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2 Economic Depreciation and the Taxation of Structures in United States Manufacturing Industries: An Empirical Analysis

Charles R. Hulten and Frank C. Wykoff

A vigorous controversy has been taking place in recent years over the appropriate specification of the neoclassical investment function. One of the central disputes concerns the extensive use of geometric depreciation, which produces a relatively straightforward, consistent model of replacement demand.[1] The conflict has generated considerable interest among econometricians in the rate and pattern of economic depreciation.[2] Recently, the United States Bureau of Economic Analysis (BEA) introduced imputed economic depreciation, based upon specific a priori rates and patterns, into the national income and product accounts.[3] Meanwhile, repeated attempts at tax reform have been focusing much attention upon the depreciation allowances permitted taxpayers. Samuelson (1964), Eisner (1973), and Coen (1975) all suggest that the tax allowances should conform to actual economic depreciation.

Of course economic depreciation, unlike an engineering production function, is not a technological datum: economic depreciation, the loss in its value as an asset ages, is a price concept. Feldstein and Rothschild (1974) point out that economic depreciation will depend upon, among other things, the tax treatment of assets. The Feldstein-Rothschild results, based upon theoretical argument and hypothetical illustration, suggest that the relation between tax and economic depreciation is very complex.[4]

In this paper we have four objectives: (1) to compare tax depreciation deductions with economic depreciation estimates, produced by

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Hulten and Wykoff (1976), for sixteen classes of commercial and industrial structures, including apartments, factories, office buildings, retail stores, and warehouses; (2) to estimate the instantaneous effect upon asset values and tax liabilities, for each asset class, of possible changes in the tax code; (3) to construct capital stock estimates of structures, employing the mortality function derived from the dual to economic depreciation, for the twenty-one two-digit level Standard Industrial Classification (SIC) manufacturing industries; and (4) to determine the rate of tax subsidy per capital dollar by industry grouping.

The economic depreciation estimates of Hulten and Wykoff (1976) are based upon observed market acquisition prices of new and used structures. These prices are reported in a 1972 United States Treasury sample survey of more than seven thousand owners of structures.[5] Tax regulations pertaining to the depreciation of structures are in section 1250 of the Federal Tax Code. Briefly, taxpayers may deduct a "reasonable allowance" for the wear, tear, and obsolescence on capital assets used to generate income. The Internal Revenue Service publishes acceptable accounting methods for calculating depreciation on each asset class. The tax life of an asset, the parameter that, combined with the accounting method, determines the stream of tax deductions, may be selected in one of two ways. The taxpayer may either use the life for his asset's class published in Revenue Procedure 62-21, Internal Revenue Service or, if warranted by his own "facts and circumstances," he may use a shorter life. A shorter tax life will usually result in lower tax liability. The 1972 Treasury survey indicated that considerable use must have been made of the "facts and circumstances" clause, because actual tax lives were far shorter than those published in Revenue Procedure 62-21. The United States Treasury announced in 1976 that only lives published in Revenue Procedure 62-21 would be allowed on structures.

Because we employ several different economic depreciation estimates and because two sets of tax depreciation practices are in use, summary information about differences between tax and economic depreciation is difficult to provide. Nonetheless, the following observations provide a general overview of our results: (1) The present value at asset acquisition of tax depreciation exceeds that of economic depreciation, for all large asset classes, apartments, factories, offices, retail stores, and warehouses, regardless of the economic depreciation estimation method employed. (2) For all asset classes, except one, actual tax depreciation deductions reported by taxpayers in the 1972 survey exceed "guideline" tax depreciation deductions.[6] However, the difference between actual tax and guideline deductions is relatively small in comparison with the difference between tax and economic depreciation. (3) The magnitude of the subsidy, assuming a corporate tax rate of 48%, varies considerably across asset classes. Unfortunately, the rank ordering of assets by class is not stationary across depreciation estimation methods. Larger subsidies do appear to be received by owners of apartments, offices, and retail trade buildings, and smaller subsidies, perhaps even surcharges, are incurred by owners of banks, recreational facilities, and medical buildings. (4) Changes in tax regulations to require that deductions be based upon guideline lives, rather than shorter lives actually used, would have only modest effect upon removing tax subsidies. Return to Bulletin F lives and to straight-line depreciation (see below for details) would remove most of the tax subsidies. (5) The magnitude of the annual subsidies per dollar of capital stock (of industrial and commercial buildings) are different for different industries in manufacturing, ranging from —2¢ on the dollar for SIC group 19 to 1.1¢ for SIC group 27.

In section 2.1, we present the theory of tax and economic depreciation to be used in this paper. In the second and third sections, we summarize the measurement of depreciation from Hulten and Wykoff (1976) and the tax regulations that pertain to industrial and commercial structures. Section 2.4 contains a comparison of tax and economic depreciation estimates and an examination of several possible changes in the tax laws. In section 2.5 the stocks of industrial and commercial structures in United States manufacturing are calculated, and in the final section we give estimates of the depreciation subsidy per dollar by two-digit manufacturing industry.

2.1 The Theory of Economic and Tax Depreciation

In efficient, competitive capital markets, the acquisition price of an asset equals the present value of the future flow of user costs on the asset throughout its economic life.[7] If $q(s,t)$ is the acquisition price of an age-s asset in time t, $c(s,t)$ is the user cost of an age-s asset at time t, r is the rate of interest, and L is the asset's life, then

$$q(s,t) = \sum_{x=0}^{L} \frac{c(s+x, t+x)}{(1+r)^{x+1}}. \tag{1}$$

Equation (1) can be modified to allow for capital taxation:[8] let u be the marginal effective tax rate, and let $d_T(s)$ be the deduction for depreciation allowed on an asset at age s, whose original acquisition price was \$1. At age s the present value of the future tax depreciation deductions can be written as $z(s)$ where:

$$z(s) = \sum_{x=s}^{T} \frac{d_T(x)}{(1+r)^{x-s+1}}, \tag{2}$$

where T is the tax life over which the deductions are allowed. The competitive asset price is the present value of the after-tax flow of income from the asset plus the tax not paid owing to the depreciation deduction allowed on the original price of the asset. Equation (1) thus modified to allow for a constant tax rate, u, becomes:

$$q(s,t) = (1-u) \sum_{x=0}^{L} \frac{c(s+x, t+x)}{(1+r)^{x+1}} + uz(s)q(0, t-s). \tag{3}$$

One may take first differences of (3) and simplify to derive:

$$(1-u)c(s,t) = rq(s,t) + [q(s,t) - q(s+1,t+1)] - ud_T(s)q(0, t-s). \tag{4}$$

From equation (4) one may compute $c(s,t)$, the before-tax service flow, and $(1-u)c(s,t)$, the after-tax service flow, from $q(s,t)$, observed acquisition prices, r, the rate of return, u the marginal tax rate, and $d_T(s)$ the tax depreciation deduction.

Economic depreciation is defined as the change in the price of the asset from aging:[9]

$$D(s,t) = q(s,t) - q(s+1,t). \tag{5}$$

If in equation (4) we add and subtract $q(s+1,t)$ to the term in square brackets, we have:

$$(1-u)c(s,t) = rq(s,t) + D(s,t) - [q(s+1,t+1) - q(s+1,t)] - ud_T(s)q(0,t-s). \tag{6}$$

Let $[q(s+1,t+1) - q(s+1,t)] = \rho(s,t)$; ρ measures the change over time in a fixed-age asset and is therefore the degree of asset inflation. Equation (6) becomes:

$$(1-u)c(s,t) = rq(s,t) + D(s,t) - \rho(s,t) - ud_T(s)q(0,t-s). \tag{7}$$

The after-tax user cost of a unit of age-s capital over time t is thus seen to consist of four terms: (1) $rq(s,t)$, the opportunity cost of holding resources in the asset over period t; (2) $D(s,t)$, economic depreciation on the asset; (3) $\rho(s,t)$; capital gains on the asset; and (4) $ud_T(s)q(0, t-s)$, the tax saving from taking depreciation deductions on the asset. The last two terms are subtracted from the after-tax user cost. The greater are capital gains, the lower is the cost of capital, and, similarly, the larger are tax depreciation deductions, the smaller will be the cost of capital.[10]

The second and fourth terms on the right side of equation (7) indicate that the after-tax cost of capital depends upon both economic depreciation and the tax deduction for depreciation. The difference between economic and tax depreciation is

$$(8) \qquad \Delta(s,t) = D(s,t) - d_T(s)q(0, t - s).$$

In the absence of inflation, the sum over the life of the asset of the difference between economic and tax depreciation, $\sum_{s=0}^{L} \Delta(s,t+s)$, equals zero; when economic and tax depreciation are congruent, $\Delta(s,t+s) = 0$, for all s. If, however, taxpayers are allowed to accelerate tax deductions relative to actual depreciation, the present value of the stream $\Delta(s,t+s)$ is, given a positive discount rate, negative. Therefore, given sufficient income to absorb the deduction, the taxpayer receives a subsidy that conceptually is equivalent to an interest-free loan from the Treasury.[11]

Equation (5) can be used to estimate economic depreciation from market prices. Since the observed prices reflect actual market conditions, depreciation estimates will reflect prevailing rates of return and prevailing tax laws. Consequently, one may directly compare existing tax depreciation with economic depreciation estimates based upon these prices. However, the problem of assessing the effect of hypothetical alternative tax regimes is more complicated, because, as equations (3) and (7) indicate, asset prices depend upon the tax treatment of capital, and one cannot therefore assume that asset prices and economic depreciation are given. One must account for the effect upon economic depreciation of changes in tax depreciation.

