	1,091	195	1,286
10	1,000	0	347	1,969	1,480	0	862	0	1,480	148	1,628	862	86	948

[a]Stock values are end-of-year values.

$$D(a) = \frac{A - a}{A - .9a} \qquad 0 \leq a \leq A,$$
$$= 0 \qquad a \geq A$$

where $D(a)$ = index of service units of asset (efficiency index) at age (a)
A = economic life of asset in years
a = age of asset in years.

Economic depreciation increases steadily over the life of the asset under the assumption that there is no decline in efficiency over the life of the asset (this assumption implies uniform maintenance costs over the life of the asset—see later section). This is directly opposite to declining-balance depreciation, which starts out much higher and declines steadily over the asset life. Under the assumption of no efficiency decline, economic depreciation is lower than straight-line depreciation initially and higher near the end of the life of the asset.

Under the assumption of a decline in productivity or efficiency over the life of the asset, economic depreciation is higher in the beginning and lower near the end (relative to the assumption of no decline in efficiency). The steeper the decline in efficiency, the more the depreciation schedule is tilted toward high initial values (in the extreme case, where efficiency declines linearly with age, it starts out nearly equal to double declining-balance depreciation but decreases more slowly with age). Within the range of realistic assumptions on the rate of efficiency decline and discount rate, surprisingly, straight-line depreciation is a fair approximation of economic depreciation over most of the life of the asset.

Cost of Capital Services

The cost of capital services is the sum of economic depreciation and the interest cost of capital (ignoring gains or losses from revaluation of assets for the time being). This cost should be proportional to the units of capital services at any point in time—the marketplace will adjust the prices of used assets so that units of capital services from used assets will cost the same as from new assets. Economic depreciation reflects this adjustment in market prices.

The costs of capital services are calculated in the last section of table C1.1. Note that under the assumption of no decline in productivity or efficiency, the cost of capital services remains constant over the life of the asset. This is true only under economic depreciation; under arbitrary accounting methods of depreciation this is not true. Under both straight-line and declining-balance depreciation, the sum of depreciation and interest cost declines steadily over the life of the asset.

Under the assumption of a decline in productivity, the cost of capital services decreases in proportion to the loss in capital service units. This may be seen by comparing the annual costs (table C1.1) with the annual service units inherent in the efficiency decline function (fig. C1.2). The cost per service unit remains constant at approximately 0.1805 per unit over the life of the asset.

Revaluation owing to price changes also affects changes in the market prices of capital goods and the implicit costs of capital services. Changes owing to revaluation are not predictable and therefore cannot be built into the depreciation schedule. Revaluations can be handled separately and need not lead to revisions in the depreciation base unless the asset is sold. This is so whether or not the investment base is revaluated for rate-of-return calculations.

Relationship of Efficiency Decline to Maintenance and Repair Costs

Efficiency decline as reflected in economic depreciation is essentially the complement of *rising* maintenance and repair costs (M&R costs) needed to keep the asset at 100% efficiency (if it is cost-effective to do so). (A uniform level of maintenance and repair costs over the life of the asset is consistent with the assumption of no efficiency decline in the calculation of economic depreciation—economic depreciation is not affected by the level but only the distribution of maintenance and repair costs over the life of the asset.) There are very few data on the distribution of M&R costs over the life of assets. It is certain that these costs generally increase with the age of the asset, if the productive efficiency of the asset is maintained at 100%. We have assumed a decline in efficiency (i.e., increasing M&R costs required for 100% efficiency over the life) at an increasing rate over the life of the asset by the following equation:

$$\begin{aligned} D(a) &= \frac{A-a}{A-Ba} \qquad & 0 \le a \le A. \\ &= 0 & a \ge A \end{aligned}$$

$D(a)$, A, and a have been defined earlier. B is a parameter to be estimated; I have assumed a value of 0.9 in the calculations in this report. The lower the value of B, the more rapid the decline in efficiency.

