

# DEPRECIATION INFLATION & THE TAXATION OF INCOME FROM CAPITAL

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# THE MEASUREMENT OF ECONOMIC DEPRECIATION<sup>1</sup>

Charles R. Hulten and Frank C. Wykoff

## I. Introduction

A reduction in business taxes, especially taxes on capital, is seen by many as the key to reversing the decline in the growth of U.S. labor productivity. One approach, which has received widespread support, is to liberalize tax depreciation deductions and to increase investment tax credits. While there is near consensus on the objective of stimulating capital formation, the most highly publicized proposal (by Representatives Conable and Jones) has attracted much critical attention.

The Conable-Jones bill (H.R. 4646) would abolish the current rules for tax depreciation, the Asset Depreciation Range System (ADR), and replace them with a greatly simplified system of depreciation allowances in which autos and light trucks would be depreciated over 3 years, other machinery and equipment over 5 years, and structures over 10 years. The straight-line, declining balance, and sum-of-the-years'-digits methods of depreciation currently allowed under ADR would be replaced with a single fixed method for each of the three Conable-Jones asset categories.<sup>2</sup>

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Much of the criticism of this "10-5-3" proposal has focused on the ten-year life for structures, which is widely regarded as being far too short even for a growth-oriented liberalization of tax policy. A counter-proposal currently pending before the Senate Finance Committee would group equipment into four classes with lives of 2, 4, 7, and 10 years, depreciated with the declining balance method of depreciation. Structures would be depreciated over a 20-year period using the straight-line method. This system would alleviate some of the concern over the 10-year structure life, but it carries on an even more important problem with the Conable-Jones proposal: no factual basis is provided to justify the choice of lives, and there is thus no factual basis for choosing between 10-5-3 or 2-4-7-10, or perhaps 1-1-1. The choice of 10-5-3 or 2-4-7-10 lives are to be politically determined and are not systematically subject to revision in light of actual experience (except insofar as the whole system might be jettisoned). Unfortunately, differences in tax lives imply significant differences in tax liabilities among taxpayers, and one can reasonably expect intense taxpayer pressure to continually alter the politically determined parameters. Furthermore, a system of politically determined depreciation lives, without some factual basis, can lead to potentially serious distortions in the incentives to invest in various types of assets, and can therefore have an adverse impact on the rate and pattern of productivity growth.

Proponents of politically determined depreciation lives may, on the other hand, point to the failure of past efforts to base policy on actual depreciation practices. Both the reserve ratio test, established by Revenue Procedure 62-21 in 1962, and the ADR reporting system (ADRS), established in 1971, proved to be administrative failures. These failures reflected, in part, a lack of consensus on the appropriate treatment of depreciable capital. While the failure of the Reserve Ratio Test and of ADRS obviously does not imply that all possible efforts would also fail, they do raise the following fundamental question: can actual depreciation be measured with sufficient precision to be useful in the formulation of tax policy?

In our judgment, the answer to this question is yes: depreciation can be measured. We will show how depreciation can be estimated using an approach which relies on market price data, and we shall argue that this is a natural starting point for the analysis of depreciation. Market prices are, after all, the *sine qua non* of microeconomics, and to deny information contained in market prices is to deny much of the modern theory of microeconomics. In the special case of used asset markets, however, some

economists believe that market prices are biased downward because the only assets which enter such markets are 'lemons,' that is, assets of inferior quality.<sup>3</sup> We will argue below (in section III) that the market for used business capital is frequently conducted between highly sophisticated specialists, and that there is thus no a priori reason to suppose that sellers systematically and persistently can dupe buyers with inferior goods. We will also suggest that the 'lemons' issue can itself be confronted with empirical evidence. Where the bias problem is present, it in principle can be measured, and the results then used to correct observed market prices.

The used market price approach to estimating depreciation is set forth in section III of this paper. In section IV this approach is compared to the methods used by the Bureau of Economic Analysis (BEA) in their numerous capital stock studies.<sup>4</sup> We find that the two approaches produce fairly similar results: the average BEA rate of depreciation for aggregate equipment is 14.1 percent, while the used market approach produces an aggregate rate of 13.3 percent; for aggregate nonresidential structures, the corresponding results are 6.0 percent and 3.7 percent. While both approaches may be wrong, it is certainly interesting that such widely differing methodologies produce reasonably similar results.

The comparison of the used market price and BEA methodologies highlights the fact that there is an important scientific reason for measuring economic depreciation quite apart from the analysis of tax policy. Economic analysis of growth and production, as well as the distribution of income, requires accurate estimates of capital stocks and of capital income. The estimation of capital stocks in turn requires an estimate of the quantity of capital used up in production, and the estimation of capital income requires an estimate of the corresponding loss in capital value. Thus, even if depreciation policy ignores economic depreciation, we must still try to measure economic depreciation for use in national income and wealth accounting.

Section V of this paper reviews other approaches to measuring economic depreciation and compares the results with those obtained by the BEA and used-market-price approaches. The results of this larger literature are by no means unanimous in support of one particular methodology or of one set of empirical results. However, there is a surprising degree of consistency in the various measured rates of depreciation for different types of assets. One finds almost no support for the proposition that economic depreciation cannot be measured with sufficient precision to be useful in policy analysis.

## II. Terms, Definitions, and Theoretical Framework

In our discussion of the measurement of economic depreciation, we will have frequent occasion to refer to the underlying theoretical structure of the problem. It is therefore useful to provide an overview of the theory of economic depreciation.<sup>5</sup> Depreciation theory involves distinguishing between the value of the stock of capital assets and the annual value of that asset's services, distinguishing between depreciation and inflation as sources of the change in asset value, and distinguishing between the depreciation in asset values and deterioration in an asset's physical productivity.

In theory, the price of a *new* asset is determined by the equilibrium between the cost of producing the asset and the value of the asset to the buyer. The value to the buyer may be related to the return obtained by renting the asset to subsequent users, or "renting" the asset to oneself. In the latter case, (i.e., when the asset is owner-utilized), the value of the capital services is usually called the quasi-rent or user cost. Under perfect foresight (i.e., perfect information about the future), the value of the asset is simply the present value of the rents or user costs.<sup>6</sup> In reality, other methods may be used in relating expected rents and user costs to asset values (e.g., the payback period approach).

Individual assets may or may not be resold after they are first put in place. If they are sold, the transaction price would reflect the remaining present value of the asset (adjusted perhaps for the risk of acquiring a defective asset). On the other hand, used assets which are not on the market also have a remaining present value. In principle, this remaining value is the same as the price of an identical market asset. (For this reason the in-place value of an asset can be called the 'shadow price'). There is an active controversy in the economic literature as to whether marketed used assets are really typical of the same type and vintage of unmarketed assets, or whether marketed assets are sold at a systematic risk discount. This problem, known as the 'lemons' problem, is discussed in detail below.

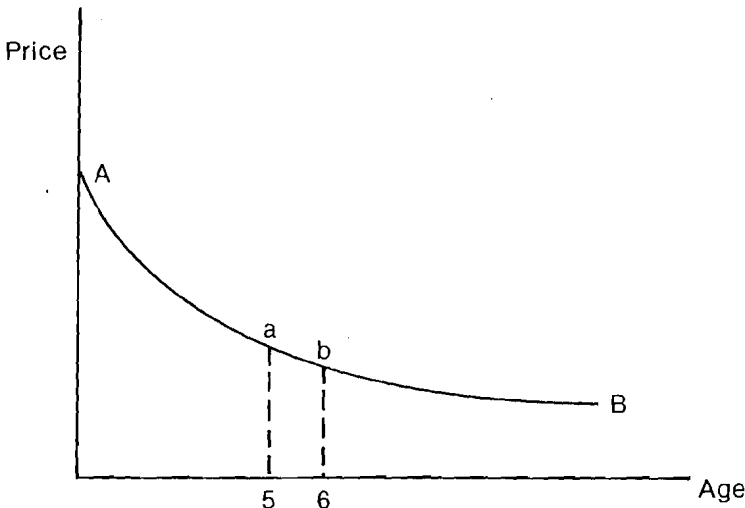
The central issue in depreciation theory is *how* the market (or shadow) prices of a collection of identical assets change with age. The older assets in the collection should be less valuable than the newer ones for two reasons: (1) the age of 'optimal' retirement from service is nearer for the older assets and (2) older assets may be less profitable because they either produce less output or because they require more input (i.e., maintenance) to operate. At any given point in time, an age-price profile of the collection of assets should be downward sloping. (A few types of assets,

like wine, may improve with age, but they are a relatively insignificant component of the stock of depreciable capital). This decline in asset value with age is portrayed in figure 1. Figure 1 shows an age-price relationship in which the largest rate of price decline occurs in the early years of asset life. Had we drawn the age-price profile as a straight line, we would be portraying the case in which asset values decline in equal increments with age (an assumption popular in the accounting literature).

We define *economic depreciation* to be the decline in asset price (or shadow price) due to aging. In terms of figure 1, the value of a five-year old asset is represented by point *a* on curve AB, and the value of a six-year old asset by the point *b*. Economic depreciation is therefore equal to the difference (on the vertical axis) between *a* and *b*. The *rate* of economic depreciation is the elasticity of the curve AB between *a* and *b* or, equivalently, the percentage decline in asset price between these two points. The rate of depreciation usually varies with age, but in the special case in which AB has the geometric form, the rate of depreciation is constant. When AB is a straight line, economic depreciation is also said to be 'straight-line', but the *rate* of depreciation actually increases as the assets age.

FIGURE 1

*Age-Price Profile for a Homogeneous Class of Assets*

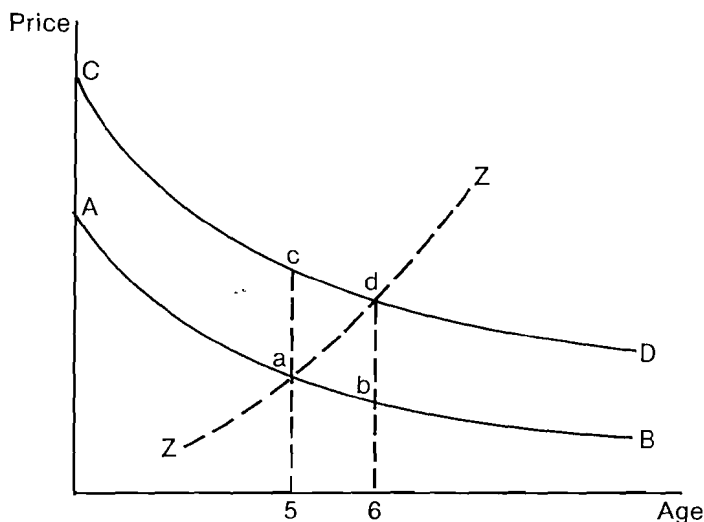


The curve AB is defined as the age-price profile of a collection of homogeneous assets at a *given* point in time. In the absence of inflation and obsolescence, AB would also trace out the price history of a single asset over time. In this special case, the *difference* in price between a five- and six-year old asset in 1979 would be the same as the *change* in the price of a given asset which is five years old in 1979 and six years old in 1980. If, however, inflation occurs between 1979 and 1980, this equivalence is no longer valid. The asset which is five years old in 1979 may actually be more valuable in 1980 because of inflation, even though it is one year older and has thus experienced an additional year's depreciation. The price history of this asset is clearly not equivalent to the movement along the curve AB from *a* to *b*.