We shall assume that the physical durability of capital is not altered by the tax laws, so that the relative productive efficiencies of new and used assets are stationary across tax regimes. We also assume that the ratio of the marginal product of an age-s asset to a new one is a function of age alone, $\phi(s)$: then, under competitive conditions:

$$(9) \qquad \phi(s) = c(s,t)/c(0,t).$$

$\phi(s)$, $s = 0,1,2, \ldots, L$ is the relative efficiency function of vintage capital. Of course, the owners of capital assets can in fact alter the durability of their assets in response to changes in tax treatment of capital by varying maintenance and repair, capacity utilization, and so on. However, these effects are extremely difficult to deal with empirically, and we are forced to treat the exogeneity of $\phi(s)$ as a maintained hypothesis. Using equation (9) we may write the acquisition price of an age-s asset, equation (3), as:

$$(10) \qquad q(s,t) = (1-u) \sum_{x=0}^{L} \frac{c(0,t+x)\phi(s+x)}{(1+r)^{x+1}} + uz(s)q(0, t - s).$$

If $c(0,t)$ is also stationary over time, we have:

$$(11) \qquad q(s,t) = (1-u)c(0) \sum_{x=0}^{L} \frac{\phi(s+x)}{(1+r)^{x+1}} + uz(s)q(0,t-s).$$

Equation (11) is useful for investigating the *short run* effect of alternative tax depreciation policies. Assuming that $c(0)$ and $\phi(s)$ are not affected in the short run by changes in tax policy, (11) can be used to generate a new sequence of acquisition prices that capture the effect of the policy change. In other words, the ceteris paribus assumption permits the calculation of the change in economic depreciation resulting from a change in tax depreciation.

2.2 Measurement of Economic Depreciation

In 1972 the United States Treasury's Office of Industrial Economics (OIE) undertook a survey of more than seven thousand taxpayers to determine the tax treatment of twenty-two classes of commercial and industrial structures. In addition to questions about their actual tax practices, respondents were asked the acquisition price of the building, the year the building was constructed, and the year they acquired it. From the responses, one can compile a cross section of acquisition prices on buildings by age and date. Distinguishing physical characteristics of buildings, square footage, construction quality, primary material, and location were also reported. Hulten and Wykoff (1976) employ this data to estimate economic depreciation and asset revaluation for sixteen classes of structures.[12] Sample size was rather large for major classes: apartments (203 usable observations), factories (526), offices (1,654), retail trade buildings (1,666) and warehouses (580). Other classes had fewer data: hotels (42), motels (65), and recreational buildings (58) were the smallest. Except for the service station and terminal building classes, considerable variations in price, age, and date were observed within each class.

To determine an asset's depreciation pattern, one must determine both the speed of depreciation and the path. Consequently, nonlinear, flexible estimation methods are needed. We used two basic approaches: a polynomial power series and a Box-Cox power transformation. Both approaches are flexible in that they admit a variety of shapes for the estimated path. The polynomial method is intrinsically linear, and additional variables could be easily introduced. The Box-Cox form includes both linear and geometric decay as special cases. In both approaches comparison was made between the best estimated form and geometric depreciation. The latter is easy to work with and, as noted above, has received considerable attention in the literature.

With the polynomial equations, comparisons to the geometric were undertaken with a modified statistic for sums of square residuals adjusted for degrees of freedom suggested by Theil (1971). Neither form consistently outperformed the other. Furthermore, the optimal polynomial forms tended to be nearly U-shaped and therefore to closely approximate the geometric form. Since the geometric is so convenient, much of the analysis in this chapter is based upon the geometric depreciation estimates.

The constant geometric depreciation form is a special case of the flexible Box-Cox depreciation estimation method. However, for most classes the depreciation rate was not constant. Nevertheless, the actual rates produced were approximately geometric. We estimated the closest geometric rate to the actual estimated Box-Cox rates and found that in most cases the constant geometric rate was very close to the actual Box-Cox rates in all but the earliest years of the assets' lives. Therefore, again, we adopt the geometric approximations here, because using actual Box-Cox estimates is more costly to their complexity, and because the Box-Cox estimates vary over both vintage and time, and a summary measure of the rate of depreciation is useful.

Because the data consist of a cross-sectional sample taken at a point in time, only assets that survived to the date of the survey were included in the study. If our depreciation estimates are to reflect the performance of typical assets of each vintage, then some allowance is needed for the nonsurvivors—assets that were scrapped or retired before the sample was collected. To compensate for the exclusion of nonsurvivors, we modified our data by reducing each observed vintage asset price by the probability that the old asset survived to the date of the cross-sectional study. This compensation amounts to adding back into the sample all assets that were retired and valuing them at zero. The retirement pattern is taken from the study by Winfrey (1935), and the resultant estimates are called Winfrey-transformed estimates.

The Winfrey retirement distribution is not based upon actual structure retirement. Rather, Winfrey studied an obscure set of assets, such as railroad ties and telephone poles. One cannot be sure, therefore, that the Winfrey distribution accurately reflects the true distribution of structures. However, the distribution is centered at the Bulletin F (1942) average lives of structures, so that only the shape of the distribution, not the location, is based upon Winfrey's study.

A case can be made that asset values are not actually zero at retirement but rather are valued the same as nonretired assets, and, because the Winfrey pattern may be unreliable in any case, we maintain depreciation estimates both for Winfrey-transformed price data and for untransformed prices. We do prefer the Winfrey transformed prices because, despite arguments to the contrary, we believe assets, when scrapped, are near zero in price. Thus we will present the Winfrey-transformed results in the text and only make general reference to other results.

Table 2.1 contains the geometric depreciation rates employed in this study. Four sets of rates are used: the geometric rates estimated directly on observed market prices, both transformed and untransformed for retirement; and the geometric approximations to the best Box-Cox patterns both transformed and untransformed. Only the details of the direct geometric on transformed prices are presented here.

Table 2.1 **Rates of Depreciation by Asset Class**

Class	Direct Geometric Estimates		Box-Cox Approximations	
	Transformed	Untransformed	Transformed	Untransformed
Apartment	3.90	1.46	3.36	2.22
Bank	3.48	2.15	5.07	1.12
Factory	4.09	1.45	3.61	1.28
Hotel	3.93	.26	—	.95
Machine shop	2.02	1.40	—	—
Medical building	3.65	1.55	8.48	7.05
Motel	4.44	1.39	4.92	.26
Office	2.97	1.26	2.47	1.05
Recreational	6.31	2.42	4.87	3.19
Repair garage	3.28	2.07	4.00	2.54
Restaurant/bar	3.36	1.32	4.34	.88
Retail trade	2.73	1.11	2.20	.82
Service station	4.01	2.67	10.80	9.55
Shopping center	2.14	.40	3.36	1.24
Terminal	2.43	1.31	5.63	1.70
Warehouse	2.95	1.76	2.73	1.22

2.3 Tax Depreciation Statutes and Practice

Taxpayers use accounting depreciation schemes allowed by the Internal Revenue Service and compute their actual tax deductions by applying a tax-life parameter to these formulas.[13] As of 1976, owners of new structures other than apartments are allowed to use the 1.5 declining-balance formula and may switch to the straight-line formula when they choose. Let $d_T(s)$ be the tax depreciation rate calculated at age s on the original acquisition price of the asset, then

$$(12) \qquad d_T(s) = \begin{cases} \dfrac{1.5}{T}\left(1 - \dfrac{1.5}{T}\right)^{s-1} & s = 1, \ldots, \tau \\ \dfrac{3}{T}\left(1 - \dfrac{1.5}{T}\right)^{\tau-1} & s = \tau, \ldots, T \end{cases},$$

where T is the tax life of the asset, and τ, the age for switching to straight-line depreciation is $2T/3$. The taxpayer is seen to use the 1.5 declining-balance formula through the first two-thirds of tax life. After $2T/3$ years, straight-line depreciation exceeds 1.5 declining-balance depreciation, and the rational owner would switch to the straight-line method.

Taxpayers have some discretion in choosing the tax life they are to apply to equation (12). They may use the lives published by the Treasury in Revenue Procedure 62-21, amended in 1971, or they may use shorter lives if the latter can be justified by the owner's "facts and circumstances." In the OIE sample, the taxpayers reported the actual tax lives they use on their assets, and the results were published by the Treasury in *Business Building Statistics*, August 1975. The actual tax lives reported were quite a bit lower than the guideline lives published in Revenue Procedure 62-21. In table 2.2, we report three sets of tax lives: Bulletin F lives, Revenue Procedure 62-21 lives, and the average tax lives reported by the taxpayer survey. Hereafter, for convenience, we refer to the Revenue Procedure 62-21 lives as "guidline" lives and the reported lives as "actual" tax lives.

Table 2.2 **Asset Lives Used for Tax Purposes**

Asset Class	Bulletin F	Revenue Procedure 16-21[a]	OIE Survey 1975
Apartment	50	40	32
Bank	67	50	43
Factory	50	45	36
Hotel	50	40	41
Machine shop	60	45	32
Medical building	67	—	34
Motel	40	40	31
Office	67	45	41
Recreational	40	—	30
Repair garage	60	45	29
Restaurant/bar	60	50	31
Retail trade	67	50	34
Service station	50	16	19
Shopping center	50	50	36
Terminal	75	—	27
Warehouse	75	60	37

[a]The 1975 OIE report indicates that these lives (updated in December 1971) are now used by taxpayers. No lives are reported for medical, recreational, and terminal buildings, so we have substituted Bulletin F lives in our analysis.