As indicated above, the equation specifying decline in efficiency has a dual interpretation: it represents either: the decline in efficiency (in terms of productive service units of the capital) with any uniform level of maintenance over the life of the capital; or the increasing costs of M&R required to maintain 100% efficiency measured at age a as follows:

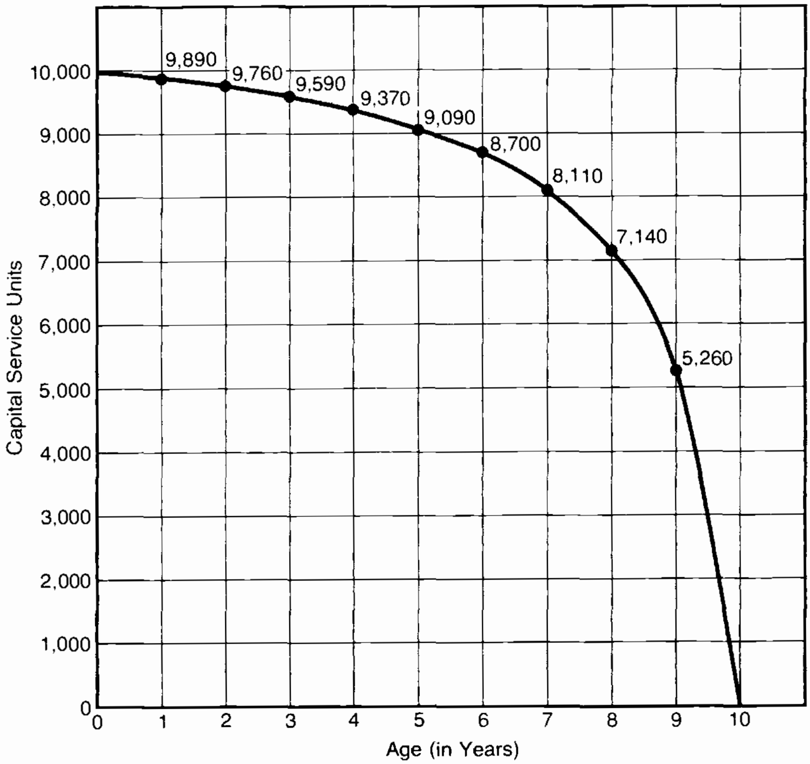

Fig. C1.2 Efficiency decline function (B = 0.9).

$$\left[1 - \frac{A - a}{A - Ba}\right] \cdot \frac{\textit{Original Cost}}{A}.$$

This formula simply states M&R cost or efficiency loss as a fraction of amortized original cost. A loss in productive service (expressed as a fraction of service units) or a maintenance cost equal to the same fraction of amortized original cost (assuming constant prices) has exactly the same effect on the market value of the asset (and therefore on economic depreciation). It does not matter to the market value whether future maintenance is actually performed; it is assumed that it will be performed if it is cost-effective and is not performed otherwise.

The distribution of maintenance and repair costs over the life of the assets can affect market value and depreciation very significantly. To illustrate the range of this effect I have calculated market values and depreciation for a $10,000 asset (original cost) under three different assumptions with respect to the distribution of maintenance and repair costs: (1) increases annually by a constant amount; (2) constant amount annually; and (3) decreases annually by a constant amount. In each case, the sum of maintenance and repair costs over the life of the asset equals 55% of original cost, or $5,500. Present values (market value) are calculated by discounting future capital services (and maintenance and repair cost) by 10%. The results are shown in table C1.2.