Since inflation is a modern reality, it must be incorporated into our framework. This can be done by observing that inflation causes the prices of assets of all ages to increase.<sup>7</sup> In terms of the figure 1, the 1979 asset prices on line AB shift upward to line CD in 1980. The price of a five-year old asset in 1980 is now *c*, and a six-year old asset is *d*. The price history of the asset described in the preceding paragraph follows the curve ZZ, since the five-year old asset in 1979, located at *a*, is located at *d* when it is six years old in 1980. Fortunately, the movement along ZZ from *a* to *d* can be decomposed into two components: a movement along AB from *a* to *b*, and a shift in the curve from *b* to *d* (alternatively, we could think of this process as a shift from *a* to *c*, and a movement along CD from *c* to *d*).<sup>8</sup> The *ab* component of the total price change along ZZ is a pure aging effect, since it represents the change in asset price from one age to the next holding time constant. It therefore satisfies our previous definition of economic depreciation. The *bd* component represents the change in asset price due to inflation. The basic result, then, is that the change in asset price over time has two components, one due to depreciation and one due to inflation.

The depreciation-inflation distinction is central both to the theory and to the measurement of depreciation. Technological obsolescence is yet another important distinction. Assets built in one year frequently embody improvements in technology and design which make them superior to assets built in previous years. If we designate the year in which a cohort of assets is built as the *vintage* of these assets then we can frame this problem as the technological superiority of one vintage over another. Such technical superiority would normally make the assets of one vintage more valuable than those of another vintage. This, in turn, should drive a wedge

FIGURE 2

*The Age-Price Profile in the Presence of Inflation*

between the asset values of different vintages, and result in a price effect called obsolescence.

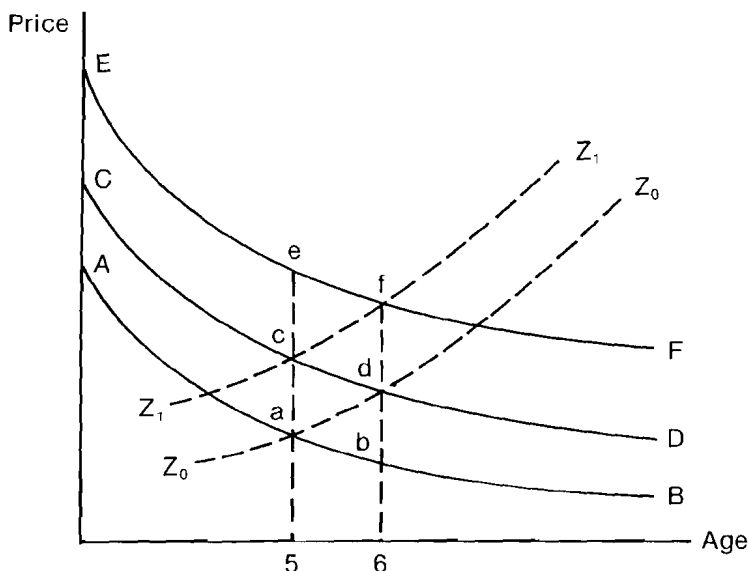
The price history of different vintages can be portrayed in the framework of figure 2. The price history of a given asset is represented in figure 2 by the curve ZZ. Figure 3 expands this diagram by adding the price history of assets built one year later. The resulting curves  $Z_0Z_0$  and  $Z_1Z_1$  thus portray the price histories of two successive vintages, and it is natural to look for the effect of obsolescence in the relationship between these two curves. Unfortunately, as shown in the seminal paper by Hall (1968), the trend effects of age, inflation, and obsolescence cannot be separately measured within the asset price framework of figure 3. He shows that the trend effect of obsolescence *is already* built both into the age-price profiles AB, CD, and EF, and into the distance between these profiles. This implies that the depreciation effect measured by the move from *a* to *b* in figure 2 combines pure depreciation with obsolescence and also that the inflation effect measured by the shift from *b* to *d* combines pure inflation and obsolescence.

Before concluding this section, a further distinction will prove useful in



FIGURE 3

*Price-History Curves (ZZ) of Assets of Different Vintage*

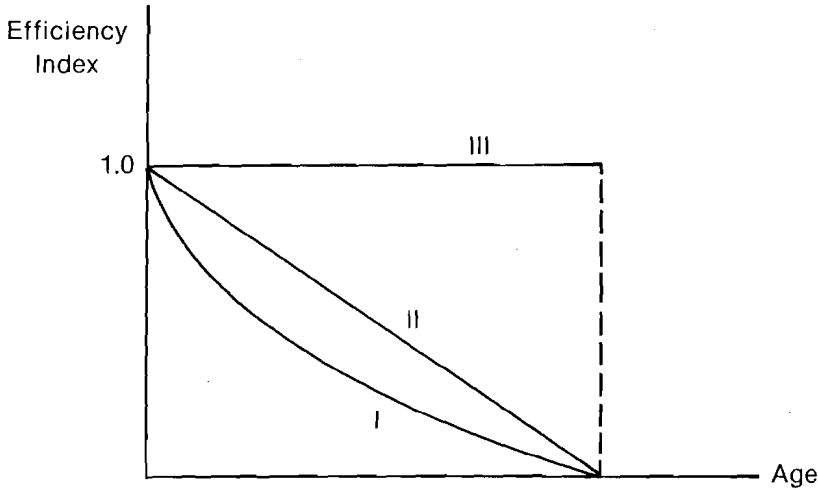


the following discussion of empirical results. We have dealt, so far, with the *value* of new and used assets, and defined economic depreciation as the decline in asset price associated with aging. Assets may also experience a decline in physical efficiency with age. A complete treatment of the relationship between declining physical efficiency (a quantity concept) and economic depreciation (a price concept) is beyond the scope of this paper.<sup>9</sup> It is sufficient for our purposes to note that the physical efficiency of a new asset can, in the absence of obsolescence, be assigned an efficiency index equal to one, and the efficiency index of a used asset can be defined as the marginal rate of substitution in production between that used asset and the new asset.<sup>10</sup> When obsolescence occurs, the efficiency index of new assets increases over time.

Figure 4 portrays three asset efficiency indexes associated with three possible efficiency decay processes. Curve I depicts geometric decay, in which the asset loses efficiency at a constant percentage rate (a melting block of dry ice or radioactive decay are two graphic examples), curve II depicts a straight-line decay process in which the asset loses efficiency in

FIGURE 4

*Alternative Efficiency Profiles for Three Types of Processes: geometric decay (I), straight-line decay (II), and one-horse-shay decay (III).*

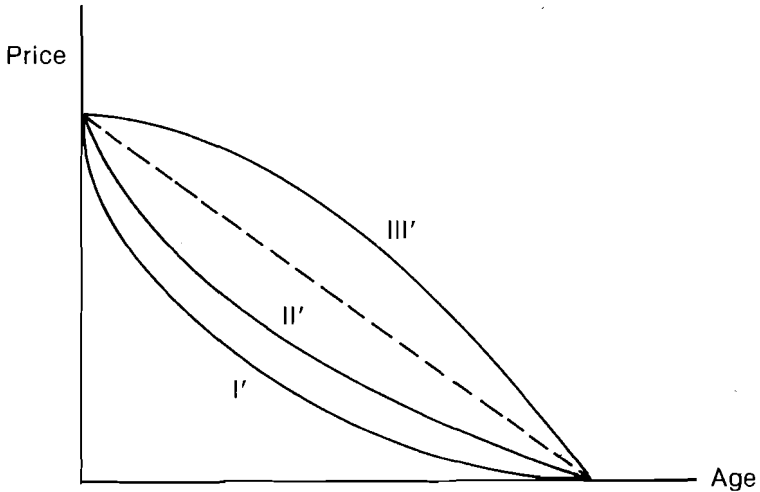


equal increments over its life. Curve III is the one-horse-shay pattern in which the asset retains its full efficiency until the moment it is retired from service (as in the case of a light bulb which burns with full brightness until it fails).

What is the relationship between the asset efficiency profiles of figure 4 and the shapes of the age-price profiles of the preceding figures? The answer is that, in most cases, the two profiles have different shapes. Only when the efficiency profile is geometric (curve I in figure 4) will the age-price profile (AB in figure 1) also be geometric, and vice versa. It cannot be overemphasized that this is the only case in which the efficiency profile and the age-price profiles have the same form. In all other cases, the two profiles differ. For example, straight-line decay (curve II in figure 4) implies a convex age-price profile (curve II' in figure 5). Conversely, a straight-line age-price profile (the dashed line in figure 5) implies a convex efficiency decay curve (i.e., one which is shaped like curve I in figure 4 but which is not geometric). Furthermore, the one-horse-shay efficiency profile (curve III in figure 4) does not lead to similar squared-off age-price profile, but rather to an average age-price profile like curve III' in figure 5.

FIGURE 5

*The Age-Price Profiles Corresponding to the Efficiency Profiles of figure 4: geometric decay (I'), straight-line decay (II'), and one-horse-shay decay (III')*



We have emphasized the general nonequivalence between the age-price profiles and asset efficiency profiles because it is probably the most misunderstood relationship in all of depreciation theory. Note, also, that asset efficiency profiles form the basis for calculations of physical capital stocks, whereas the corresponding age-price profiles form the basis for calculations of the capital income flows.

### III. The Estimation of Economic Depreciation from Used Asset Prices

The analytical framework set out in the preceding sections will now be applied to the problem of estimating depreciation. In the first part of this section, we will describe an econometric model based on that framework. We will also report actual estimates of the rate of economic depreciation for 32 types of plant and equipment. These estimates are assessed in the second part of this section, with special attention given to the lemons problem.

## A. THE ECONOMETRIC MODEL

Given a sufficient quantity of market price data, the age-price profiles AB and CD in figure 2 could be calculated directly. The average price of five-year old assets which were purchased in 1979 would be given, and the result plotted as point *a*. Point *b* would then be the average price of six-year old assets bought in 1979, etc. In this way, the whole curve AB would be traced out. The rate of depreciation could then be calculated directly as the percentage change between adjacent prices.

Such a procedure would, however, miss an essential point. Used market prices reflect only the value of assets which have survived long enough to be eligible for sampling. For example, the average market price of 10-year old cars represents the value of cars which have survived 10 years. Many cars of this vintage (i.e., cars put in service 10 years previously) have already been retired from service. The price of surviving assets does not, therefore, accurately measure the average experience of the vintage as a whole. This is unfortunate, since we are typically interested in evaluating policy as it pertains to a whole vintage of assets, or in measuring the amount of capital represented by the vintage.

In the terminology of econometrics, this problem is known as a 'censored sample bias.' This type of bias has been widely discussed in the context of labor supply schedules, where the part of the potential work force leaves the labor market, and where data is frequently 'capped' (meaning that incomes above a certain cutoff point are identified only as being larger than the cutoff amount). In the current context, the retirement of assets from service has the effect of censoring each vintage of assets.