To illustrate the application of table 2.2 to formula (12), consider a factory, the original basis of which is \$1,000. The guideline tax life is forty-five years. Thus, the guideline deduction at age ten is

$$d_T(10) = \frac{1.5}{45}\left(1 - \frac{1.5}{45}\right)^9 = .02457. \tag{13}$$

In dollar terms the deduction is \$24.57.

The tax treatment of apartments is unique for Code 1250 property. Apartment owners may depreciate their property according to the double-declining balance formula and switch to straight-line when desired. For apartment owners, equation (12) is modified so that the depreciation rate is 2 over the tax life rather than $1.5/T$, so that τ is $T/2$, not $(2/3)T$. No allowance was made for the recapture provisions.

2.4 Tax versus Economic Depreciation

2.4.1 Comparisons of Economic Depreciation to Existing Tax Depreciation Rules

For each asset class, we calculate the economic depreciation on an hypothetical asset that has a new acquisition price of \$1,000. The depreciation rates employed are those from table 2.1. To translate an economic depreciation rate, $d(s)$, into actual economic depreciation value, we assume the initial acquisition price of an asset to be \$1,000, and we assume the cost to depreciate at rate $d(s)$ at age s, *and that there is no inflation*:

$$\begin{aligned} q(0) &= \$1{,}000.00 \\ q(s) &= q(s-1)\,[1 - d(s)] \end{aligned} \tag{14}$$

and

$$D(s) = q(s) - q(s+1). \tag{15}$$

The asset is depreciated according to (14) up to age $L - 1$, where L is the economic life calculated by Hulten and Wykoff (1976) from the straight-line depreciation estimates. The remainder of the asset is then fully depreciated at age L.

As a detailed example of comparisons between economic and tax depreciation streams, table 2.3 contains the economic, guideline tax, and actual tax depreciation values of apartment buildings computed for selected years of an asset's life. The economic depreciation values are based upon semilog least-squares estimates from Winfrey-transformed prices.

Row 1 of table 2.3 indicates that, in the first year of an apartment's life, economic depreciation is \$39.00, while the guidelines allow tax deductions of \$50.00 and actual tax practice consists of deductions of \$62.50. For apartments, tax deductions continue to exceed economic depreciation through the first thirty years of economic life. Of course, eventually these larger tax deductions are offset by large economic de-

Table 2.3 Apartment Buildings: Economic and Tax Depreciation by Age
(Geometric Economic Depreciation on Winfrey-Transformed Prices)

Age in Years	Economic Depreciation	Tax Depreciation	
		Guideline	Actual
1	39	50	62.50
2	37.48	47.5	58.59
3	36.02	45.13	54.93
4	34.61	42.87	51.50
5	33.26	40.73	48.28
6	31.97	38.69	45.26
7	30.72	36.75	42.43
8	29.52	34.92	39.78
9	28.37	33.17	37.295
10	27.26	31.51	34.96
15	22.35	24.38	25.32
20	18.32	18.87	22.25
30	12.30	17.92	22.25
50	5.55	0	0
100	0.76	0	0

preciation in later years. However, in present value terms, tax exceeds the economic depreciation stream, as we will shortly see. Tables, like table 2.3, have been prepared for each asset class and are available on request from the authors. Furthermore, similar tables have been prepared for each method of measuring economic depreciation.

Let us now summarize the findings. Economic depreciation when using transformed prices is as large as actual tax depreciation in early years only for banks, hotels, and recreational buildings; thus, subsidies were received by owners for all other new structures. Compared with the depreciation rates in the guidelines, Revenue Procedure 62-21, economic loss of value is greater for medical buildings, motels, repair garages, restaurants, factories, and warehouses as well. But, for the large classes of office buildings and retail stores, economic depreciation is small compared with early deductions allowed for tax purposes, both according to the guidelines and in actual practice.

When nontransformed prices form the basis of empirical estimation, geometric economic depreciation is slower than when transformed prices were used. In every case, economic depreciation in early years is less than guidelines and actual tax depreciation practice. Furthermore, the gap between economic depreciation and guidelines is usually far greater than the distance between the latter and actual tax practice. When the geometric approximation to Box-Cox estimates of economic depreciation are compared with tax depreciation, the rankings of assets by depreciation comparison are changed. But this change has a smaller effect upon the levels of depreciation than does the Winfrey transformation for retirement.

A convenient summary picture of the differences between tax and economic depreciation can be obtained by computing the present value at acquisition of a new asset of economic depreciation and the two tax depreciation streams.[14] Table 2.4 contains the present-value calculations, for each asset class, using the direct geometric estimates on transformed prices and assuming a constant rate of time discount of 10%.

Table 2.4 **Present Value of Economic and Tax Depreciation Streams** (Direct Geometric Winfrey Depreciation Rates)

Class	Economic Depreciation	Tax Depreciation: Guideline	Tax Depreciation: Actual
1. Apartment	308.63	372.08	431.97
2. Bank	285.21	261.53	295.89
3. Factory	319.31	285.17	340.41
4. Hotel	308.63	313.52	307.42
5. Machine shop	183.68	285.17	372.16
6. Medical building	291.18	204.21	355.64
7. Motel	336.11	313.52	380.97
8. Office	251.89	285.17	307.42
9. Recreation	425.19	313.52	390.12
10. Repair garage	272.98	285.17	399.81
11. Restaurant/bar	279.11	261.53	380.97
12. Retail trade	233.86	261.53	355.64
13. Service station	315.10	577.41	525.63
14. Shopping center	190.91	261.53	340.41
15. Terminal	212.93	185.27	420.33
16. Warehouse	253.85	224.38	333.30

The same calculations were undertaken for the other sets of economic depreciation estimates. When the present value of tax depreciation exceeds that of economic depreciation, the purchase price of the asset includes the purchase of a tax rate below the statutory tax rate for that taxpayer's adjusted gross income.

Consider the five large asset classes—apartments, factories, offices, retail trade stores, and warehouses. For apartments, both the tax depreciation streams exceed the economic depreciation stream present value at acquisition, and this result holds up regardless of economic depreciation method used. On an apartment class asset valued at $1,000 when new, actual tax deductions are worth $60 more than the guidelines suggest. The guideline deduction's value itself exceeds economic deductions by between $60 and $230, depending upon the estimation method used. Recall that apartment owners compute deductions on a double-declining balance formula rather than on the 1.5 declining-balance scheme.

Factory, office building, and retail trade store owners appear to receive considerable net subsidies as well. Economic is nearly the same as tax depreciation for only one set of depreciation estimates and only for factories. Otherwise actual tax depreciation streams are valued higher at acquisition than the corresponding economic depreciation streams, regardless of estimation method for all three large classes. Warehouse results are ambiguous when we compare economic with guideline tax depreciation. The warehouse economic depreciation estimates vary from $130 to $253, and guideline deductions are valued at $224.

An additional exercise that should shed light upon the implications to taxpayers of these depreciation regulations is to compute the reduction in tax liability as a result of large tax depreciation deductions. For this purpose we assume the marginal corporate tax rate of 48%.[15] The marginal tax rate times tax minus economic depreciation yields the "tax saving." Table 2.5 contains the tax savings according to both actual and guideline tax practice. In some cases taxpayer savings are negative, because economic depreciation is more rapid than the tax deduction. For the larger classes, however, we have subsidies rather than surcharges. For factories and warehouses, if guideline lives were used we would have surcharges. In short, even if one uses the Winfrey retirement distribution to modify prices and to increase economic depreciation, sub-

Table 2.5 **Present Value of Tax Saving over Asset Life**
(Direct Geometric on Winfrey Prices)

	Tax Saving		Difference
	Guideline	Actual	Actual — Statute
1. Apartment	63.45	123.34	59.89
2. Bank	– 23.68	10.69	34.36
3. Factory	– 34.13	21.10	55.24
4. Hotel	4.38	– 1.22	– 6.10
5. Machine shop	101.49	183.48	86.99
6. Medical building	– 86.97	64.46	151.43
7. Motel	– 22.60	44.86	67.46
8. Office	33.28	55.53	22.25
9. Recreation	–111.67	– 35.07	76.60
10. Repair garage	12.20	126.83	114.64
11. Restaurant/bar	– 17.58	101.87	119.45
12. Retail trade	27.67	121.78	94.11
13. Service station	262.30	210.52	– 51.78
14. Shopping center	70.62	149.50	78.88
15. Terminal	– 27.66	207.39	235.06
16. Warehouse	– 29.47	79.45	108.92

sidies are received by asset holders in large classes. The third column of the table contains the difference between actual and guideline tax depreciation methods. Except for hotels and service stations, actual deductions exceed guideline deductions. However, large differences still tend to maintain between guideline tax and economic depreciation. Although subsidies would be reduced by movement toward guideline deductions, the greater portion of the subsidies would remain.

One concluding point must be emphasized. The question of who benefits from the subsidies implied by the divergence of tax and economic depreciation is similar to the question of who pays the corporation income tax. If a depreciation subsidy is unexpectedly given to a certain type of asset, the after-tax rate of return to that asset will rise. Since after-tax rates of return (in each risk class) tend to be equated in a competitive capital market, investment will flow toward the subsidized asset. The rates of return of other assets will therefore tend to rise (assuming a fixed amount of capital), and the subsidy will be diffused to these assets. This is, of course, the same mechanism underlying the Harberger model of the incidence of the corporation income tax.[16] Our findings must therefore be interpreted as short run, or impact, rates of subsidy.

