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The Analytical Derivation and Empirical Test of a Tax-Adjusted Fundamental Value Model

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1. *Introduction*

In implementing the theory of current valuation for fixed assets, accountants encounter a range of difficult estimation problems. Many of these problems arise because fixed assets yield their productive potential over many accounting periods. Theoreticians, regulators, users, and preparers have sought to overcome difficulties in estimating values for owned used assets by estimating the historical cost or the current cost of a new asset and applying a depreciation factor that adjusts for diminished productive capacity. The resulting depreciated cost estimate then serves as a proxy for the economic value of the owned used asset.

Previous research has demonstrated that this depreciated cost estimate of economic value is sensitive to both the valuation model and the assumed depreciation schedule (see, for example, Greenball [1969], Beaver and Dukes [1973], Beaver and Landsman [1983], Mohr and Dilley [1984], Swenson [1987], and Kim and Moore [1988]). The purpose of our study is to extend prior research by examining the interactive

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effects of differential tax benefits and alternative productive capacity depreciation schedules on the estimation of the economic value of owned used assets.

The importance of tax effects in asset valuation has been noted by Scholes and Wolfson [1992, p. 99]: "If two assets yield identical pretax cash flows, but one is more heavily taxed than the other, then the price of the more lightly taxed asset will be bid up relative to the price of the more heavily taxed asset." An enhanced valuation model, therefore, should reflect the effects of differential tax treatments on expected cash flows because an asset's economic value represents the discounted sum of expected after-tax cash flows.

In the following sections we derive and test a model for valuing fixed assets that specifies the effects of differential tax treatments on expected after-tax cash flows for owned used assets. Our tax-adjusted fundamental value (*FV*) framework is an extension of previous accounting valuation models. For example, the traditional historical cost (*HC*) valuation framework specifies the association between asset cost and productive capacity, while the current cost (*CC*) valuation framework specifies the association among asset cost, productive capacity, and specific price changes.[1] The *FV* model, however, further specifies the association among asset cost, productive capacity, specific price changes, and differential tax effects. In other words, just as the *CC* model reduces to the *HC* framework when specific prices are constant, the tax-adjusted fundamental value model reduces to the *CC* model when, for assets of varying ages, effective tax rates are identical and discounted pretax cash flows are a constant proportion of current productive capacities.

Our results indicate that the *HC* point estimates are most accurate (relative to used asset prices) when generated by a straight-line capacity depreciation schedule, while the *CC* point estimates are most accurate when generated by an accelerated depreciation schedule. In contrast to the *HC* and *CC* models, the *FV* point estimates are consistently accurate across the alternative capacity depreciation schedules.

Section 2 specifies the *HC*, *CC*, and *FV* valuation frameworks. Section 3 provides evidence on differential tax benefits between new and owned used assets. In section 4, point estimates of economic values for owned used assets are computed for the *HC*, *CC*, and *FV* valuation models. Section 5 compares the point estimates for industrial machinery and equipment with actual market prices obtained from active secondary markets. The conclusions of our study are in section 6.

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[1] Current cost is defined in FASB [1979] as the current cost of acquiring the same service potential (indicated by operating costs and physical output capacity) as embodied by the owned asset.

2. *Valuation Models for Fixed Assets*

Roughly half of all assets in the corporate sector are fixed assets that periodically must be valued. Three alternative models for estimating asset values can be specified. The historical cost (*HC*) model relies on formulas explicitly specifying the association between the acquisition cost and an exogenous capacity depreciation schedule. The current cost (*CC*) valuation model extends the *HC* model by integrating into the formulas the association between asset value and specific price level changes. An extension to the *CC* model, designated the tax-adjusted fundamental value (*FV*) framework, is derived herein. This extension adds to the information in the *CC* model the association among asset value, taxes, and the risk-adjusted discount rate. The *HC*, *CC*, and *FV* frameworks are presented in section 2.1, and the frameworks are compared in section 2.2.

2.1 SPECIFICATIONS FOR THE *HC*, *CC*, AND *FV* MODELS

As a starting point for specifying the historical cost (*HC*) estimate, let $p_t q_t$ denote the gross investment in new fixed assets at time t. The price or nominal component, p_t, represents the specific price at time t of a new asset possessing one unit of productive capacity. The quantity or real component, q_t, represents the number of units of productive capacity acquired at time t. The fixed asset expenditure is pq.

The valuation frameworks specify a pattern of capacity depreciation describing the decline throughout the asset's service life of its potential productive capacity. The capacity depreciation schedule typically is distinct from the tax depreciation schedule. The series d_j for $j = 0, \ldots, \infty$ represents the capacity depreciation schedule; d_j denotes the proportional decline in productive capacity occurring at the end of the jth year of service. For example, with straight-line capacity depreciation over a four-year service life $d_j = 1/4$ for $j = 1, \ldots, 4$ and $d_j = 0$ otherwise. Accumulated capacity depreciation for an asset concluding its tth year of service equals $\sum_{j=0}^{t} d_j$.