We have corrected for censored sample bias in our analysis of used asset prices by multiplying each price by an estimate of the probability of survival. For example, the price of a five-year old asset is multiplied by the probability of having survived five years, that is, of not being retired in the first four years. If the assets which *were* retired in the first four years generated no net income at retirement (because removal and demolition costs just balanced scrap value), then the value of these retired assets to the original vintage is zero. The *average* price of assets in the fifth year of the vintage's existence is thus the price of surviving assets, multiplied by the probability of survival, plus the zero value of retired assets times the probability of retirement. The average price of assets in the vintage is therefore equal to the price of survivors multiplied by the probability of survival. The outcome of this analysis is that our procedure for dealing with censored sampled bias is equivalent to converting the price of surviving assets into an average price which takes into account both survivors and nonsurvivors.<sup>11</sup>

We applied this procedure to a diverse sample of used asset prices. For nonresidential structures, we used the sample collected by the Office of Industrial Economics, which is summarized in *Business Building Statistics*. For machinery and equipment, we used the machine tools sample collected by Beidleman, and we developed data on construction machinery, autos, and office equipment from a variety of sources, including the *Forke Brothers Bluebook*, *Ward Automotive Yearbooks*, *Kelly Bluebooks*, and auction reports from the General Services Administration.<sup>12</sup> The survival probabilities used to adjust this data were based on the Winfrey retirement distribution and *Bulletin F* mean asset lives.<sup>13</sup>

While the data samples contained a great quantity of information, there were not enough data to completely fill out the age-price profiles AB, CD, etc. of figure 2, for a reasonable number of years and asset ages.<sup>14</sup> Thus, it was necessary to estimate these age-price profiles econometrically. The prime consideration in selecting an econometric model is that the model be sufficiently flexible to avoid indirectly limiting the shape of AB. For example, if a linear regression model were selected, we would be assuming that the age-price profiles were all linear. In order to avoid this problem, we selected a highly flexible model which contains all the age-price profiles shown in figure 5 (geometric, linear, one-horse-shay) as special cases.

This model, the Box-Cox power transformation, involves jointly estimating the parameters which determine specific functional forms within the Box-Cox class, and the parameters which determine the slope(s) and intercept of the equation.<sup>15</sup> Unlike the standard regression model, the Box-Cox model assigns two parameters to each regressor. Letting  $q_i$  represent the market transaction price of an asset of age  $s_i$  in year  $t_i$ , we apply the Box-Cox model to the used asset pricing problem in the following way:

$$q_i^* = \alpha + \beta s_i^* + \gamma t_i^* + u_i \quad i = 1, \dots, N \quad (1)$$

where

$$q_i^* = \frac{q_i^{\theta_1} - 1}{\theta_1}, \quad s_i^* = \frac{s_i^{\theta_2} - 1}{\theta_2}, \quad t_i^* = \frac{t_i^{\theta_3} - 1}{\theta_3} \quad (2)$$

and where the subscript  $i$  indexes observations from 1 through  $N$ , and the  $u_i$  are  $N$  independent random disturbance terms which are assumed to be normally distributed with zero mean and constant variance  $\sigma^2$ .<sup>16</sup> The unknown parameters  $\theta = (\theta_1, \theta_2, \theta_3)$  determine the functional form within the Box-Cox power family, whereas the unknown parameters  $(\alpha, \beta, \gamma)$  determine the intercept and slope(s) of the transformed model.

To see the degree of flexibility associated with the Box-Cox model, it is

useful to compare equations (1) and (2) to the age-price profiles of figure 5. When  $\theta = (0, 1, 1)$ , the Box-Cox model has the semi-log form, and is equivalent to the geometric curve I' of figure 5.<sup>17</sup> When  $\theta = (1, 1, 1)$ , the Box-Cox model is linear, and is equivalent to the dotted straight line in figure 5. When  $\theta = (1, 3, 1)$ , curve III' is reproduced. Note, also, that the time variable  $t$  allows for shifts in the age-price profile. In terms of figure 2, the time variable allows for the profile to shift from AB to CD.

The Box-Cox model was applied to our various samples, and the parameters were estimated using maximum likelihood methods. We then used the asymptotic likelihood ratio test to determine which case, the geometric, linear, or one-horse-shay fit the data best. We found that, in general, none of these alternatives is statistically acceptable. However, we also found that the age-price profiles estimated using the Box-Cox model were very close, on average, to being geometric in form. In other words, when we plotted the age-price profiles implied by the Box-Cox parameter estimates, they looked very much like the curve I' in figure 5.

The approximately geometric form of the age-price profiles for assets ranging from buildings to machine tools to construction equipment is the most significant finding of our research. It is particularly important when one recalls that the geometric form is the only pattern for which the associated rate of depreciation is constant. Geometric age-price profiles imply that each class of assets in our sample can be approximately characterized by a single constant rate of depreciation (although the actual average rates of depreciation vary among asset classes).

In order to find the constant rate of depreciation associated with each asset class, we estimated the geometric curve which most nearly fit the corresponding Box-Cox age-price profile. We did this by regressing the logarithm of the Box-Cox fitted prices (i.e., the estimated values of  $q_i$  in (1)) on age,  $s$ , and year,  $t$ . The coefficient of age in this regression is the predicted average percentage change in asset price for a one-year change in age. Since this percentage corresponds to the definition of economic depreciation given in section II, the coefficient of age can be interpreted as the average geometric rate of depreciation associated with each asset class.<sup>18</sup> We also calculated the  $R^2$  statistic for each of these regressions and found that the geometric approximation provided very close fits to the underlying Box-Cox age-price profiles.

The analysis, as outlined, left us with summary rates of depreciation for a large and diverse variety of assets. The list of assets studied, however, did not come close to providing a comprehensive characterization of depreciable assets used in business. What is needed for policy analysis and capital stock estimation is a summary rate of depreciation for each of the

22 types of producers' durable equipment and 10 types of nonresidential structures defined in the *U.S. National Income and Product Accounts* (NIPA). For those NIPA asset classes that contained our asset types, we used an average of our depreciation rates. For example, we averaged the rates of depreciation for the four types of machine tools in our study to obtain an average rate for the NIPA classes 'metal working machinery' and 'general industrial equipment.' Using this approach, we derived depreciation rates for 8 of the 32 NIPA assets categories: tractors, construction machinery, metalworking machinery, general industrial equipment, trucks, autos, industrial buildings, and commercial buildings. Although only a quarter of the asset categories are accounted for by this approach, these categories included 55 percent of 1977 NIPA investment expenditures on producers' durable equipment and 42 percent of 1977 NIPA investment in nonresidential structures.<sup>19</sup>

Depreciation rates for the remaining 24 NIPA asset classes were derived by exploiting the fact that all of the assets in our sample seemed to have approximately geometric age-price profiles. Since assets as diverse as buildings and machine tools seemed to have the geometric form, we thought it reasonable to impose this form on the asset categories for which we had no direct information. The geometric form implies a constant rate of depreciation,  $\delta$ , for these classes. Furthermore, the rate of depreciation can (by definition) be written:

$$\delta \equiv \frac{R}{T} \quad (3)$$

where  $T$  is mean asset life and  $R$  is called the declining balance rate, (i.e., when  $R$  equals two, (3) defines the double-declining balance form of depreciation).

The problem now is to impute a value for  $\delta$  for each NIPA asset class. This was done by observing that the BEA capital stock studies contain estimates of  $T$  for each of the 32 asset categories in question. We estimated the average  $R$  for the four equipment categories for which information was available using  $R = \delta T$ . The resulting value for  $R$  was 1.65. The average value for the two types of structures was found to be 0.91. We then estimated the depreciation rate for the remaining equipment categories using the relationship  $\delta = (1.65)/T$ ; the remaining structure categories were estimated using  $\delta = (0.91)/T$ .

Table 1 sets out the results of these calculations. The average rate of depreciation for equipment was found to be 13.3 percent. The average

TABLE 1  
ASSET CLASSES AND RATES OF ECONOMIC DEPRECIATION  
(ANNUAL PERCENTAGE RATES OF DECLINE)

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Producer Durable Equipment	
1. Furniture and fixtures	.1100
2. Fabricated metal products	.0917
3. Engines and turbines	.0786
4. Tractors	.1633
5. Agricultural machinery (except tractors)	.0971
6. Construction machinery (except tractors)	.1722
7. Mining and oilfield machinery	.1650
8. Metalworking machinery	.1225
9. Special industry machinery (not elsewhere classified)	.1031
10. General industrial equipment	.1225
11. Office, computing, and accounting machinery	.2729
12. Service industry machinery	.1650
13. Electrical transmission, distribution, and industrial apparatus	.1179
14. Communications equipment	.1179
15. Electrical equipment (not elsewhere classified)	.1179
16. Trucks, buses, and truck trailers	.2537
17. Autos	.3333
18. Aircraft	.1833
19. Ships and boats	.0750
20. Railroad equipment	.0660
21. Instruments	.1473
22. Other	.1473
Private Nonresidential Structures	
1. Industrial	.0361
2. Commercial	.0247
3. Religious	.0188
4. Educational	.0188
5. Hospital and institutional	.0233
6. Other	.0454
7. Public utilities	.0316
8. Farm	.0237
9. Mining exploration, shafts, and wells	.0563
10. Other	.0290

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SOURCE: The Hulten and Wykoff studies of economic depreciation.



rate for structures was found to be 3.7 percent.<sup>20</sup> Autos had the largest depreciation rate (33 percent), with office equipment and trucks following (25 and 27 percent respectively). Other equipment categories had depreciation rates ranging from 6.6 percent to 18.3 percent, a not unreasonable range of rates. The depreciation rates for structures were considerably lower, ranging from 1.9 percent to 5.6 percent.

We wish to emphasize, at this point, that the numbers shown in table 1 are in no way intended to be definitive estimates of depreciation. There is a great deal of room for further research, particularly in the areas of (1) improved estimates of the retirement process (and thus of the survival probabilities used to weight the data); (2) larger and more detailed samples of those assets included in our statistical analysis; (3) extension of the list of assets for which used assets prices can be analyzed; and (4) improvements in the method for inferring the depreciation rates for assets for which no market information exists. We offer table 1 as an example of what can be achieved with the used asset price approach and as a basis of comparison with existing methodologies and results.

#### B. THE LEMONS PROBLEM

The depreciation rates shown in table 1 are derived (directly or indirectly) from information on the price of used capital assets. If these estimates are to be of any use in policy analysis or capital stock estimation, the market oriented estimates must also be applicable to those assets which are never sold. This raises the issue of whether a systematic difference exists between assets which find their way into used markets and those which are held until retirement by their original owners. Proponents of the lemons argument would say that a substantial difference does indeed exist.<sup>21</sup>

The lemons argument may be explained in the following way. Suppose that a certain type of machine is produced so that some units are defective and will subsequently require a great deal of maintenance, while others will require only a nominal amount of maintenance. Suppose, furthermore, that the two types of machines (lemons and pearls, respectively) are outwardly identical so that neither buyer nor seller initially knows which is which. Of course, once the machine is put in place, the owner is able to tell which sort of machine he has. If the machine is a lemon, the owner may wish to sell it in the used machine market, since prospective buyers cannot (by hypothesis) distinguish lemons from pearls.