2.4.2 Consideration of New Tax Depreciation Rules

Since actual tax practice over the sample period appears to have resulted in potential subsidies to holders of most commercial and industrial structures, one may wish to consider changes in the tax laws. In fact, the United States Treasury has already announced that taxpayers are to use the Revenue Procedure 62-21 lives rather than the shorter lives reported in *Business Building Statistics*, August, 1975. Up to now we have treated tax and economic depreciation as given, but, as is shown in section 2.1, changes in the tax treatment of assets can alter the economic depreciation stream. We now consider the problem of measuring the short-run effect of several plausible alternatives to existing actual tax practice and recompute economic and tax depreciation for each new tax regime before comparing the two streams.

For comparison, we select a hypothetical asset that, when new, provides a service flow of $1,000 and that loses productive efficiency according to the geometric decay rates in table 2.1. For each tax regime, a new sequence of acquisition prices $q(0)$, $q(1)$, $q(2)$, . . . over age is calculated using equation (11) in section 2.1. Economic depreciation is calculated from the new sequence, and the present value of economic depreciation, as measured, is calculated. The "tax saving" is the corporate tax rate times the difference between tax and economic depreciation. Because asset values are also changed by the tax laws, we report the present values of the hypothetical asset in each class under each tax regime.[17]

Table 2.6 contains the present value of the hypothetical asset, with the characteristics discussed above, in each class, given current actual taxpayer practice. Column 2 contains the tax saving τ. (All results in this section are for the direct geometric estimate based on transformed prices.) The magnitude of the tax subsidies is large, amounting to about 10% of asset value.

Table 2.6 **Tax Savings and Asset Values under Existing Tax Practice**

Class	New Asset Acquisition Price	Tax Saving
Apartment	$5,191.56	$272.23
Bank	4,945.62	53.89
Factory	4,942.54	148.56
Hotel	4,817.05	25.51
Machine shop	5,791.50	479.44
Medical building	5,053.06	167.18
Motel	4,847.70	127.33
Office	5,173.60	151.69
Recreation	4,314.83	19.91
Repair garage	5,329.82	321.09
Restaurant/bar	5,239.58	265.59
Retail trade	5,418.24	305.61
Service station	5,454.47	499.13
Shopping center	5,631.93	376.93
Terminal	5,764.68	519.71
Warehouse	5,258.20	216.04

Assumptions: Relative efficiency functions are based upon geometric estimates of Winfrey-transformed prices. All assets, except apartments, are depreciated for tax purposes at 1.5 declining-balance. Apartment tax depreciation is double declining-balance. Tax lives are taken from *Business Building Statistics* (1975) and the lives by which geometric decay is computed are from Hulten and Wykoff (1976). See eq. (11) (section 2.1) for the formula used to obtain column 2.

Four hypothetical tax regimes, in addition to actual practice, are considered. Regime 1: The adoption of Revenue Procedure 62-21 guideline lives rather than the shorter actual lives now used. Regime 2: The adoption of straight-line depreciation, rather than 1.5 declining-balance, and the return to early Bulletin F lives, which are even longer than Revenue Procedure 62-21 lives. Regime 3: A more liberal tax package—the adoption of the double declining-balance depreciation method, more accelerated than 1.5 declining balance, with maintenance of the actual lives now used. Regime 4: Adoption of our economic depreciation estimates for tax depreciation so as to eliminate subsidies.

Table 2.7 contains the asset values and tax savings that would prevail under each of the alternative sets of tax regulations. Regime 1, the new

Table 2.7 New Asset Prices and Tax Savings under Alternative Tax Regimes

	I		II		III		IV
Class	q(0) (1)	τ (2)	q(0) (3)	τ (4)	q(0) (5)	τ (6)	q(0) (7)
Apartment	$5,009.86	$143.38	$4,596.34	−$137.61	$5,191.56	$272.23	$4,115.11
Bank	4,852.33	− 23.92	4,605.53	− 218.34	5,110.87	157.76	4,243.20
Factory	4,778.76	20.87	4,534.36	− 156.59	5,121.55	247.54	4,059.61
Hotel	4,883.65	38.89	4,586.45	− 140.67	4,980.65	126.29	4,106.25
Machine shop	5,511.32	256.18	5,214.26	25.92	6,001.26	595.42	4,756.92
Medical building	4,645.86	−170.47	4,548.31	− 235.67	5,233.76	269.80	4,190.48
Motel	4,662.93	− 15.83	4,548.33	− 79.15	5,024.45	223.78	3,961.22
Office	5,109.59	99.14	4,786.77	− 158.56	5,349.30	259.93	4,410.18
Recreational	4,128.08	−162.32	4,026.63	− 218.38	4,473.07	65.20	3,506.85
Repair garage	4,990.03	55.21	4,721.08	− 152.00	5,526.26	425.19	4,306.99
Restaurant/bar	4,896.06	− 8.73	4,693.07	− 160.57	5,430.63	369.84	4,281.44
Retail trade	5,138.35	78.87	4,877.00	− 127.08	5,612.00	415.65	4,493.31
Service station	5,642.02	622.53	4,555.24	− 160.02	5,659.13	589.82	4,078.30
Shopping center	5,388.08	177.83	5,262.70	102.38	5,830.69	492.72	4,711.70
Terminal	5,050.78	− 58.23	4,949.81	− 128.29	5,979.40	630.14	4,601.62
Warehouse	4,950.11	− 40.65	4,751.18	− 198.04	5,442.39	324.63	4,416.96

Treasury regulations of Revenue Procedure 62-21 lives and 1.5 declining-balance on all asset classes except apartments, which use double declining-balance, has the effect of reducing the tax subsidies by about one-third. If the tax regulations were to return to old Bulletin F lives and the original straight-line depreciation method, regime 2, then the subsidies would be converted into surcharges. Columns 3 and 4 contain these latter results. Regime 3 liberalizes depreciation regulations by allowing double declining-balance over the short lives now reported by taxpayers. The consequence is, of course, to increase the subsidy by further reducing the liability. The last column of table 2.7 contains asset values if tax is congruent with economic depreciation.

2.5 Capital Stock Estimation

We turn now to the construction of capital stock estimates based upon the Hulten-Wykoff economic depreciation estimates. These capital stock figures will be used to determine the tax subsidies, under existing practice, by industry groups in manufacturing. However, these stock estimates are useful in their own right. As we indicated in our introduction, BEA recently introduced imputed economic depreciation into the United States National Income and Product Accounts. The BEA imputations are based upon straight-line and double declining-balance formulas, Bulletin F lifetimes, and a modified Winfrey S_3 retirement distribution. The next step logically would be to replace these accounting-based imputations with those based upon actual empirical estimates.

The dual problem to measuring asset prices is that of measuring the quantity of capital. As Jorgenson has shown (1973), the quantity and price figures, to be internally consistent, must both be based upon the same relative efficiency function. In this section we discuss and employ this theory of replacement and depreciation.

In a competitive capital market, economic depreciation is the dual of physical deterioration. This can be shown by substituting equation (1) into the definition of economic depreciation, equation (5), which yields

$$(16) \qquad D(s,t) = \sum_{x=0}^{L} \frac{c(s+x, t+x) - c(s+1+x, t+x)}{(1+r)^{x+1}}.$$

Applying the basic duality relationships from equation (9), we have:

$$(17) \qquad D(s,t) = \sum_{x=0}^{L} \frac{c(0, t+x)\,[\phi(s+x) - \phi(s+1+x)]}{(1+r)^{x+1}}.$$

The term in square brackets is the one-period loss in relative economic efficiency, called the "mortality sequence," in Jorgenson (1973). Equation (17) indicates that economic depreciation is equivalent to the present value of the income lost by shifting the relative efficiency profile by one year. Equation (17) explicates the relationship between the decline in asset value, $D(s,t)$, and the decline in asset efficiency, $\phi(s+x) - \phi(s+1+x)$.

The basic conclusion of this analysis is that the decline in asset value owing to aging cannot be estimated independently of the corresponding decline in asset quantity. For example, if economic depreciation occurs at a constant (geometric) rate, then the relative efficiency sequence must also be geometric, that is,

$$\phi(s) = (1-\delta)^s, \tag{18}$$

where δ is the constant rate of economic depreciation. The geometric case is, however, the only one in which both depreciation and the efficiency functions are of the same form. Straight-line depreciation does not imply that $\phi(s)$ declines linearly, nor does a linear decline in $\phi(s)$ imply straight-line economic depreciation.

The stock of capital at any point in time depends upon $\phi(s)$, the relative efficiency function. Letting $K(t)$ and $I(t)$ denote the stock of capital and flow of gross investment respectively,

$$K(t) = \sum_{s=0}^{\infty} \phi(s) I(t-s); \tag{19}$$

that is, the capital stock is the efficiency-weighted sum of past investments. Taking first differences yields the recursive equation widely used in estimating capital stock:

$$K(t) = I(t) - R(t) + K(t-1). \tag{20}$$

$R(t)$ denotes the cumulative replacement requirements on the existing capital stock:

$$R(t) = \sum_{s=1}^{\infty} [\phi(s-1) - \phi(s)] I(t-s). \tag{21}$$

In the case of geometric depreciation, equation (21) reduces to the familiar

$$K(t) = I(t) + (1-\delta) K(t-1), \tag{22}$$

which provides a convenient method for estimating the capital stock, since the relative efficiency profile is summarized by the one parameter δ.