The *HC* model equates owned used asset value to the acquisition cost less accumulated capacity depreciation. More precisely, the historical cost valuation estimate at time s for an asset concluding its tth year of service, denoted $HC_{s,t}$, is:

$$HC_{s,t} = p_{s-t} q_{s-t} \{1 - \sum_{j=0}^{t} d_j\}. \tag{1}$$

The term in curly brackets represents the proportion of original productive capacity remaining. That proportion is multiplied by the actual investment cost, thereby highlighting the direct link in the *HC* model between historical acquisition cost and remaining productive capacity.

The current cost (*CC*) of owned used assets adds to the *HC* framework the effect of the cumulative change in the specific price of new assets. The *CC* model partitions the time t fixed asset expenditure into a quantity component, q_t (net of accumulated capacity depreciation), and a price component, p_t, obtained by referencing the current specific price of a new asset. Accordingly, the current cost valuation estimate at time s for an asset concluding its tth year of service, denoted $CC_{s,t}$, is:

$$CC_{s,t} = p_s q_{s-t} \{1 - \sum_{j=0}^{t} d_j\}. \tag{2}$$

This formulation of *CC* as a new price component less a depreciation component was adopted by over 90% of the preparers of *CC* data in the FASB [1979] *Statement No. 33* supplementary disclosures (see Shriver [1987]). The dependence of *CC* on the current specific price of fixed assets is evident in equation (2); a value of p_s is assigned to each unit of productive capacity retained in the asset. Comparison of equations (1) and (2) reveals that with constant specific prices the *CC* model reduces to the *HC* model.

An asset's tax-adjusted fundamental value (*FV*) is defined as the discounted sum of its expected after-tax cash flows. The existence of a zero net present value investment equilibrium in the fixed asset market assures that *FV* and *CC* are identical for new assets. For owned used assets, however, the two valuation estimates may diverge. Theoretical analyses by Summers [1981] and Hayashi [1982] indicate that for the entire corporate sector aggregate *CC* does not equal aggregate *FV* when firms are price-takers with constant returns to scale technologies. They argue that a divergence between *CC* and *FV* arises due to differences in the tax treatment of income from new and owned used assets. The model presented below expands on the importance of tax effects in specific asset valuation.[2]

Tax-adjusted fundamental value at time s for an asset concluding its tth year of service, denoted $FV_{s,t}$, is:

$$FV_{s,t} = \tau Y_{s,t} + (1 - \tau) C_{s,t}. \tag{3}$$

$Y_{s,t}$ is the present value at time s of the tax depreciation deductions promised by an asset concluding the tth year of service; it is obtained by depreciating the fixed asset expenditure with the tax schedule in effect at time of investment, allocating the stream of deductions across time, and making the appropriate discounted summation. The discounted depreciation tax savings equal $\tau Y_{s,t}$, where τ denotes the statutory corporate tax rate. $C_{s,t}$ is the present value at time s of the pretax cash flow expected from an asset concluding its tth year of service. The expected pretax cash flow for each point beyond time s equals the quantity of

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[2] Variants of the *FV* model are used for analyzing the effects of federal tax reform on stock prices by Downs and Hendershott [1987], Downs and Tehranian [1988], and Downs and Demirgures [1992]. The relationship between *FV* and the stock market is discussed by Downs [1991]. Downs [1992] uses the *FV* model to explain time-series and cross-sectional variation in industry Tobin's *Q* ratios.

productive capacity retained in the asset multiplied by the user cost of capital.[3] As shown by Jorgenson [1967], the user cost is the equilibrium pretax cash flow produced per unit of capital such that the asset possesses a zero net present value.

Equation (3) specifies an empirically operational model for computing tax-adjusted fundamental value as the discounted depreciation tax savings plus discounted pretax cash flow net of proportional taxes.[4] The *FV* estimates are generated by constructing $Y_{s,t}$ and $C_{s,t}$ as described in Appendix A. The resulting *FV* point estimates are related, in theory, to the "used asset price" approach to asset valuation advocated by Revsine [1979], Beaver and Landsman [1983], and Swanson and Shriver [1987], because the *FV* model calculates the present value of an asset's remaining after-tax cash flows.

2.2 ANALYTICAL COMPARISON OF THE VALUATION MODELS

The *FV* model given in equation (3) is an extension of the *CC* model presented in equation (2), which in turn is an extension of the *HC* model presented in equation (1). Under restrictive conditions, the *FV* and *CC* specifications reduce to the *HC* model. More generally, however, the models yield different valuation estimates. Nonetheless, the alternative models may be compared by first examining the conditions under which the *FV* model reduces to the *CC* model; as previously noted, *CC* reduces to *HC* in an environment characterized by constant specific prices.