The outcome of the Lemons Model is that lemons dominate the used

machine market. This occurs through the following process: owners of pearls will tend to hold on to their high quality machines rather than risk replacement with new or used lemons. Owners of lemons, on the other hand, have an incentive to get rid of their machines with the hope of duping an unaware buyer. As a result, lemons will begin to appear on the used machine market with a much greater proportion than their share in the new machine market. If the owners of pearls must sell, then they have a strong incentive to go outside the organized used machine market to trade with an acquaintance with whom their credibility is established and who will accept the statement that the machine is a pearl. In this way, the original owner of the pearl can extract the maximum price for the machine. The result is that buyers increasingly assume that marketed used machines are lemons and thus offer reduced prices as a hedge against the increased probability of acquiring a lemon. Lower average used market prices act as a further disincentive to the sale of used pearls, and ultimately an equilibrium is reached in which only lemons are sold in used markets.

Asymmetric market information is, of course, the essence of this result. Sellers, with more information about asset quality than buyers, exploit this informational advantage and offer only lemons. Buyers soon come to realize that the appropriate strategy is to assume that they are buying a lemon, and offer only lemon prices. If, on the other hand, buyers and sellers have the same information, then the lemons dominance does not hold. Under equal information, lemons and pearls will receive their true separate value in used asset markets, and there is no advantage (in equilibrium) to selling a lemon or to withholding a pearl.

The Lemons Model is thought by some to characterize the market for used business assets. Were this contention true, then the market-oriented depreciation rates of table 1 would not be representative of all vintage assets. Now, while it is plausible to assume a priori that the owner will know more about his asset than a prospective buyer, this assumption fails to take into account the nature of prospective buyers. Buyers of used business assets are typically specialists at buying and refurbishing used assets for resale (often under warranty). Many used-asset buyers acquire and then resell used equipment as a routine and ancillary part of their enterprise, (i.e., construction contractors and commercial real estate investors). In both cases, buyers of used business assets are likely to have both the incentive and expertise to identify unprofitable assets (those whose prices do not reflect their in-place value).

We have now seen that the viability of the lemons argument depends on

the assumption of asymmetric information. In fact, the extent to which the Lemons Model applies to the market for used business assets is ultimately an empirical issue. It is, in principle, possible to compare marketed and unmarketed assets of a given type to see what difference, if any, really exists. If a given asset is truly a lemon, then there must be some observable manifestation of this fact such as increased maintenance costs or increased breakdown rates. If such manifestations do not appear, then one would be inclined to be skeptical of the Lemons Model. Where differences do exist, their importance can be evaluated and then perhaps used to correct the observed market prices.

One piece of evidence which tends to reject the importance of the Lemons Model is found in the market for heavy construction machinery. Construction machinery (e.g., D-7 tractors) are frequently sold after the completion of a given contracted project and are then repurchased when new work is begun. There is little reason to believe that the assets in this market are lemons. Indeed, the routine sale and resale of equipment in a comparatively active auction market would seem to be testimony to the fact that lemons are not a practical problem. Our analysis of this particular market shows that the age-price profiles of construction equipment are very nearly geometric, just like the profiles of the other assets in our Box-Cox analysis. This point is significant, because proponents of the Lemons Model have argued that the age-price profiles can *appear* to be geometric because (a) used asset prices reflect lemons dominance; (b) lemons are heavily discounted relative to typical used assets still in place, and thus (c) the price of used marketed assets is seen to fall rapidly in the early years of asset life, which gives rise to the apparent geometric age-price profile. The construction equipment market serves as a counter-example to this line of reasoning.<sup>22</sup>

Before leaving this section, we shall consider one further criticism of the used market approach to measuring depreciation. Taubman and Rasche (1971) and Feldstein and Rothschild (1974) both note that the price of used assets depends on taxes, interest rates, and other variables which are subject to change over time. When such changes occur, asset prices will also change, and there is no a priori reason to believe that the rate of depreciation (i.e., the rate of change of the asset price) remains constant.<sup>23</sup> In order to evaluate this possibility, we took one of our largest samples (office buildings) and applied the Box-Cox analysis to individual years in that sample (i.e., we calculated Box-Cox estimates separately for 1951, 1954, etc.). We then applied a statistical test to see if the parameter estimates changed from year to year, an implication of the variability of

asset prices. We found almost no statistical evidence that parameters changed significantly over time, and we therefore concluded that this instability issue did not appear to pose a major problem for our analysis.<sup>24</sup>

#### IV. The Bureau of Economic Analysis Methodology<sup>25</sup>

The capital stock studies of the U.S. Bureau of Economic Analysis provide a natural basis for evaluating our depreciation estimates which were obtained from the used market price approach. BEA capital stock estimates have been widely used by economists, and, since 1976, BEA has presented a revised version of the *U.S. National Income and Product Accounts* which substitutes their estimate of economic depreciation for the alternative tax based estimate used in the main version of the NIPA, (i.e., "economic" depreciation is substituted for the depreciation allowances claimed by taxpayers).<sup>26</sup>

The BEA provides estimates of gross and net capital stocks for a variety of assets and sectors. Since our intent is to compare our approach with that of BEA, we will restrict our attention to the 32 categories of producers' durable equipment and nonresidential structures which appear in table 1. We will also restrict our comparison to the calculation of net (rather than gross) capital stocks. (The gross stock concept is meaningful only if efficiency change follows the one-horse-shay pattern of curve III in figure 4. Since our used market price results have rejected the one-horse-shay pattern, we omit gross stocks from our comparisons).

The BEA uses a capital stock methodology which focuses on physical quantities rather than prices and income, and their approach therefore refers to the quantity framework of figure 4 rather than to the price framework of figure 5. However, in the case of geometric depreciation (and only in this case), the rate of (price) depreciation is the same as the rate of change of physical capital used up in production (i.e., the rate of "physical depreciation" or replacement). The geometric price depreciation rates of table 1 can thus be reinterpreted as rates of physical depreciation and compared to BEA physical depreciation rates.

The BEA procedure for imputing physical depreciation is based on the Winfrey retirement studies and on *Bulletin F* asset lives. (Recall that we also used these sources in our calculation of our survival probabilities).<sup>27</sup> The actual imputation procedure is rather complicated, but an illustrative example will be useful. Suppose that \$300 of a particular type of asset was produced in 1975. BEA procedures would assign to that vintage of assets a

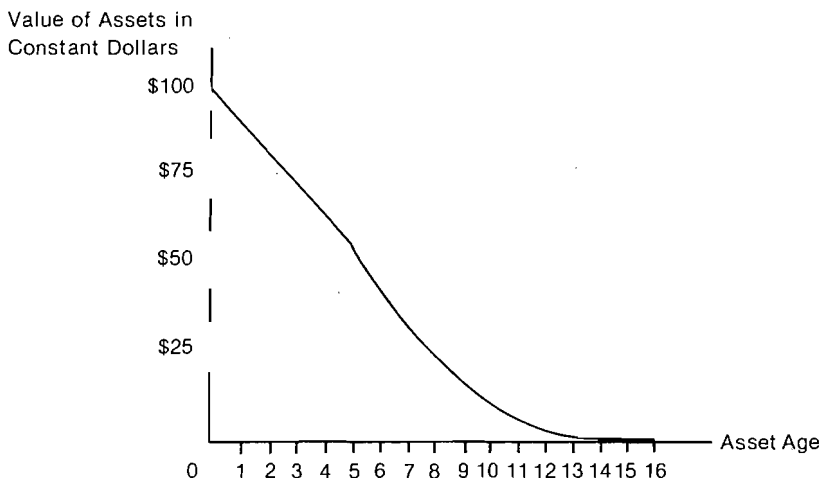
*mean useful life*, (say 5 years), and a retirement pattern (say one-third of the vintage retired at the mean life and one-third in the years immediately preceding and following the mean life). Three subcohorts are then created from the original \$300 asset investment: a \$100 subcohort with a four-year life, a \$100 subcohort with a five-year life, and a \$100 subcohort with a six-year life. The first subcohort is depreciated using the straight-line form and a four-year life; the five- and six-year subcohorts are depreciated using straight line with five and six years lives. Total depreciation attributable to this whole vintage cohort is therefore \$61.67 in each of the first four years ( $\$25 + \$20 + \$16.67$ ), \$36.67 in the fifth year, and \$16.67 in the sixth and last year of the cohort's existence. The original \$300 is added to the perpetual inventory of cumulative gross investment, and the depreciation deductions are added to the inventory of accumulated depreciation. The net capital stock is the difference between the two inventories.

As noted, the actual mean useful asset lives for plant and equipment are based on the allowable IRS tax lives published in the 1942 edition of *Bulletin F*. The *Bulletin F* lives are shortened by 15 percent to reflect the belief that the original lives were probably too long. Alternative estimates based on the original lives and on 25 percent shorter lives are also calculated. The retirement distribution used by BEA for plant and equipment is a truncated form of the 1935 Winfrey S-3 distribution. The S-3 distribution is a bell shaped distribution which has been truncated so that no retirement occurs before 45 percent of mean useful life and retirement is completed at 155 percent of useful life. The subcohorts defined by the S-3 distribution are "depreciated" using the straight-line form, although alternative estimates using the double declining-balance form are also calculated. An adjustment for accidental damage is added to the "depreciation" estimates.

The combined effects of straight-line depreciation and S-3 retirement can lead to potential confusion about the actual form of BEA depreciation. While each subcohort is depreciated using the straight-line form, retirement is also occurring, and the depreciation of the cohort as a whole is accelerated relative to straight-line. Figure 6 depicts a BEA efficiency profile based on our analysis of their procedures which is conceptually analogous to the curves shown in figure 4. In figure 6, a \$100 cohort of assets is assigned a 10-year mean useful life, and retired according to the truncated S-3 distribution. For the first  $4\frac{1}{2}$  years, the depreciation of the cohort as a whole follows the straight-line pattern. This is reflected in figure 6 by a linear decline in the value of assets remaining in the cohort.

FIGURE 6

*Depreciation Profile for an Investment Cohort  
under BEA Capital Stock Methodology*



After 4 1/2 years, the retirement process begins and the value falls off more rapidly than straight-line, and then begins to level off, and at 15 1/2 years the cohort is fully depreciated. The depreciation pattern between 4 1/2 and 15 1/2 years is thus closer to the geometric (or constant rate) pattern than it is to the straight-line pattern. It would therefore be incorrect to say that the BEA procedures imply straight-line depreciation for each annual investment cohort taken *as a whole*.

The *actual* rates of depreciation implicit in the BEA methodology can be calculated using BEA data on gross investment. The starting point for this calculation is the BEA perpetual inventory method, which can be represented by the following equation:

$$K_t = I_t - D_t + K_{t-1} \quad (4)$$

where  $D_t$  is total physical depreciation (or loss of efficiency, in the terminology of section II) occurring on all assets in year  $t$ ,  $I_t$  is total gross investment, and  $K_t$  is the stock of capital. Defining the one-period rate of physical depreciation to be

$$\delta = \frac{D_t}{K_{t-1}} \quad (5)$$

equation (4) can be written

$$K_t = I_t + (1 - \delta_t) K_{t-1} \quad (6)$$

The parameter  $\delta_t$  is the rate of physical depreciation of the capital stock and combines the effects of retirement from service and the in-place loss of efficiency. The special case of geometric depreciation occurs when  $\delta_t = \delta$ , that is, when the rate of depreciation is constant over time.