A modified version of equation (19) forms the basis for the capital stock estimates of this chapter.[18] Investment by input-output sector is taken from the capital stock study of Jack Faucett Associates (1973), and the relative efficiency sequence is derived from the Box-Cox estimates of Hulten and Wykoff (1976). Table 2.8 summarizes the Box-

Table 2.8 Transformed Box-Cox Estimates of Economic Depreciation on a $1,000 Asset, by Asset Class for the Year 1966

Age in Years	Asset Class[a] 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	$36.94	$67.91	$30.23	−$531.56	$1.22	$25.67	$34.64	$43.20	$52.71	$ 7.53	$33.09	$35.36	$21.63	$93.43	$108.93	$55.68
2	33.70	50.61	29.14	− 433.74	1.19	23.99	31.94	35.97	47.61	9.38	30.27	30.90	22.79	60.25	64.82	44.48
3	31.44	41.55	28.20	− 380.37	1.19	22.82	30.11	31.70	43.89	10.82	28.32	28.09	23.42	45.24	46.24	38.11
4	29.66	35.71	27.32	− 345.04	1.19	21.88	28.69	28.71	40.88	11.97	26.80	26.00	23.79	36.49	35.90	33.75
5	28.17	31.54	26.50	− 319.26	1.19	21.10	27.50	26.42	38.30	12.95	25.33	24.36	23.98	30.69	29.31	30.51
6	26.87	28.37	25.71	− 299.32	1.19	20.40	26.47	24.59	36.04	13.78	24.42	22.98	24.05	26.55	24.73	27.95
7	25.71	25.85	24.97	− 283.23	1.19	19.78	25.56	23.06	34.01	14.52	23.46	21.81	24.04	23.42	21.36	25.84
8	24.65	23.79	24.23	− 269.88	1.19	19.20	24.72	21.75	32.17	15.13	22.55	20.78	23.96	20.97	18.78	24.09
9	23.69	22.06	23.54	− 258.56	1.19	18.68	23.96	20.62	30.48	15.68	21.75	19.87	23.82	19.00	16.75	22.56
10	22.80	20.58	22.86	− 248.77	1.19	18.18	23.25	19.61	28.93	16.16	20.99	19.04	23.64	17.37	15.09	21.24
15	19.10	15.50	19.79	− 214.12	1.19	16.07	20.23	15.87	22.57	17.70	17.88	15.81	22.27	12.19	10.03	16.46
20	16.24	12.43	17.15	− 192.25	1.19	14.35	17.79	13.33	17.87	18.16	15.44	13.50	20.46	9.39	7.44	13.38
30	11.99	8.78	12.83	− 164.97	1.16	11.61	13.82	9.97	11.42	17.12	11.77	10.27	16.33	6.40	4.84	9.53
50	6.70	5.21	7.05	− 135.87	1.12	7.69	7.92	6.20	4.77	11.30	7.04	6.43	8.32	3.83	2.76	5.54
99	1.51	1.98	1.36	− 104.65	1.06	2.58	0.08	2.31	0.51	0.64	1.92	2.37	0.02	1.78	1.26	1.91

[a]See table 2.5 for the asset classes corresponding to the class number codes.

Cox depreciation rates on transformed prices for one year, 1966. The BEA's 1967 capital flow matrix provides the link between the efficiency estimates by asset type and investment by I-0 sector.[19] The steps in the capital stock construction can be briefly outlined. First, the Box-Cox estimates for each asset class are used to generate "fitted" acquisition prices, $q(s,t)$, for each vintage and year. These prices are then used to impute service prices, $c(s,t)$, using the conceptual framework of section 2.1.[20] The imputed service prices were then used to calculate the relative efficiency function: $\phi(s,t) = c(s,t)/c(0,t)$. This function differs from $\phi(s)$, equation (9) in that efficiency sequence is not now assumed to be stationary.

As indicated above, the investment series, in constant prices, used here are obtained from the 1973 Faucett study of capital stocks. The Faucett estimates have the following properties: (1) they cover the period 1890–1966; (2) they are reconciled to the 1957 Standard Industrial Classification; (3) they are based on establishment; (4) investment in nonresidential structures is net of land values; (5) they include investment in establishments not in operation; (6) they include expenditures for administrative facilities; (7) they cover both corporate and noncorporate sectors; and (8) they include government-owned–contractor-operated capital. The estimates are of lower quality in the early years, as Faucett himself points out. However, these early years receive the smallest weight in the perpetual inventory calculation, so that the effect of an increasing measurement error, backward over time, is minimized. BEA control totals were used to improve the accuracy of the estimates.

The allocation of real investment data by sector between the various types of nonresidential business structures is based upon BEA's 1967 capital flow matrix. Although twenty-six types of structures are identified and allocated across I-0 sectors, the only asset types relevant for our purpose are the nonresidential buildings. These classes of structures account for 32% of total new investment in all structures in 1967. The asset types for which the estimated relative efficiencies are available account for 80% of total investment in nonresidential buildings in 1967. The 1967 proportions of these asset types in each I-0 sector are used to allocate Faucett investment in all years; the resulting allocation separates annual gross investment by I-0 sector between categories for which $\phi(s,t)$ is available. A residual category for which capital stocks were not calculated is included in the allocation of gross investment.

In this chapter we are focusing on the manufacturing sector. Approximately 93% of the 1967 investment in all manufacturing structures is classed as "industrial structures and office buildings," a class for which Box-Cox relative efficiencies have been produced.[21] An apparent enigma about the resultant capital stock figures requires comment. When acquisition prices are transformed to allow for asset retirement, using Winfrey's L_0 transformation, the average rate of depreciation tends to be larger than estimates of depreciation derived from untransformed prices. Naturally one would expect, therefore, that stock estimates based upon transformed data would be smaller than their untransformed counterparts. However, in some classes transformed prices produced larger capital stock estimates than those of untransformed prices. The reason for this unexpected result is that transformed prices often produced large relative efficiency values, $\phi(s,t)$, for young assets, and consequently, a high rate of investment in such classes led to comparatively larger stocks for transformed data.

The total stocks of nonresidential structures in manufacturing are given in table 2.9. The last two columns do not include the unallocated investment, but this amounted to only 7% of new investment in manufacturing structures in 1967. For comparison, we include recent BEA estimates based on Musgrave (1976). The BEA net stocks are calculated using straight-line depreciation and a modified Winfrey S_3 distribution centered on 85% of the 1942 Bulletin F asset lives. These BEA assumptions produce stock estimates that are quite a bit lower than either

Table 2.9 **Stock of Nonresidential Structures in United States Manufacturing (Billions of 1958 Dollars)**

Year	BEA[a] Net Stocks	Box-Cox, Transformed[b]	Box-Cox, Untransformed[b]
1948	31.8	51.9	48.6
1949	32.3	52.5	49.0
1950	32.5	52.6	49.0
1951	33.3	53.8	50.0
1952	33.4	54.7	50.9
1953	34.6	55.8	52.0
1954	35.1	56.7	52.9
1955	36.0	57.7	53.8
1956	37.1	59.3	55.4
1957	38.3	61.0	57.1
1958	39.1	62.1	58.2
1959	39.1	62.3	58.5
1960	39.5	63.0	59.3
1961	39.8	63.5	60.0
1962	39.9	64.0	60.7
1963	40.2	64.7	61.6
1964	40.6	65.5	62.6
1965	41.8	66.9	64.3
1966	43.6	69.0	66.7

[a]Table 4 of Musgrave (1976), converted to 1958 dollars.
[b]Totals for industrial buildings and office buildings, which constitute 93% of net investment in all structures in manufacturing in 1967.

version of our Box-Cox estimates. The reason for such low BEA estimates is the higher implicit rate of replacement under the BEA method. Equation (22) was used to calculate an implied constant rate of depreciation, δ, given the stock estimates of table 2.9 and Faucett's gross investment data for manufacturing structures. The average rate of depreciation is approximately 6.5% for the BEA stocks, and 3.7% and 3.9% respectively for the transformed and untransformed Box-Cox stocks. These last two numbers differ sharply from the average geometric rates for the factory class (which dominates the manufacturing calculation) given in table 2.1—3.6% for the transformed data and 1.3% for the untransformed. The reason for this difference is explained above: the rate of depreciation is not constant in the early years of asset life and is actually slower with the transformed data than with the untransformed. Given a higher rate of investment, the result is a larger stock of capital with the L_0 retirement transformation than without it.

2.6 Economic and Tax Depreciation in Manufacturing Industries

We have so far considered the depreciation subsidy problem and the capital stock estimation problem separately. We now combine the two in order to ask how much subsidy is received by the various industries in manufacturing. First, we compute $\phi(s,t)$ (the difference between economic and tax depreciation), as defined in equation (8) of section 2.1, for $t = 1966$ and for s varying between one and one hundred. When the result is divided by the value of allocated structures in each manufacturing industry in 1966, the rate of subsidy per dollar of capital is obtained. This index is a rough measure of the distribution of the depreciation subsidy across manufacturing industries. The actual value of the subsidy to each producer would depend upon his marginal tax rate. The annual rates of subsidy per dollar of capital in each two-digit SIC group in 1966 are given in table 2.10.[22] It is evident that the rate of subsidy varies across industries, from —2 cents to 1.1 cents per year per dollar of capital stock. In assessing these results, one must recall the caveat above that to determine who benefits from these subsidies and to determine their precise allocative effect requires a tax incidence analysis well beyond our scope here. At the same time, considerable economic research indicates that divergence between tax and economic depreciation can lead to distortions in economic decisions, and thus to excess burdens and to reductions (increases) in business tax liabilities.