Table C1.2 **Present Value of Assets and Depreciation under Alternative Distributions of Maintenance and Repair**
$10,000 Original Cost
Ten-Year Life
10% Discount Factor

	Present (Market) Value (End of Year)			Depreciation (During Year)		
Year	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
1	8,223	9,372	11,000	1,777	628	−1,000
2	6,578	8,682	11,633	1,645	690	− 663
3	5,078	7,923	11,957	1,500	759	− 294
4	3,733	7,088	11,884	1,345	835	113
5	2,562	6,170	11,283	1,171	918	561
6	1,585	5,160	10,223	977	1,010	1,060
7	820	4,049	8,628	765	1,111	1,595
8	283	2,826	6,434	537	1,223	2,194
9	0	1,480	3,580	283	1,346	2,854
10	0	0	0	0	1,480	3,580

Note:
Case 1: Maintenance and repair costs are $100 in first year and increase by $100 each year.
Case 2. M&R costs are $550 each year.
Case 3. M&R costs are $1,000 in first year and decrease by $100 each year.

These extreme cases dramatize the effect of the distribution of maintenance costs over the life of the asset. Note that in the first case the market value declines not unlike double declining-balance depreciation initially, and less rapidly after the midpoint of its life. Note further that the market value has declined to zero after nine years, since in the last year the M&R costs are equal to the value of the capital services (based on amortized original cost). In this case the assumed rate of increase in M&R is unrealistically high (M&R increases by tenfold over the life of the equipment).

The second case illustrates the effect of constant M&R costs over the life of the asset. Note that the market values and depreciation are identical with those in table C1.1 for the assumption of no decline in productivity (economic depreciation is affected only by the time distribution and not by the *level* of M&R).

The third case requires some interpretation. In this case M&R costs are heavy initially and decline to one-tenth of the first-year amount by the tenth year—admittedly, not a very likely case. (As a possible example, some machinery requires an extensive breaking-in period as well as initial adjustments and does not reach full productivity until after a few years). The heavy initial costs (either for costs of adjustments or for loss in output) result in increases in the value of the machine (negative depreciation) over the first few years.

The assumption we have made with respect to the distribution of M&R over the life of the asset is embodied in our efficiency decline function, previously described. It is plotted to scale in figure C1.2. The units represent capital service units, arbitrarily normalized to the initial purchase price for convenience in exposition. M&R in a given year necessary to maintain 100% efficiency is, then, the area between the 100% efficiency line and the efficiency curve for that year expressed as a fraction of the total area over all years, times the original purchase price ($10,000). However, this M&R may be increased by a constant amount each year and still be consistent with the annual market values and depreciation derived by applying this function. Hence, our function establishes only the distribution and not the level of M&R.

The annual market values and depreciation consistent with this efficiency decline/M&R assumption are plotted in figure C1.3 from data in table C1.1. The approximation to straight-line depreciation is remarkable. It is somewhat ironic that simple straight-line depreciation is a fair approximation of economic depreciation. We must keep in mind that the assumptions made on M&R and the discount factor both influence the distribution of depreciation over the life of the asset. The effect of the M&R distribution has been discussed above. As for the effect of the discount factor, a higher discount factor results in a lowering of economic depreciation in the early years and an increase in later years. Consequently, market values tend to be higher, the higher the discount factor. The effect of the discount factor is illustrated in table C1.3 for three rates; 6%, 10%, and 14%. It can be seen that these differences in rates yield significant differences in market values (and the distribution of depreciation over the life of the assets).

Caution on Market Value

"Market value" as used in this paper refers to the depreciated original cost of the asset with a proportionate adjustment—that is, revaluation—for price change in equivalent new assets. Thus it is an estimate of reproduction cost adjusted for depreciation. This measure will differ from observed market values if the asset is obsolete and no longer being