Equation (6) can be rearranged to a yield a relationship which is useful in comparing BEA procedures to used market estimates of depreciation:

$$\delta_t = - \frac{K_t - K_{t-1} - I_t}{K_{t-1}} \quad (7)$$

We have used equation (7) to obtain the values of  $\delta_t$  implied by the BEA estimates of net capital stock and the underlying gross investment series. The average annual results for aggregate plant and equipment reported in table 2, and the results for the 32 asset classification are given in Appendix table A.1, for a 26-year period ending in 1974. Inspection of this table reveals that for equipment, the BEA  $\delta_t$  figures display a high degree of constancy. This observation is confirmed by a linear regression of  $\delta_t$  on time, that is,

$$\delta_t = \delta + \beta t + \epsilon_t \quad (8)$$

When corrected for first-order autocorrelation, only 5 of the 20 equipment coefficients of time were statistically significant at the 95 percent level. This implies that the hypothesis that  $\delta_t$  is constant cannot be rejected for a majority of PDE classes. The situation is different for nonresidential structures. Here, the coefficient of time was significant in 8 of the 10 classes, indicating that the rate of depreciation cannot be treated as being constant.

The relative constancy of the implicit BEA rates of depreciation for equipment may be somewhat surprising, in view of the widely held belief that BEA uses the straight-line depreciation method. Inspection of figure 6, however, shows that approximately two-thirds of a vintage cohort's life is spent in the convex (nearly geometric) portion of the depreciation profile. Given a more or less constant growth in total gross investment, this means that approximately two-thirds of all unretired investment is being depreciated with a nearly constant rate of depreciation. For short-lived assets (equipment), abnormally large or small variations in the quantity of gross investment will pass rapidly through the linear range of figure 6 into

the geometric range and will not exert a prolonged departure from the constant rate. With longer-lived assets (plant), the effects of large swings in gross investment are more pronounced, since the aberration occurs on the linear segment for a longer period of time. This effect may explain the greater variability in the rate of depreciation of structures.

The depreciation rates of table 2 were aggregated to the level of total plant and total equipment by applying equation (7) to the aggregate capital stock series.<sup>28</sup> As noted in the introduction, the aggregate BEA equipment rate is 14.1 percent while the used asset price rate for equipment is 13.3 percent. In view of the vast difference in the two methodologies, these rates are remarkably close. Indeed, in only 5 of the 22 equipment classes is the divergence in rates across methods more than 30 percent: tractors, construction machinery, autos, aircraft and railroad equipment. The first three of these categories were studied directly in our statistical samples, and therefore represent our best information. That three of the five equipment classes in our direct Box-Cox analysis should differ significantly from the BEA rates is somewhat unfortunate, but, in our judgment, for at least one of these classes (autos) the BEA estimates are suspect. Autos are the one class of equipment which BEA values directly, rather than employing the methodology underlying figure 6. The BEA autos' rate of 12.6 percent is far below the rates of depreciation usually found in the numerous studies of the auto market (and certainly does not conform to the intuition of those who drive airport rental cars with any degree of frequency).

The BEA aggregate structures rate is 6.0 percent, and the used asset price is 3.7 percent. A 6.0 percent depreciation rate for buildings and other structures seems (to us) to be somewhat high, but we do not have direct evidence to support this intuition.

The aggregate capital stock estimates corresponding to our table 1 rates of depreciation are shown in table 3. These stocks were calculated for the 32 asset categories of table 1 using BEA investment data to arrive at the aggregate figures for plant and equipment. The stock of aggregate equipment is \$451.9 billion in 1974, compared to \$434.7 billion using the BEA approach. These two estimates are obviously quite close. The structures comparison, on the other hand, is quite different. Our estimate of aggregate nonresidential structures is \$696.0 billion in 1974, while the BEA figure is \$530.3 billion. The used asset price approach thus leads to an estimate (in 1974) which is 31 percent larger than the corresponding BEA estimate. This difference could significantly alter the estimates of the differential return to various types of capital.<sup>29</sup>



TABLE 2  
COMPARISON OF DEPRECIATION RATES BY ASSET CLASS

ASSET CLASS	AVERAGE IMPLICIT BEA RATES	TABLE 1 RATES	PERCENTAGE DIFFERENCE BEA/TABLE 1 RATES
<b>A. Producers' Durable Equipment</b>			
Furniture and fixtures	.1267	.1100	15.18
Fabricated metal products	.1012	.0917	10.36
Engines and turbines	.0888	.0786	12.98
Tractors	.2542	.1633	55.66
Agricultural machinery	.1094	.0971	12.67
Construction machinery	.2316	.1722	34.49
Mining and oilfield machinery	.1924	.1650	16.61
Metalworking machinery	.1278	.1225	4.33
Special industry machinery	.1161	.1031	12.61
General industrial machinery	.1320	.1225	7.76
Office, computing, and accounting machinery	.2569	.2729	-5.86
Service industry machinery	.1860	.1650	12.73
Electrical and communication equipment	.1251	.1179	6.11
Trucks, buses, and truck trailers	.2301	.2537	-9.30
Autos	.1263	.3333	-62.11
Aircraft	.0755	.1833	-58.81
Ships and boats	.0947	.0750	26.27
Railroad equipment	.1697	.0660	157.12
Instruments	.1659	.1473	12.63
Other	.1695	.1473	15.07
<b>B. Nonresidential Structures</b>			
Industrial	.0721	.0361	99.72
Commercial	.0518	.0247	109.72
Religious	.0355	.0188	88.83
Educational	.0352	.0188	87.23
Hospitals and institutional	.0340	.0233	45.92
Other	.0600	.0454	32.16
Public utilities	.0588	.0316	86.08
Farm	.0466	.0237	96.62
Mining exploration, shafts and wells	.1174	.0563	108.53
Other	.0638	.0290	120.00

SOURCE: See text.

TABLE 3

COMPARISON OF AGGREGATE NET CAPITAL STOCKS  
(BILLIONS OF 1972 DOLLARS)

Year	TOTAL			EQUIPMENT			PLANT		
	Used Asset Price	BEA	Percentage Difference	Used Asset Price	BEA	Percentage Difference	Used Asset Price	BEA	Percentage Difference
1949	451.8	350.0	28.86	168.4	151.4	11.21	283.4	198.5	42.8
1950	469.4	367.5	27.62	177.2	162.1	9.36	292.2	205.4	42.2
1951	488.0	385.9	26.46	186.5	172.7	8.00	301.5	213.2	41.4
1952	503.1	401.1	25.43	193.1	180.5	6.96	310.1	220.5	40.6
1953	521.5	418.3	24.67	201.5	189.1	6.55	320.0	229.2	39.6
1954	537.0	432.6	24.13	206.5	194.1	6.41	330.4	238.5	38.5
1955	557.3	451.3	23.49	213.9	201.7	6.06	343.4	249.6	37.6
1956	579.8	472.2	22.79	221.9	209.4	5.97	357.9	262.8	36.2
1957	601.9	492.3	22.26	229.8	216.9	5.93	372.1	275.3	35.1
1958	615.0	504.4	22.19	203.7	217.9	5.88	384.2	285.3	34.7
1959	631.8	517.0	22.21	235.1	221.5	6.12	396.7	295.4	34.3
1960	651.6	533.0	22.25	240.3	225.9	6.40	411.2	307.1	33.9
1961	669.8	547.1	22.43	243.7	228.5	6.68	426.1	318.7	33.7
1962	692.1	565.3	22.43	250.1	223.9	6.90	442.1	331.4	33.4
1963	715.7	584.5	22.45	258.2	244.2	7.06	457.5	343.3	33.3
1964	745.0	609.5	22.23	270.5	252.4	7.17	474.5	357.1	32.9
1965	785.8	645.9	21.66	288.5	269.7	6.98	497.3	376.2	32.2
1966	832.8	689.2	20.84	310.9	292.0	6.45	521.9	397.1	31.4
1967	872.8	725.6	20.29	328.4	310.2	5.88	544.4	514.5	31.0
1968	914.4	763.2	19.81	347.2	329.4	5.40	567.3	433.8	30.8
1969	958.2	802.5	19.40	367.5	349.9	5.02	590.7	452.6	30.5
1970	993.4	833.7	19.16	381.0	364.4	4.57	612.4	469.3	30.5
1971	1023.8	859.5	19.12	391.3	375.4	4.22	632.5	484.1	30.7
1972	1060.2	889.8	19.15	407.0	390.4	4.25	653.2	499.4	30.8
1973	1106.3	929.5	19.02	431.6	414.3	4.16	674.8	515.2	31.0
1974	1148.9	965.1	19.04	451.9	434.7	3.95	696.0	530.3	31.2

## V. Review of Other Studies of Depreciation

The preceding sections have presented, and compared, two approaches to measuring depreciation. In this section, we will provide an additional perspective on the problem by giving an overview of other depreciation studies. We group these studies into two categories: studies which base their estimates of depreciation on price data (like the model of section III), and studies which base their estimates on nonprice information (like the BEA methodology of section IV). We shall review the former in part A of this section, and the latter in part B. Rather than aiming at a comprehensive literature review, we will try to indicate general directions of the relevant research.

### A. PRICE-ORIENTED STUDIES OF DEPRECIATION

Our study of used asset prices is by no means the first effort in this direction: the use of asset prices to study depreciation goes back at least as far as Terborgh (1954). The largest number of used price studies have dealt with automobiles: Ackerman (1973), Cagan (1971), Chow (1957, 1960), Ohta and Griliches (1976), Ramm (1970), and Wykoff (1970). Tractors have been studied by Griliches (1960), pickup trucks by Hall (1971), machine tools by Beidleman (1976), ships by Lee (1978), and residential housing by Chinloy (1977), and Malpezzi, Ozanne, and Thibodeau (1980). The statistical methods used in these studies vary greatly and include the analysis of variance model, the hedonic price model, and various linear and polynomial regression models. Many studies use dealers' price lists or insurance data sources rather than market transaction prices. Furthermore, none of these studies adjust for censored sample bias. However, even though methods do vary across studies, the general conclusion which emerges is that the age-price patterns of various assets have a convex shape (as in curve  $I'$  in figure 5). Some studies, particularly those of automobiles, found that depreciation was even more rapid than implied by the constant depreciation rate pattern of the geometric form.

We have summarized the rates of depreciation reported in the various studies in table 4. A comparison of the columns of table 4 shows reasonably close agreement between our auto estimate of table 1 and the estimates of the five other studies of the used auto market. Our estimate is at the top of the depreciation ranges of these studies, but it must be remembered that we have corrected for censored sample bias, and this has the effect of increasing the average estimated rate of depreciation. For this reason, we interpret our truck results as being basically consistent with the

TABLE 4  
A COMPARISON OF RESULTS FROM VARIOUS STUDIES  
OF USED ASSET PRICES

Study	Approximate Range of Depreciation Rates	Table 1 Rates	Implicit BEA Rates
Auto:			
Ackerman (1973)	28%-34%	33%	13%
Cagan (1971)	21%-30%		
Chow (1957, 1960)	19%-30%		
Ohta-Griliches (1976)	25%-33%		
Ramm (1970)	25%-30%		
Wykoff (1970)	17%-27%		
Pickup trucks:			
Hall (1971)	17%	25%	23%
Tractors:			
Griliches (1960)	11%-12%	10%	11%
Machine tools:			
Beidleman (1976)	4%-21%	12%	13%
Ships:			
Lee (1978)	12%-15%	7%	9%

study by Hall but our estimates are not in agreement with the Griliches study, nor is our estimate for 'ships and boats' in agreement with Lee's studies (the Lee study, however, refers to the Japanese fishing fleet and may therefore not correspond well to the NIPA 'ships and boats' category).