Table 2.10 Economic and Tax Depreciation in Manufacturing Industries, 1966 (Millions of 1966 Dollars)

Two-digit SIC Industry	Economic Depreciation (ED)	Tax Depreciation: Statute (TD_S)	Tax Depreciation: Actual (TD_A)	$ED\text{-}TD_A$ ÷ Value of Structures
19	54.8	54.1	89.3	−0.020
20	242.5	300.8	272.2	−0.004
21	7.4	7.9	8.4	−0.004
22	68.3	67.0	57.8	−0.005
23	33.2	35.0	35.4	−0.002
24	67.5	70.8	58.6	0.004
25	23.8	25.5	27.5	−0.005
26	93.0	98.3	102.5	−0.003
27	181.2	211.7	120.8	0.011
28	231.8	238.2	310.7	−0.011
29	309.7	339.0	326.4	−0.002
30	30.7	32.4	35.0	−0.004
31	10.3	11.6	10.1	0.001
32	95.9	102.8	109.9	−0.005
33	433.6	494.3	422.0	0.001
34	94.9	100.1	109.3	−0.005
35	143.5	150.4	171.7	−0.006
36	115.0	122.4	121.1	−0.002
371	94.1	100.3	105.5	−0.004
37–371	132.4	137.8	175.9	−0.011
38	28.7	29.8	35.4	−0.007
39	22.7	23.8	24.9	−0.001

Notes

1. Jorgenson (1971) reviews the literature on geometric depreciation in investment studies. Jorgenson (1973) discusses his model of replacement and depreciation. A contrary position on depreciation is contained in Eisner (1974). Feldstein and Rothschild (1974) question a number of the assumptions of the Jorgenson model.

2. Since Jorgenson's 1971 review, empirical analysis of vintage asset prices has been undertaken by Ackerman (1973) and Ramm (1971) of automobiles and by Wykoff (1974) and Hulten and Wykoff (1976) of structures. Robert Coen (1975) has studied depreciation in investment models.

3. See Young (1975) and the *Survey of Current Business*, January and March 1976.

4. Feldstein and Rothschild (1974) analyze the endogeneity of economic depreciation in detail. Their analysis raises the possibility that built-in physical durability, as well as in-use productive efficiency, will change with changes in the tax laws and rates of return. Our analysis treats asset productivity, that is, the relative efficiency function, as given. We have been unable to detect, in our

empirical analysis, changes in relative efficiencies as a result of variations in tax parameters and rates of return.

5. The survey results are summarized in *Business Building Statistics*, August, 1975, Office of Industrial Economics, Department of the Treasury, Washington, D.C.

6. "Actual" practice refers to depreciation practices reported to the Treasury in the 1972 survey. Tax deductions calculated on the basis of Revenue Procedure 62-21 lives are referred to as "guideline" deductions. See section 2.3 for details. Both methods were, of course, quite legal.

7. The fundamental relation between asset and service prices is contained in Hotelling (1925) and discussed in detail in Hall (1968), Jorgenson (1973), and Wykoff (1970, 1973). Hulten and Wykoff analyze the depreciation term derived from equation (1) in "Empirical Evidence of Economic Depreciation of Structures," *Conference on Taxation*, August 1975, U.S. Treasury Department, forthcoming.

8. Modification of the user cost of capital to allow for various tax regulations is undertaken by Hall and Jorgenson (1967) and by Christensen and Jorgenson (1969).

9. See Wykoff (1970), Hall (1968), and Jorgenson (1973).

10. Arguments for accelerating tax depreciation have been advanced to the effect that inflation slows investment through increased replacement costs at retirement. This view is in part valid: inflation does indeed raise the value of capital services lost through wear and tear and through obsolescence. However, for this to justify a change in tax policy, part of the increased value of existing assets should be treated as a capital gain and included as an item of taxable income. The issue of depreciation and inflation is discussed in the testimony of Tax Treatment of Capital Recovery, Committee on Ways and Means, 93d Congress, February 1973 (cf. Eisner 1973). Also, the publication *Essays on Inflation and Indexation*, American Enterprise Institute for Public Policy Research, Washington, D.C., contains several articles (Giersch et al. 1974) on inflation finance. John B. Shoven and Jeremy I. Bulow (1975) suggest new accounting methods under inflation.

11. If, of course, tax depreciation is decelerated with respect to economic depreciation, the taxpayer is in effect assessed a surcharge. The use of the terms subsidy and surcharge is taken from Taubman and Rasche (1969).

12. The six classes excluded had too few observations, or were too ill defined, for analysis. Excluded were theaters, stadiums, parking garages, supermarkets, and several catchall categories; 90% of the data was in the remaining sixteen classes.

13. These tax methods are discussed in the 1971 IRS publication *The Asset Depreciation Range System.*

14. These formulas are derived in Wykoff (1974).

15. The statutory marginal rate 48% is used for illustration only. The effective marginal tax rate varies from taxpayer to taxpayer and is less than the statutory rate, since not all business taxpayers are taxed as larger corporations, interest payments are deductible, and so on.

16. Harberger (1962). For a recent review of the literature on excess burden and tax incidence, see Break (1974). Distortions due to differences between tax and economic depreciation are discussed by Smith (1963) and Samuelson (1964).

17. Calculations of asset prices and subsidies will now differ from those recorded earlier, because we are now undertaking a different experiment. Rather

than taking depreciation based directly on estimated acquisition prices, we treat the estimation process as yielding only in-use relative efficiencies of assets as they age. From these efficiency functions, Φ (s), we then compute new prices. Thus the entire economic depreciation stream will be computed. Consequently, different subsidies and asset values are now calculated.

18. The actual capital stock calculation is based upon a revision of equation (19), in which there is an initial capital benchmark. Because of the length of the investment series, however, the benchmark value is assumed to be zero.

19. Specifically, the link is based on table 1 of *Interindustry Transactions in New Structures and Equipment*, 1963 and 1967, vol. 1, United States Department of Commerce, Bureau of Economic Analysis.

20. In these calculations, the rate of return, r_{ts} for the period 1937 to 1970 was taken to be the four- to six-month prime commercial paper rate published in the *Survey of Current Business*. For the period 1890 to 1936, the commercial paper rate calculated by Macaulay (1938) was used.

21. See Hulten and Wykoff (1976).

22. The calculations are based on the formulas:

$$\sum_s D(s,1966)I(1966-s)$$

$$\sum_s d_T(s)I(1966-s).$$

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Comment Paul Taubman

Hulton and Wykoff are to be congratulated on working on two extremely important and, as they point out, interrelated problems. They are also to be applauded for bringing to light the issue of the treatment of retirements and disappearances. And while I am still praising, I might as well mention the Congress and Treasury, who initiated a study to try to resolve an important empirical issue.

The object of this paper is to measure economic depreciation, which is then compared with tax depreciation and used to generate new estimates of industry capital stock. The basic data used in this study are from a survey of building owners conducted by the Treasury. The survey contains information on various classes of structures for example, office buildings and shopping centers. The data on each building include date of construction, date of acquisition, price of acquisition, square footage, and other characteristics.

Hulten and Wykoff divide the sample into classes of building, then run equations of the following form

$$P_t = F(Age_t, t, x), \tag{1}$$

where P_t is the acquisition price in year acquired, denoted by t. The price is not deflated.

Age_t is the age of the building, or date of acquisition
t is year of acquisition
x is a vector of characteristics, such as square footage.

In parts of the analysis they adjust for previous retirements of assets of a particular age cohort. In estimating this equation they employ Box-Cox and polynominal forms to try to determine the age price profiles.

They use the derivative of these profiles with respect to age to calculate economic depreciation, assuming there is no adjustment to the taxes. They then compare the annual estimates of economic depreciation with the charges contained in the tax statutes and with actual tax depreciation, which can differ from the statutory amount if nonstatutory lives are used. They generally find that in the early years economic depreciation is less than statutory depreciation, which is less than actual tax depreciation. The present discounted value of the three depreciation series are ranked in the same order, and the tax depreciation allowances confer a tax subsidy.

Using an input-output approach, they can allocate investment flows to various industries and then calculate total investment in each in-

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dustry. Then, using perpetual inventory methods, estimates of economic depreciation and assumptions on retirement patterns, they can calculate capital stock by industry. Since they estimate depreciation to be lower than straight-line, which is used by BEA, and since investment has an upward trend, they find higher capital stocks than BEA.

After this brief outline of their paper, let me begin my critique. I think I can assert that Bob Rasche and I were the first persons to try to examine the pattern of economic depreciation of structures. Since we based our results on net rent for only four or five broad age groups, I can say without fear of contradiction that the data used in the current study are better than those previously available. I am not sure, however, whether the results are better or worse or more or less believable.

How can we measure the way the value of a given asset would vary over time, all else being equal? Ideally, we want data on the sales price of the same or homogeneous assets throughout the lifetime of the asset during a steady-state period when relative and absolute market prices and tax regimes and their future expectations remain constant. We could, of course, use data when there were only random deviations from these conditions—a situation probably met in the eight markets for secondhand machinery and equipment examined by Terborgh or the markets for automobiles examined by Wykoff. Since we do not live in this world, or in one that deviates only randomly from it, we must be more ingenious. The first step in this direction is to use theory to obtain an equation.