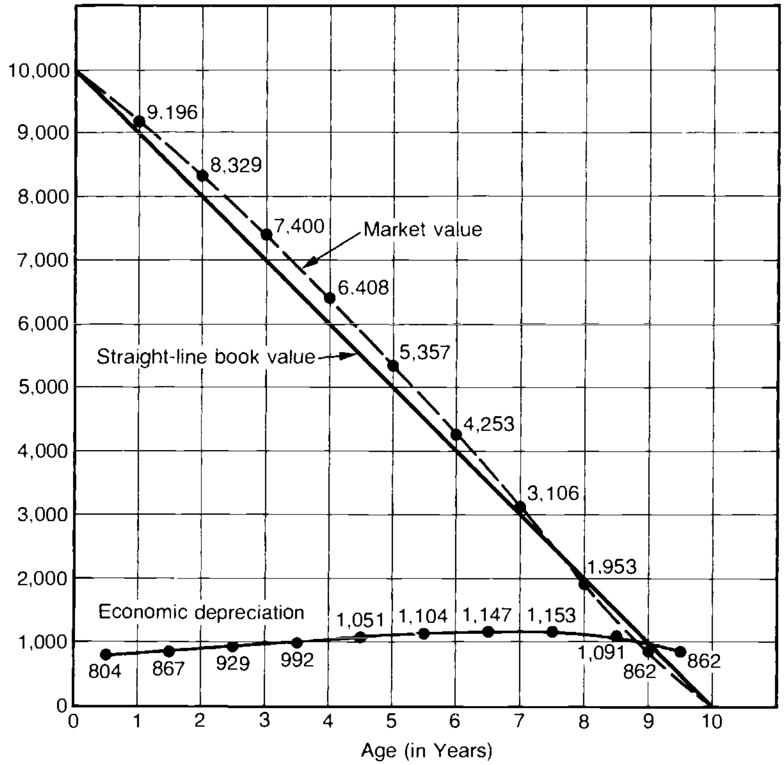

Fig. C1.3 Market value and economic depreciation, in constant dollars. From table C1.1 (efficiency decline, B = 0.9; discount factor, 10%).

produced. It also will differ from net sales value due to transfer costs—that is, sales commissions, moving costs, and so forth. It may also differ from market value owing to imperfections and uncertainties in the marketplace; for example, a new car drops significantly in value with the first few miles because of the potential buyer's uncertainty and suspicion about its condition.

For all these reasons—apart from any errors owing to the assumptions with respect to average life, M&R costs, or the discount factor—the market values discussed in this paper must be interpreted with caution.

Table C1.3 **Market Value and Depreciation for Selected Discount Assumptions**
$10,000 Original Cost
Ten-year Life

	Market Value (End of Year)			Depreciation (During Year)		
Year	6%	10%	14%	6%	10%	14%
1	9,073	9,196	9,299	927	804	701
2	8,107	8,329	8,524	966	867	775
3	7,102	7,400	7,665	1,005	929	859
4	6,063	6,408	6,725	1,039	992	940
5	4,996	5,357	5,697	1,067	1,051	1,028
6	3,908	4,253	4,584	1,088	1,104	1,113
7	2,815	3,106	3,396	1,093	1,147	1,188
8	1,746	1,953	2,169	1,069	1,153	1,227
9	758	862	968	988	1,091	1,201
10	0	0	0	758	862	968

Note: Efficiency decline as in table C1.1.

Reply by Young and Musgrave

We endorse the comments of both Faucett and Rymes on the need for more information, particularly better empirical evidence on service lives and depreciation. Perhaps we should have stressed our position on this point more strongly.

We agree with Rymes on his exposition of the time pattern of the value of the net stock of an asset using the discounted value definition of depreciation. However, our four examples were based on what we have considered to be the NIPA definition, not on the discounted value definition. In our paper, we attempted to contrast these two approaches to depreciation, both of which have received considerable attention in the past by this conference.

Two additional pieces of evidence seem to support the use of straight-line depreciation. First, Faucett's judgment approach yields a depreciation pattern that is close to straight-line. Second, BEA's stocks and depreciation estimates fall about halfway between those presented by Coen and those presented by Hulten and Wycoff in their chapters in this volume. While the empirical studies by Coen and by Hulten and Wycoff are based on limited data and may involve considerable statistical difficulties, it is interesting that these independently derived estimates bracket the BEA estimates. In this connection we note that the results in Coen's chapter in this volume imply a greater incidence of accelerated depreciation than the results in his 1975 article that we cited.

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