The general agreement with the geometric (or near-geometric) form of the age-price profiles, along with the rough consistency among depreciation rates in table 4, has led us to the following conclusion: used asset prices do contain systematic information about the pattern and rate of depreciation of capital assets which can be helpful in policy analysis and useful in capital stock measurement.

A second major component of the price-oriented literature on depreciation deals with rental prices rather than asset prices. The basic rental price approach is to estimate age-rent profiles instead of age-price profiles. The estimated age-rent profiles are potentially interesting because they relate directly to the asset efficiency profiles of figure 4. This relationship arises from the equilibrium relationship between rents and asset efficiency indexes, which (in the absence of obsolescence) takes the following form:

$$\Phi(s) = c(s)/c(0) \quad (9)$$

where  $\Phi(s)$  is the relative asset efficiency index of an  $s$  year old asset, and  $c(0)$  and  $c(s)$ , the rental prices (or quasi-rents) of new and  $s$  year old assets.<sup>30</sup> The curves in figure 4 are plots of the function  $\Phi(s)$ . Equation (9) indicates that the figure 4 curves can be inferred from data on relative rental prices.

Suppose, for example, that assets have the one-horse-shay form of asset efficiency. In this case, the  $\Phi$  function takes the following form:

$$\begin{aligned} \Phi(0) = 1, \quad \Phi(1) = 1, \quad \Phi(2) = 1, \quad \dots, \\ \Phi(T) = 1, \quad \Phi(T+1) = 0, \quad \dots \end{aligned} \quad (10)$$

that is, the asset retains full efficiency until it is retired at age  $T$ , and has zero efficiency thereafter. From (9), this form of the efficiency function implies that the rental prices are equal for all assets up to age  $T$ . When depreciation occurs at a constant (geometric) rate  $\delta$ , then the function takes the following form:

$$\Phi(s) = (1 - \delta)^s = c(0)/c(s) \quad (11)$$

equation (11) implies that the age-rent profile is also geometric. In general, the age-rent profile can assume any of the forms consistent with the form of the  $\Phi$  function, and the function can be estimated from rental data by normalizing the rental price of a new asset to equal one (again, this assumes no obsolescence). Given this normalization,  $\Phi(s) = c(s)$ .

The advantage of the rental price approach is that it sidesteps the issue of lemon-dominated used asset markets. Firms engaged in the leasing business would seem to have no incentive to provide their clients with lemons, since the lessor typically maintains the assets and the lessee usually has the option of not renewing the lease. On the other hand, rental prices are subject to another important source of sampling bias. This sampling bias is over and above the censored sample bias associated with the retirement process (which applies to both asset and rental prices). This additional source of bias in rental prices arises because leasing firms generally have an inventory of unrented assets (which, in buildings, takes the form of a nonzero vacancy rate). The charges on assets which are actually rented must include the cost of idle assets (vacancies), and rental charges are therefore not representative of the typical asset available for leasing.

Firms typically deal with the idle asset (vacancies) problem by offering discounts on long-term leases. A recent inquiry to a leasing firm uncovered the following pricing schedule for a portable computer terminal:

TABLE 5

Length of Lease	Annual Rental Cost
2	\$996
3	\$775
4	\$678
5	\$612

This leasing rates schedule indicates a considerable incentive for lessees to undertake long-term contracts. From the standpoint of lessees, discounts for long-term contracts compensate for the decreased flexibility implied by the long-term commitment as well as for the implicit requirement to use the asset when it is older (and potentially more obsolete) in the later years of the contract.

The econometric problem with the availability of long-term leases is that there is, by the terms of the lease, no variation in rentals with age. In view of equation (10), this leasing practice implies that an analysis of rents would be biased in favor of the one-horse-shay hypothesis. Thus, even if asset efficiencies followed the geometric pattern of equation (12), a market dominated by long-term leases would give the impression that (11) is the correct form.

The well-known Taubman and Rasche study of office building rentals found a one-horse-shay pattern of asset efficiency, and in assessing their results the remarks of the preceding paragraph should be borne in mind. While, of course, a potential for bias does not necessarily mean that it exists, one must realize that office space is frequently rented under long-term lease agreements. In this context, the study of Malpezzi, Ozanne, and Thibodeau of residential rentals is extremely interesting. Residential units (apartments and houses) are typically rented with leases of one year duration or less, and Malpezzi, Ozanne, Thibodeau found the age-rent profile for this type of asset to be geometric. This finding, along with our analysis, suggests to us that (a) the rental price and asset price approaches are inherently consistent, and (b) that the one-horse-shay pattern found by Taubman and Rasche may have been the result of long-term lease bias.

The above observations are particularly important since the Taubman and Rasche "one-horse-shay" finding could be interpreted as implying the existence of a lemons bias in the used asset approach.<sup>31</sup> If depreciation were, in fact, one-horse-shay, then the geometric age-price profiles could reflect price profiles of lemons only (i.e., the rapid fall in price during the

early years of asset life could be due to the fact that only lemons are entering the used asset markets). If, however, it is the Taubman-Rasche result which is biased (and we believe it to be biased upward), then their result obviously cannot be adduced as evidence in favor of the lemons argument. One should note, however, that regardless of the true form of the depreciation pattern, the central conclusion of this paper, that economic depreciation can be measured, still holds.

#### B. NONPRICE STUDIES OF DEPRECIATION

The nonprice studies of depreciation employ a wide variety of approaches. It is consequently difficult to provide an integrated and comprehensive picture of this part of the literature on the measurement of depreciation. Instead, we shall describe three of the main nonmarket approaches: the retirement approach, the investment approach, and the polynomial-benchmark approach.

The BEA methodology described in section III is a good illustration of the retirement approach. A retirement distribution is estimated either directly, such as in the Winfrey studies, or indirectly through the analysis of book values or through analysis of changes in the stock of physical assets, such as would have been possible with data from the ADR information system. The estimated retirement distribution is then used to allocate each year's investment flow into subcohorts which are each identified by their date of retirement. A method of in-place depreciation is then selected (usually by assumption) and applied to each subcohort separately. The straight-line and declining balance form are typically assumed. The Faucett capital stock studies are another interesting example of this approach.<sup>32</sup>

The investment approach was developed by Robert Coen (1975, 1980). Coen's procedure was to find which form of depreciation (one-horse-shay, geometric, straight-line, sum-of-the-years'-digits) best explained the investment flows in two-digit manufacturing industries within the context of a neoclassical investment model.<sup>33</sup> Coen (1980) found that for *equipment*, 14 of the industries had depreciation patterns which were more accelerated than straight-line (11 were geometric with a truncation at the end of the service life, and 3 were sum-of-the-years'-digits). The remaining seven industries had straight-line depreciation patterns, and none had one-horse-shay patterns. For *structures*, Coen found that 14 industries had geometric patterns, 5 had straight-line patterns, and only 2 had one-horse-shay patterns.

The weight of Coen's study is evidently on the side of the geometric and near-geometric forms of depreciation. Coen's results are thus consistent

with the results obtained from the used asset price approach, and are basically inconsistent with the results of the Taubman-Rasche study of office buildings. (However, we should note that most manufacturing structures are factories rather than the type of structures studied by Taubman and Rasche: office buildings).

The third nonprice approach we shall summarize, the polynomial-benchmark approach, is based on the perpetual inventory model of equation (6). This equation states that the capital stock in year  $t$  is equal to the real gross investment in that year, plus the undepreciated remainder of the preceding year's stock:  $K_t = I_t + (1 - \delta_t)K_{t-1}$ . A similar expression holds for the preceding year's stock,  $K_{t-1} = I_{t-1} + (1 - \delta_{t-1})K_{t-2}$ . By assuming geometric depreciation (i.e., that  $\delta$ 's are the same in all equations), and by repeatedly substituting for the preceding year's capital stock, we obtain

$$K_t = I_t + (1 - \delta)I_{t-1} + (1 - \delta)^2 I_{t-2} + \dots \\ + (1 - \delta)^{s-1} I_{t-s+1} + (1 - \delta)^s K_{t-s} \quad . \quad (12)$$

This expression defines a polynomial in  $(1 - \delta)$ . Given estimates of the benchmarks  $K_t$  and  $K_{t-s}$ , and of the investment series  $I_{t-k}$ , equation (12) can frequently be solved for a unique value of  $1 - \delta$ .

Nishimizu has applied the polynomial-benchmark approach to data from the Japanese National Wealth Survey. The results for equipment are shown in table 6. (Structures are omitted because the different nature of construction in Japan makes comparison with the U.S. meaningless). With three exceptions—agriculture, construction, and real estate—the Japanese machinery depreciation rates are quite similar to the U.S. machinery rates reported in table 1. The Japanese ships and boats figures are, however, much larger than the U.S. figure. In the other transportation equipment category, the Japanese depreciation rates tend to be quite a bit lower than the U.S. rates but are higher in one industry. The Japanese tools and fixture category has no counterpart in table 1.

It is difficult to draw conclusions from a comparison of tables 1 and 6 because of the potential differences in the composition of the capital stocks of the two countries, and because 22 categories are compared with 4. There does appear to be sufficient similarity between the two sets of results to warrant further investigation of the polynomial-benchmark method as a source of valuable information.<sup>34</sup> Note, that this approach also has been applied to tenant-occupied and owner-occupied housing by Leigh (1977), using data from the Census of Housing. Leigh obtains results which are generally consistent with the results of other studies (see Leigh, p. 233, Chinloy (1977), and Malpezzi, Ozanne, Thibodeau (1980)).



TABLE 6

IMPLICIT RATES OF EQUIPMENT REPLACEMENT FROM NISHIMIZU'S  
STUDY OF JAPANESE CORPORATE INDUSTRIES, 1955-1960s:  
AN APPLICATION OF THE POLYNOMIAL-BENCHMARK METHOD

Industry Asset	ASSET			
	Machinery	Ships and Boats	Other Transportation	Tools and Fixtures
1. Agriculture forestry, and fishery	0.0533	0.6854	0.0892	0.0646
2. Mining	0.0748	0.2274	0.2075	0.2055
3. Manufacturing	0.1328	0.5122	0.0530	0.1269
4. Construction	0.3387	0.6854	0.1939	0.5305
5. Electricity, gas, and water	0.1911	NS	0.4324	0.2370
6. Transportation and communication	0.1819	0.5511	0.1944	0.2513
7. Wholesale and retail trade	0.2506	0.4835	0.0306	0.1329
8. Finance and insurance	0.1782	NS	0.1328	0.0827
9. Real estate	0.0381	NS	0.0689	0.0488
10. Services	NS	0.1095	0.2396	0.1343

SOURCE: Nishimizu (1974).

NOTE: NS indicates "no solution" using the polynomial benchmark technique.

## VI. Summary

We return, in conclusion, to the starting point of our remarks. A major policy initiative is currently under way which would result in a system for nearly total political determination of tax depreciation periods. We believe that politically determined depreciation lives make sense only if true depreciation cannot be measured. We have argued against the proposed system by showing that depreciation can indeed be measured using a variety of approaches. We have also shown that many of these studies obtain the result that depreciation is accelerated relative to straight-line and can be reasonably well approximated by geometric (or declining balance) depreciation. This last conclusion is by no means unanimously supported, but it is sufficiently well established that it should serve as the working hypothesis for the vast amount of research which still remains to be done.