In a competitive market, in equilibrium and with no uncertainty, the price of an asset should be equal to the present discounted value (PDV) of its after-tax income stream, discounted at the appropriate interest rate, which I will assume is the after-tax interest rate at which the investor can borrow or lend. Hulton and Wykoff following the lead of Jorgenson and others, then express this equilibrium price in terms of the construction price and tax law features. I have several complaints about the formula they use. First, they call it a "user cost" price, the term Jorgenson originally used in his pioneering work on investment functions but subsequently changed to "rental" price. I believe Jorgenson made this change because the term he and they derive differs from what Keynes earlier meant by "user" cost. To avoid confusion I would hope the authors would also switch to "rental" price. Second, their formula assumes that the whole complex of the tax law can be written so the tax base equals revenues minus the sum of wage, repair, other money costs, and the tax allowance for depreciation. That is, they use Jorgenson's standard formula with the investment tax credit set equal to zero. Tax lawyers, tax reformers, and the people I have known at the Treasury's Office of Tax Analysis would double up with laughter at the idea that that formula captures the essence of the situation *for structures.*

I will not try to be exhaustive but will only point out a few highlights. I will also restrict my comments primarily to office and apartment buildings—the two major categories of structures I have studied, though I suspect they apply to many other major categories of structures. One particular feature of the tax laws that increases the profitability of such investment and has been the subject of much debate is the conversion of ordinary income to tax-preferred capital gains. Everyone agrees with Hulton and Wykoff that, for structures, tax depreciation is greater than economic depreciation in the early years of the assets' lives. Since the tax base is original purchase price minus accumulated depreciation, the tax base is less than the current selling price with the difference taxable as a capital gains, subject to a holding-period rule. This rule states that, for the first eight years, all the excess tax depreciation above straight-line is taxed as ordinary income, and that for each additional month the percentage of this excess taxed as ordinary income decreases. This conversion to capital gains is not in their formula, though it is very important, especially since the recapture applies only to excess depreciation above that granted by the straight-line methods. Nor is there any provision for the treatment of interest payments. Most purchases of office and apartment buildings are financed by mortgages that are often 90% of purchase price, and 100% mortgages are not unknown. Most of the mortgage payments in the early years are interest payments, which are deductions against the *owners'* income tax. These owners are the ones who determine the asset's market price, and they should make the price calculation on income after taxes. Second, in this market, the interest payments and tax depreciation decline as the building ages. With the decrease in expenses, eventually taxable income appears, but then tax-sheltered investors sell and obtain capital gains.

These might be considered nitpicking comments for the calculation of economic depreciation, since the authors are using market prices that should incorporate all relevant market and the real world phenomena, as perceived through the eyes of tax lawyers and investors. There are two problems with this response. First, my comments do apply to the calculation of the value of the tax subsidies, which is a part of the paper. Second, as far as I can tell, the market prices the authors are using are those at *date of acquisition*, which must be no later than 1972. During the preceding decade, there were many changes in the tax laws, some of which pertained directly to structures. For example, some of the assets must have been purchased when double declining-balance was available for structures or before the imposition of the previously described partial recapture rule. The change in tax rules here would have lowered current market prices but not *recorded acquisition prices* on previously purchased structures. Also, some of these acquisition prices were recorded before the introduction of shorter lives under Asset Depreciation Range System (ADR). The tax laws indirectly affect the market price of structures through the tax rate schedule and the treatment of all other incomes. The value of the tax subsidies depends upon the taxpayer's marginal tax rate. Decreases in this rate such as occurred in 1964 and 1965 decrease the value of tax subsidies. Closing or creating loopholes also affects the supply of investors for a given loophole. The recorded prices are also inappropriate because they reflect the mortgage conditions then current.

Finally, these recorded prices depend on the prevailing price level. The only adjustment made for inflation is the introduction of a polynominal in time. They find that this variable is not very important, probably because inflation did not proceed smoothly and tax changes with positive and negative effects occurred at various points in time.

For all these reasons, the recorded prices on past acquisitions are not appropriate to measure economic depreciation unless you assume that the future changes were expected and incorporated into the acquisition price (and that inflation is unimportant). But, I repeat, as far as I can determine, and I think note 20 bears this out, the authors have not adjusted the past market prices for the tax law and mortgage changes or inflation. The tax law and mortgage features can be calculated at least roughly, as Rasche and I have done, and inflation can be handled by better means than a time trend.

Incidentally, there is another potential problem with these data that I am less certain how to handle. Presumably, some of these buildings underwent major repairs and modernization that show up in the prices and thus reduce their calculated economic depreciation.

For these reasons I do not think Hulton and Wykoff have measured even the short-run effects of tax laws on tax subsidies. I suppose I would be less concerned with this if their numbers were in accord with what I believe and have published. Rasche and I, using a bit of information on profit age profiles, have calculated that for office and apartment buildings the rate of depreciation was very low for the first fifteen years and that in each of the first forty years or so true depreciation was less than the tax depreciation then allowed. (Allowances for the early years have been increased since then.)

In the early years we did not have depreciation rates nearly as large as the ones cited in this paper. Ours began at less than half of 1% and generally rose steadily. Thus what we found was not a constant geometric decay but a pattern that was approximately the reverse sum of the years' digits. There is some other evidence that we are in the correct ballpark when we say there is little depreciation in early years. In the early sixties, when there was little or no inflation for several years, you could get fifteen-year, 100% mortgages. Banks must have expected little depreciation if they felt the mortgage was secured. Second, I once saw a draft of a paper by Wykoff on apartment buildings, in which he concluded there was appreciation for the first fifteen years of the asset's life. If this is so, why use a constant depreciation rate, which I must add Hulton and Wykoff say does not work well for the first fifteen years —the very years that naturally receive the highest weight in a PDV calculation.

The authors have calculated the PDV of economic and tax depreciation rules. They find that most structures are subsidized. I think this is true, but I do not think their numbers are correct. For this calculation they do need to use the correct formula and, as I noted, they do not have it. Moreover, they assume that the marginal tax rate is the corporate rate of 48%. But, for much of this market, the investors are individuals in higher marginal tax brackets.

Finally, let me turn to the capital stock calculation. The authors are absolutely right that one should integrate the economic depreciation series into the capital stock series. They are also right that something has to be done about retired, abandoned, and destroyed assets. I do not fault them for using the Winfrey estimates, since nothing else is available. But I think the Winfrey Study is far out of date, and the patterns found for a few assets need not apply to all structures. I would like to see a study done on survival rates—perhaps by drawing a random sample of permits from fifty to seventy-five years ago and then periodically seeing if the buildings are still in use and what major innovations, if any, they have undergone.

I do think there is at least one problem in the authors' capital stock accounting. Essentially, their paper focuses on the calculation of economic depreciation. They do not try to examine responses of the structure industry to tax law provisions. If in the adjustment process all that happens is that rental prices change, there is no difficulty, since they or the census use market information on construction costs. But there is every reason to suspect that one result of the tax law is a reduction in quality of the building. This occurs because the tax law encourages fairly frequent sales to convert ordinary income to capital gains. Initial and subsequent owners have an incentive to cut corners on construction and maintenance of hard-to-observe characteristics of the building, whose defects will not be noticed until the building has been disposed of. Moreover, and perhaps more germane, Rasche and I demonstrated in another paper that nearly every tax subsidy scheme would cause buildings to be destroyed earlier than with no subsidy. Thus the useful life of the assets should have changed with tax laws—a modification it would be well to incorporate in perpetual inventory methods.

As I said in the beginning, the authors are working on important problems. I think what they have done provides a useful starting point.

It may be that the numbers would not change much if they made the adjustments I suggested, but I would like to see the authors try to incorporate them.

Reply by Hulten and Wykoff

We wish to thank Professor Taubman for his detailed assessment of our work. That he does not believe our numbers is no doubt the result of his (1969) work with Rasche on the depreciation of office buildings. Taubman and Rasche report an age-price pattern in which the price declines very little in the early years of asset life and accelerates rapidly toward the end. This pattern is consistent with the conventional view that the relative efficiency of buildings declines very little with age; that is, physical depreciation is acts like the one-horse shay. Our results are quite different. We estimate an age-price pattern that is convex with respect to the origin rather than concave. Our prices thus decline more rapidly in the early years of asset life than in the later years. We wish to stress Taubman's assertion that "the data used in [our] study is better than that available [to him and Rasche]," for the main thrust of our reply will be to show that the fundamental conclusion of convex depreciation, rather than concave, follows from the basic data rather than from our treatment of inflation, taxes, or user costs.

First, let us begin by illustrating the age-price pattern of our *raw* data.[1] In figure C2.1 we have plotted the *average* acquisition price per square foot in each five-year age interval against age for each of our four largest building classes (offices, retail trade, factories, and warehouses).[2] No adjustment is made for asset retirement or for the differing average date of purchase within each age interval. For example, the average date of purchase for new office buildings is 1957, and the average for the age interval six to ten years is 1965. The resulting age-price pattern is somewhat variable and shows some tendency for the average price to remain high in the first fifteen to twenty years of asset life. However, the general shape is distinctly convex and provides little support for the concave, "one-horse-shay" age-price pattern.

This point is made even clearer by figure C2.2. Here the mean acquisition price in each age interval has been adjusted for asset retirement using the Winfrey L_0 distribution and deflated to constant (1967) dollars using a "Boeckh" construction price index.[3] The adjusted data are unmistakably convex, and introducing the business tax code is unlikely to alter the evident conclusion.