APPENDIX TABLE A.1  
BEA DEPRECIATION RATES BY ASSET CLASS  
ANNUAL PERCENTAGE DECLINE

	Furniture and Fixtures	Fabricated Metal Products	Engines and Turbines	Tractors	Agricultural Machinery	Construction Machinery
1949	12.92	9.26	9.38	23.15	10.24	21.02
1950	12.82	9.28	9.66	23.59	10.03	20.27
1951	12.51	9.39	9.01	23.34	9.93	20.58
1952	12.33	9.43	9.14	23.86	9.92	23.68
1953	12.25	9.43	8.88	24.38	9.94	24.13
1954	12.37	9.48	8.99	25.08	10.10	24.42
1955	13.06	9.44	8.39	26.71	10.32	24.99
1956	12.92	9.57	8.45	26.76	10.46	25.21
1957	12.73	9.75	8.54	26.27	10.70	24.18
1958	12.66	9.78	8.37	26.84	11.10	23.91
1959	12.63	9.85	8.48	27.04	11.18	24.32
1960	12.58	10.00	8.49	25.68	11.27	23.89
1961	12.58	10.19	8.45	26.62	11.42	23.58
1962	12.69	10.37	8.56	26.66	11.59	23.35
1963	12.74	10.65	8.73	26.73	11.78	24.40
1964	12.77	10.86	8.90	26.44	11.77	24.38
1965	12.83	11.00	9.04	25.51	11.80	23.74
1966	12.81	10.99	9.14	25.18	11.71	22.67
1967	12.60	10.84	9.21	23.82	11.55	21.92
1968	12.54	10.76	9.20	23.98	11.34	21.90
1969	12.50	10.69	9.08	24.09	11.27	22.13
1970	12.41	10.63	8.95	25.02	11.19	22.28
1971	12.41	10.55	8.84	25.37	11.00	22.54
1972	12.57	10.52	8.78	26.28	11.06	22.95
1973	12.72	10.56	8.72	26.67	11.13	23.20
1974	12.73	10.51	8.72	25.98	10.94	22.71

SOURCE: See text.

APPENDIX TABLE A.1 (continued)  
 BEA DEPRECIATION RATES BY ASSET CLASS  
 ANNUAL PERCENTAGE DECLINE

	Mining and Oilfield Machinery	Metal- working Machinery	Special Industry Machinery	General Industrial Machinery	Office, Computing, and Accounting Machinery	Service Industry Machinery
1949	18.30	11.29	11.03	12.44	22.83	16.49
1950	18.85	13.22	10.92	12.39	23.20	16.70
1951	19.23	14.60	10.95	12.92	24.32	16.79
1952	19.07	14.37	10.97	13.08	24.67	17.71
1953	18.84	14.21	11.20	13.31	25.28	18.47
1954	18.82	13.73	11.21	13.41	25.66	18.70
1955	19.38	12.98	11.41	13.48	25.65	19.16
1956	19.17	13.53	11.65	13.56	26.01	19.28
1957	18.93	13.21	11.71	13.47	25.84	19.17
1958	18.53	12.73	11.72	13.30	25.09	18.79
1959	19.13	12.76	11.89	13.42	24.99	18.91
1960	19.72	12.94	12.08	13.51	25.62	19.05
1961	19.86	12.82	12.06	13.51	25.79	19.04
1962	20.23	12.83	12.17	13.57	26.11	19.25
1963	20.72	12.93	12.11	13.63	27.45	19.22
1964	20.52	12.92	12.20	13.60	27.20	19.40
1965	20.13	13.00	12.23	13.41	27.14	19.49
1966	19.46	12.89	12.00	13.25	27.58	19.28
1967	18.57	12.44	11.69	12.91	26.17	18.81
1968	18.74	11.99	9.39	12.82	25.46	18.62
1969	18.93	11.91	13.37	12.90	25.62	18.55
1970	19.45	11.74	11.48	12.88	25.39	18.35
1971	19.33	11.54	11.44	12.88	25.24	18.37
1972	19.09	11.70	11.56	13.03	26.27	18.66
1973	19.23	11.89	11.70	13.23	26.84	18.66
1974	18.61	12.01	11.69	13.35	26.55	18.58

SOURCE: See text.

APPENDIX TABLE A.1 (continued)  
 BEA DEPRECIATION RATES BY ASSET CLASS  
 ANNUAL PERCENTAGE DECLINE

	Electrical and Communications Equipment	Trucks, Buses, and Truck Trailers	Autos	Aircraft	Ships and Boats	Railroad Equipment
1949	11.83	20.21	19.31	22.80	8.14	8.11
1950	11.97	20.51	17.82	24.76	7.58	7.58
1951	12.10	21.05	14.14	27.19	10.75	7.51
1952	12.33	20.73	12.16	30.89	8.22	7.25
1953	12.32	21.68	15.24	28.92	8.58	7.09
1954	12.30	23.11	15.20	28.02	8.73	6.93
1955	12.25	23.60	11.65	18.67	8.72	7.03
1956	12.42	22.79	14.03	23.49	9.67	7.17
1957	12.46	23.50	13.10	21.84	9.66	7.26
1958	12.30	23.40	12.08	17.28	9.14	7.15
1959	12.54	24.51	11.84	21.60	9.42	5.56
1960	12.77	24.56	12.41	19.21	9.58	9.19
1961	12.78	24.64	12.33	19.38	9.64	7.61
1962	12.78	25.18	11.57	19.39	10.16	7.74
1963	12.72	24.62	11.56	19.72	10.37	7.93
1964	12.77	23.83	13.41	21.78	10.41	8.09
1965	12.80	23.88	11.75	21.65	10.50	8.13
1966	12.80	23.53	9.15	23.60	10.78	8.05
1967	12.61	22.26	10.90	20.89	10.77	7.83
1968	12.58	22.94	10.77	20.53	10.33	7.67
1969	12.62	23.28	13.16	17.12	9.67	7.75
1970	12.61	22.45	11.10	17.86	9.39	7.63
1971	12.55	22.81	9.16	16.61	9.21	7.64
1972	12.54	23.69	12.78	16.89	9.16	7.61
1973	12.75	23.32	10.54	20.11	9.01	7.64
1974	12.87	22.21	11.22	19.74	8.65	7.67

SOURCE: See text.

APPENDIX TABLE A.1 (continued)  
 BEA DEPRECIATION RATES BY ASSET CLASS  
 ANNUAL PERCENTAGE DECLINE

	Instruments	Other PDE	Industrial Construction	Commercial Construction	Religious Buildings	Educational Buildings
1949	14.91	16.38	7.85	6.23	4.17	3.87
1950	14.94	16.34	7.74	6.17	4.10	3.82
1951	15.24	16.24	7.25	6.07	4.00	3.77
1952	15.56	16.54	7.05	5.98	3.89	3.71
1953	15.82	16.83	6.96	6.02	3.86	3.70
1954	15.85	17.09	6.93	5.95	3.84	3.67
1955	16.57	17.49	9.15	5.88	3.77	3.57
1956	16.83	17.48	7.05	5.66	3.70	3.57
1957	16.98	17.46	6.92	5.41	3.61	4.47
1958	16.91	17.53	6.72	5.27	3.54	3.47
1959	17.32	17.50	6.99	5.23	3.47	3.42
1960	17.53	17.35	7.29	5.07	3.44	3.41
1961	17.56	17.14	7.58	4.93	3.39	3.40
1962	17.60	17.00	7.67	4.87	3.34	3.39
1963	17.85	16.87	7.53	4.75	3.31	3.37
1964	17.81	16.76	7.20	4.69	3.29	3.35
1965	17.83	16.65	7.29	4.85	3.29	3.34
1966	16.95	16.70	7.19	4.62	3.26	3.35
1967	16.37	15.77	7.00	4.59	3.24	3.34
1968	16.21	16.72	6.94	4.62	3.25	3.32
1969	16.31	16.96	6.99	4.48	3.25	3.30
1970	16.37	17.06	6.72	4.45	3.27	3.28
1971	16.55	17.30	6.49	4.46	3.29	3.81
1972	16.62	17.45	6.54	4.48	3.33	3.33
1973	16.65	17.43	6.62	4.47	3.38	3.34
1974	16.72	17.15	6.71	4.45	3.42	3.37

SOURCE: See text.

APPENDIX TABLE A.1 (continued)  
 BEA DEPRECIATION RATES BY ASSET CLASS  
 ANNUAL PERCENTAGE DECLINE

	Hospitals and Institutional Buildings	Other Nonfarm Buildings	Public Utilities	Farm Buildings	Mining, Exploration, Shafts, and Wells	All Other Private Construction
1949	3.96	7.16	6.17	5.40	11.62	8.52
1950	3.99	7.01	6.07	5.20	11.57	8.50
1951	3.84	6.91	5.99	5.03	11.46	8.09
1952	3.69	6.75	5.93	4.90	11.29	8.08
1953	3.61	6.68	5.88	4.76	11.17	7.98
1954	3.57	6.59	5.80	4.67	11.09	7.70
1955	3.55	6.38	5.75	4.60	11.04	7.49
1956	3.50	6.33	5.76	4.56	10.97	7.10
1957	3.54	6.24	5.73	4.52	10.91	7.00
1958	3.49	6.20	5.70	4.50	10.91	6.68
1959	3.43	6.09	5.69	4.51	11.10	6.42
1960	3.40	5.98	5.71	4.46	11.22	6.31
1961	3.38	5.79	5.72	4.45	11.42	5.92
1962	3.36	5.66	5.76	4.46	11.67	5.77
1963	3.29	5.58	5.81	4.44	11.81	5.64
1964	3.27	5.48	5.86	4.43	12.03	5.50
1965	3.20	5.47	5.91	4.45	12.15	5.43
1966	3.15	5.36	5.94	4.46	12.21	5.30
1967	3.11	5.28	5.95	4.48	12.25	5.17
1968	3.11	5.13	5.96	4.47	12.31	5.15
1969	3.12	5.23	5.93	4.49	12.38	5.14
1970	3.10	5.31	5.93	4.52	12.39	5.10
1971	3.08	5.40	5.91	4.54	12.40	5.01
1972	3.07	5.51	5.92	4.56	12.55	4.93
1973	3.05	5.62	5.91	4.63	12.58	4.92
1974	3.01	5.70	5.92	4.66	12.65	4.97

SOURCE: See text.

APPENDIX TABLE A.2  
 CAPITAL STOCKS BY ASSET TYPE  
 (BASED ON DEPRECIATION RATES OF TABLE 1)

	Furniture and Fixtures	Fabricated Metal Products	Engines and Turbines	Tractors	Agricultural Machinery	Construction Machinery
1949	8202.21	5887.07	3583.05	6067.21	10838.18	6394.41
1950	8599.96	6245.22	4051.42	6733.44	11820.80	6381.30
1951	9160.97	6743.54	4286.98	7316.87	12658.00	6428.44
1952	9611.26	7350.15	4696.02	7735.02	13375.91	6724.46
1953	9970.02	7965.15	5023.91	7957.89	13817.11	6881.51
1954	10439.32	8604.74	5603.03	7751.37	14111.46	6785.51
1955	11188.00	9054.69	5998.64	8048.57	14450.24	6974.05
1956	11951.32	9500.37	6306.14	8190.24	14528.12	7332.12
1957	12504.67	10090.19	6721.48	8082.77	14514.44	7382.53
1958	12991.16	10522.92	7127.17	8138.86	14992.09	7420.25
1959	13468.13	10765.97	7402.98	8403.78	15358.36	7684.49
1960	13900.64	10948.73	7628.10	8051.44	15481.06	7736.22
1961	14212.57	11042.73	7758.53	7922.64	15538.85	7638.04
1962	14577.18	11033.11	7802.71	7899.88	15637.03	7619.77
1963	15107.69	11156.37	7842.42	8121.83	16003.67	8070.65
1964	15783.85	11455.34	7868.01	8646.53	16374.72	8801.88
1965	16626.62	11972.88	7915.58	9199.55	16999.73	9655.20
1966	17678.70	12639.97	8066.42	10191.27	17754.06	10515.57
1967	18580.04	13198.88	8444.40	10693.03	18590.14	11124.79
1968	19364.23	13721.55	8942.67	11134.86	19170.04	11820.10
1969	20281.17	14275.28	9460.77	11277.54	19934.63	12559.68
1970	20975.24	14830.24	9946.16	11505.92	20837.97	13126.90
1971	21399.96	15262.30	10339.39	11507.00	21339.61	13573.45
1972	21973.97	15666.75	10703.71	11937.91	22237.53	14337.10
1973	23066.83	16249.11	11055.40	13018.45	24124.27	15512.25
1974	24341.48	16822.07	11441.45	14474.53	26325.80	16305.04

SOURCE: See text.

APPENDIX TABLE A.2 (continued)  
 CAPITAL STOCKS BY ASSET TYPE  
 (BASED ON DEPRECIATION RATES OF TABLE 1)

	Mining and Oilfield Machinery	Metal- working Machinery	Special Industry Machinery	General Industrial Machinery	Office, Computing, and Accounting Machinery	Service Industry Machinery
1949	3611.24	13489.62	16965.99	15099.01	2293.57	5192.30
1950	3681.39	13930.14	17956.80	15080.38	2459.66	5620.57
1951	3887.96	14976.70	18991.45	15308.04	2658.42	5791.18
1952	4066.45	15897.05	19604.44	15400.80	2820.93	6025.63
1953	4147.48	17201.66	20287.22	15789.20	3012.10	6433.40
1954	4136.15	18554.46	20576.61	16119.03	3132.10	6716.89
1955	4340.68	19040.54	21190.16	16754.45	3324.35	7131.60
1956	4533.47	20141.07	21977.45	17492.03	3623.13	7656.89
1957	4647.45	20898.79	22523.58	18144.25	4106.38	8160.50
1958	4448.62	20529.69	22669.40	18262.58	4440.75	8366.02
1959	4296.60	20243.80	22932.18	18473.42	4682.87	8537.63
1960	4227.66	20249.94	23523.87	18908.42	5032.91	8719.92
1961	4092.09	19919.32	23876.56	19174.14	5174.43	8827.13
1962	3973.90	19732.20	24426.89	19600.31	5250.33	9004.66
1963	4034.21	19901.01	24855.48	20365.27	5796.51	9136.89
1964	4174.56	20122.13	25692.88	21497.53	6401.65	9414.30
1965	4388.76	20917.17	27311.94	22863.08	7139.64	9956.94
1966	4601.61	22143.82	29061.08	24562.35	8576.23	10668.05
1967	4530.35	23842.20	30229.88	25633.46	9751.78	11235.82
1968	4474.84	24948.53	31403.18	26467.36	10564.52	11824.91
1969	4442.49	25924.34	32488.51	27580.11	11813.46	12527.80
1970	4629.48	26494.61	33387.95	28460.55	12805.57	13058.71
1971	4886.62	26078.02	33835.65	28922.13	13288.93	13538.02
1972	5140.32	25929.46	34503.19	29437.17	13999.38	14429.26
1973	5688.17	26303.10	35836.92	30473.12	14974.95	15491.42
1974	6215.62	27203.97	37228.13	32223.16	15094.29	16672.34

SOURCE: See text.



APPENDIX TABLE A.2 (continued)  
 CAPITAL STOCKS BY ASSET TYPE  
 (BASED ON DEPRECIATION RATES OF TABLE 1)

	Electrical and Communications Equipment	Trucks, Buses, and Truck Trailers	Autos	Aircraft	Ships and Boats	Railroad Equipment
1949	13587.46	11846.07	5305.51	2402.06	13922.14	17927.51
1950	14893.50	12862.72	6809.18	2107.76	13237.98	18386.30
1951	16447.55	13834.45	6384.68	1864.41	13560.13	19327.80
1952	18488.39	13395.65	5326.67	1869.66	13322.13	19970.17
1953	20583.61	13036.17	6081.29	1850.95	13172.97	20373.14
1954	22304.80	12727.90	6179.40	1892.67	12690.99	20006.51
1955	24012.06	13339.83	6563.80	1748.75	12167.17	19793.08
1956	26182.04	13576.51	5840.09	1978.20	11854.63	19903.74
1957	28475.18	13545.15	5648.59	2339.60	11739.53	20383.09
1958	29645.95	12954.75	4203.91	2369.75	11540.07	19806.81
1959	31079.70	12847.13	4365.75	3054.37	11281.56	19362.56
1960	33238.40	12737.81	4654.64	3483.51	10996.45	19249.63
1961	35630.59	12756.23	4568.25	3884.98	10649.71	18775.15
1962	38274.75	13713.97	5174.65	4162.86	10410.98	18722.99
1963	40620.15	14711.74	5358.94	4018.81	10142.16	18759.27
1964	43284.04	15606.37	5941.81	4346.16	9960.50	19348.16
1965	46650.85	17347.03	7220.40	4636.51	9885.46	20311.18
1966	50789.71	19541.09	7010.84	5989.64	9890.05	21576.65
1967	54281.61	20345.52	6733.13	7764.74	9948.30	22419.59
1968	57671.81	22127.86	7671.98	10512.46	10160.18	22637.89
1969	61738.30	24886.02	8808.91	11476.53	10380.16	23430.79
1970	65971.35	25731.44	7331.90	11762.88	10558.65	23760.36
1971	69136.33	27107.37	7782.18	10611.74	10643.75	24172.18
1972	71046.16	30801.23	9288.38	10069.61	10977.47	24409.81
1973	73735.82	35519.96	10802.56	10682.85	11677.16	24770.77
1974	76559.37	37670.55	10524.07	10116.68	12373.37	25512.90

SOURCE: See text.

APPENDIX TABLE A.2 (continued)  
 CAPITAL STOCKS BY ASSET TYPE  
 (BASED ON DEPRECIATION RATES OF TABLE 1)

	Instruments	Other PDE	Industrial Construction	Commercial Construction	Religious Buildings	Educational Buildings
1949	2697.76	3100.33	58833.42	62111.38	9610.67	7587.51
1950	3060.38	3307.65	59800.54	63609.23	10300.99	8070.87
1951	3447.59	3414.44	61767.74	64870.08	10955.33	8566.14
1952	3852.76	3535.49	63815.92	65394.79	11478.37	9046.09
1953	4246.25	3658.71	65617.17	67080.54	12120.58	9651.03
1954	4431.77	3770.78	67124.39	69599.65	12999.71	10457.59
1955	4775.97	3990.35	70698.20	73555.54	14035.32	11117.98
1956	5144.47	4201.57	73740.99	78257.72	15135.45	11862.97
1957	5486.69	4406.68	76967.94	82205.75	16262.91	12589.94
1958	5621.50	4678.57	78244.40	86288.27	17401.17	13313.25
1959	5837.45	5032.42	79220.78	90944.95	18666.02	13941.96
1960	6118.60	5442.15	81592.91	95922.61	20031.10	14640.85
1961	6366.33	5902.52	83967.40	101524.32	21343.52	15390.61
1962	6624.57	6426.08	86367.18	107763.67	22670.26	16238.26
1963	7186.77	7022.52	88517.32	113375.91	23871.06	17034.98
1964	8101.16	7674.10	91278.85	119374.52	25012.28	17831.73
1965	9188.86	8339.70	96197.68	127206.97	26413.05	18634.49
1966	10501.34	9131.27	102783.95	134347.96	27622.49	19676.16
1967	11594.49	9470.23	107804.45	140863.56	28608.18	20723.25
1968	12606.62	9930.27	112407.71	148256.23	29541.35	21835.65
1969	13753.67	10462.54	117094.79	156219.31	30190.97	22680.14
1970	14948.75	10899.41	120460.67	163483.69	30669.38	23226.75
1971	16377.80	11453.92	121841.04	171831.64	30946.80	23781.09
1972	17946.35	12190.76	122166.57	181290.40	31209.00	24302.01
1973	19568.85	13016.06	123472.36	191163.52	31367.27	24611.13
1974	21372.36	13452.80	125526.01	200112.79	31571.56	24714.44

SOURCE: See text.

## APPENDIX TABLE A.2 (continued)

CAPITAL STOCKS BY ASSET TYPE  
(BASED ON DEPRECIATION RATES OF TABLE I)

	Hospitals and Institutional Buildings	Other Nonfarm Buildings	Public Utilities	Farm Buildings	Mining, Exploration, Shafts, and Wells	All Other Private Construction
1949	5504.79	10909.92	100041.87	22103.84	23775.78	6710.40
1950	6108.52	11223.61	103149.55	23169.98	25156.20	6744.80
1951	6752.20	11554.06	106225.02	24117.85	26748.91	6663.20
1952	7313.87	11784.50	109486.31	25128.26	28427.94	6614.97
1953	7719.46	12058.49	113132.54	25949.72	30183.45	6630.13
1954	8169.59	12536.03	116181.56	26703.71	32045.12	6653.86
1955	8594.24	12692.90	118638.22	27363.83	34060.98	6742.90
1956	8977.00	12950.64	122141.25	28050.31	36074.35	6758.35
1957	9621.83	13203.68	125719.59	28623.52	37731.36	6875.36
1958	10401.64	13720.23	128723.85	29171.14	38851.09	6975.97
1959	11119.28	14412.33	131171.18	30088.78	40042.77	7109.67
1960	11887.21	15340.01	133637.17	30814.68	40864.36	7366.49
1961	12908.23	16154.58	135651.23	31551.37	41587.70	7562.86
1962	14254.47	16981.16	137582.66	32412.60	42508.31	7784.54
1963	15597.34	17894.22	139930.05	33202.42	43177.09	8041.79
1964	17303.92	18707.82	142688.26	33951.53	44102.22	8329.58
1965	19072.74	20017.48	146243.31	34763.88	45068.27	8709.02
1966	20749.35	21266.69	150721.02	35617.97	45905.93	9150.46
1967	22151.89	22360.18	155754.23	36659.83	46568.42	9510.09
1968	23789.75	22195.03	161784.40	37450.99	47117.62	9995.30
1969	25880.45	22144.37	167673.01	38176.40	47683.90	10625.44
1970	28119.43	22038.02	174042.55	38970.62	47976.29	11387.30
1971	30473.25	21895.49	179949.80	39682.02	47899.23	12110.07
1972	32935.22	21815.44	186568.39	40173.55	48034.50	12699.88
1973	35050.83	21818.02	192950.83	41157.44	47975.16	13176.58
1974	37012.15	21688.48	199277.58	42414.01	47827.16	13666.46

SOURCE: See text.

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