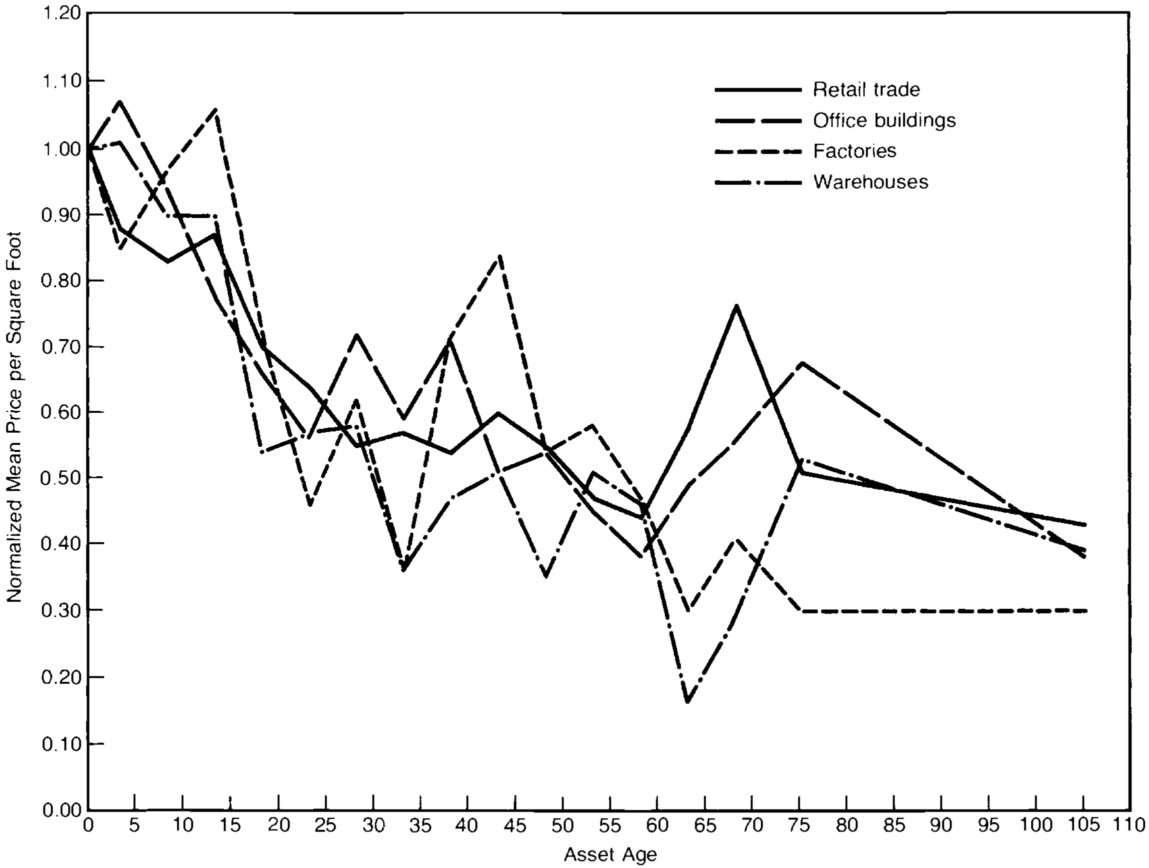

Fig. C2.1 Mean asset price by age interval, untransformed/undeflated.

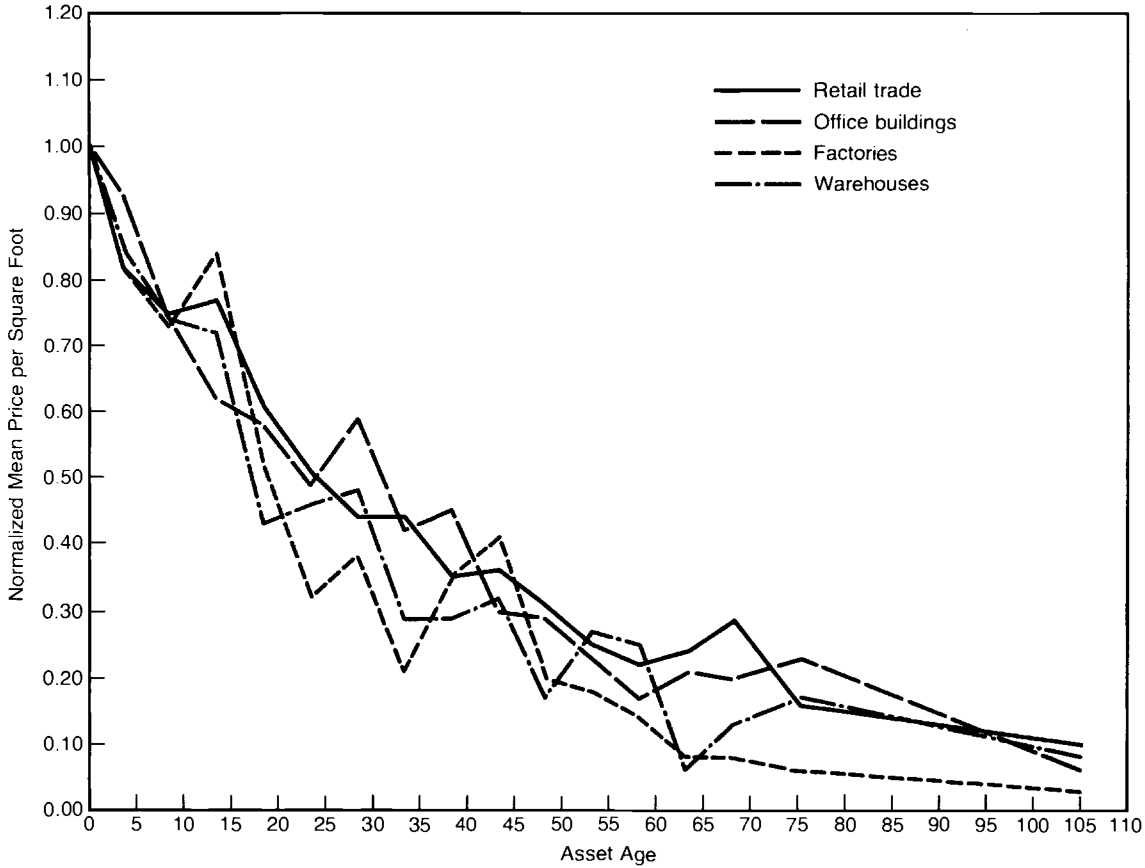

Fig. C2.2 Mean asset price by age interval, transformed/deflated.

We wish to emphasize that the data underlying figures C2.1 and C2.2 refer to market transactions of new and used buildings. Economic depreciation is usually thought of as the rate of change of an asset's market value, implicit or explicit, owing to the process of aging.[4] The data in figures C2.1 and C2.2 thus provides a basis for the *direct* measurement of economic depreciation. We would certainly agree with Taubman that changes in the tax code will in general change the market value of new and used buildings.[5] Assets with the same relative efficiency patterns can therefore have different market values at different dates of purchase. The data in figures C2.1 and C2.2 is an average across different dates of purchase, and, as noted above, the average date of purchase varies across age intervals. It is therefore possible that a systematic relationship between date of purchase and age could bias the age-price patterns of these figures. Table C2.1 does reveal some relationship between age and date.[6] It is therefore useful to consider the direction and magnitude of the possible bias. The tax code changes of 1954 and 1962 liberalized depreciation allowances on structures, and thus they exert an upward bias in the observed prices. A correction for this bias would thus tend to make the age-price pattern even more convex. Depreciation allowances were tightened starting in the middle 1960s by such provisions as recapture, and this exerts a downward bias in the observed prices that tends to offset the earlier

Table C2.1 **Average Date of Purchase, by Age Interval**

Age Interval	Retail Trade	Office Buildings	Factories	Warehouses
New	1957	1957	1954	1957
0–5	1959	1962	1955	1963
6–10	1959	1965	1962	1964
11–15	1959	1963	1958	1964
16–20	1958	1958	1958	1961
21–25	1958	1956	1959	1960
26–30	1957	1957	1961	1957
31–35	1956	1960	1957	1956
36–40	1960	1962	1961	1965
41–45	1960	1962	1961	1963
46–50	1961	1963	1956	1967
51–55	1960	1962	1964	1965
56–60	1960	1962	1964	1959
61–65	1963	1962	1961	1968
66–70	1963	1966	1966	1963
71–80	1969	1963	1958	1968
81–115[a]	1961	1961	1957	1964

[a]The average age in the last interval is 99 years for retail trade, 110 for office buildings, 100 for factories, and 113 for warehouses.

effects. The net bias will depend on the relative strengths of the bias and—more importantly—on the lag with which the effects take place.

It is important to recognize that while the tax code indicates large, discrete changes in the treatment of corporate capital, Ture and others point out that businesses adopted new procedures gradually and with some skepticism. Built-in durability changes probably require rather substantial procedural changes in durable goods and construction industries. Producers are unlikely to undergo such disruptions unless they are reasonably certain that the tax environment mandating these changes is likely to persist. The numerous code changes and tax debates have not provided such a stable environment. Furthermore, major changes in asset valuations are not likely to occur as a result of changes in a fluid tax code subject to different interpretations. The effect of changes in the tax code is therefore likely to be spread over a considerable period of time.

In view of the ambiguous direction of the bias, we are inclined to stand by the conclusions reached in our statistical analysis and reinforced by figures C2.1 and C2.2.

We would also like to point out that we attempted to estimate the effect on asset prices of a term reflecting the business tax code from 1954 to 1972 and of a rate of return term. These new terms contributed nothing to the regressions. Their coefficients were small, insignificant, and often perverse in sign. In view of the lags discussed above, this is not particularly surprising.

Notes

1. We emphasize the use of raw data rather than data weighted by sampling probabilities. We rejected the weighted data because the weights showed extreme variability and because of certain technical problems associated with their construction. Hulten and Wykoff (1978) contains a more detailed discussion of the weighting problem. We note here that the use of the unweighted data results in an unbiased estimate of the age-price pattern.

2. Average prices have been normalized on the average price of new assets for purposes of comparison. Furthermore, the end points of the curves in figures C2.1 and C2.2 differ among the classes. The footnote to table C2.1 gives the actual terminal points.

3. The Boeckh indexes were taken from the *Construction Review*, Bureau of Domestic Commerce, United States Department of Commerce.

4. Or, in other words, depreciation is the dollar amount that must be "put back" in order to keep capital intact, holding asset inflation constant.

5. This is, in fact, one of the main points of our paper.

6. The simple correlation between age and date is 0.14 for retail trade and 0.13 for office buildings in the underlying sample.

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