The comparison begins by summing across all age cohorts, thereby arriving at a specification of the time *s* tax-adjusted fundamental value for total owned used assets, denoted FV_s. That summation shows:

$$FV_s = \sum_{t=o}^{\infty} \{\tau Y_{s,t} + (1 - \tau) C_{s,t}\}.$$

The expression for $C_{s,t}$ is substituted from Appendix A and the equation is simplified, thereby yielding:

$$\begin{aligned} FV_s &= p_s K_s \{(1 - v - \tau Z_s)(1 - H_s)/(1 - D_s) + \tau Y_s\}, \\ &= CC_s \{(1 - v - \tau Z_s)(1 - H_s)/(1 - D_s) + \tau Y_s\}. \end{aligned} \tag{4}$$

CC_s is the current cost for total owned used assets at time *s* and equals $p_s K_s$. K_s is the quantity of potential productive capacity embodied in total owned used assets; i.e., K_s is the real capital stock. The variables H_s and D_s are measures of discounted capacity depreciation for the total owned used assets and for new assets, respectively. Y_s and Z_s are the

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[3] This modeling assumes a constant real marginal physical product of capital beyond time *s*. In other words, the relative contribution of capital to production remains the same as it is at time *s*. In the framework devised by Thomas [1969, esp. pp. 41–47], this formulation imposes restrictions on cost and revenue functions of continuity, constant returns to scale, and simultaneous successive expansion.

[4] The tax-adjusted fundamental value for a new asset, $FV_{s,o}$, equals the right-hand side of equation (3) plus the investment tax credit, $v p_s$, where v is the rate of the *ITC*.

discounted tax depreciation deductions per dollar of total owned used assets and per dollar of new assets, respectively. Explicit specifications for all variables are presented in Appendix A.

The general relation between tax-adjusted fundamental value and current cost is depicted in equation (4). Under some conditions the term in curly brackets is unity, implying *FV* and *CC* are conceptually equivalent. Differences between *FV* and *CC*, however, arise from both discounting effects and tax effects. These two effects are multiplicatively related and, consequently, examining one effect requires holding the other constant.

In order to focus on the relation between *FV*, *CC*, and the discounting effect, suppose there are no taxes (v and τ equal zero). The specification for tax-adjusted fundamental value reduces to:

$$FV_s = CC_s\,(1 - H_s)/(1 - D_s). \tag{5}$$

H and *D* are related to the discounted real service stream embodied in the total owned used assets and in new assets, respectively. If the real capital service streams beyond time *s* for new and owned used assets are identical, then *H* and *D* are identical and *FV* equals *CC*. If, on the other hand, the total owned used assets depreciate along a different pattern than the one characterizing new assets, then *FV* and *CC* diverge because the specific price of new assets capitalizes the real service stream of the assets. The specific price is then utilized in the current cost methodology as a benchmark for valuing owned used assets and adjustments are made for differences in current productive capacities. When the future productive capacity relative to current capacity differs depending on whether assets are new or used, however, the current specific price does not accurately reflect the discounted pretax cash flow stream embodied within owned used assets.

The *HC* and *CC* models are insensitive to the shape of the expected pretax cash flow streams. Both models implicitly assume that the decline over time in productive capacity is equiproportional to the decline in future discounted cash flows. Seldom, however, will such equiproportionate declines occur. For example, assume that the productive capacity for an asset declines along a straight-line pattern over a ten-year service life. When the asset concludes its fifth year of service the *CC* model sets the asset's value at 50% of the current specific price for a new asset. Consequently, two such five-year-old assets would have a *CC* identical to one new asset. The two owned used assets, however, promise a five-year cash flow stream whereas the new asset promises a ten-year stream. *FV* for the two owned used assets is substantially less than for the new asset, even though their *CCs* (and current productive capacities) are identical.[5]

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[5] The ratio of *FV* to *CC* is $(1 - H)/(1 - D)$, as specified in equation (5). With the 10-year straight-line capacity depreciation schedule, $d_j = 1/10$ for $j = 1, \ldots, 10$. Discounting the

In the absence of taxes a capacity depreciation schedule for which *FV* necessarily equals *CC* is geometric depreciation over an infinite service life. Jorgenson [1967] assumes geometric capacity depreciation in the neoclassical model (albeit over a finite service life) and Hulten and Wykoff [1981] provide evidence supporting this pattern.[6] The geometric assumption has been challenged, however, by Eisner [1972] and Feldstein and Rothschild [1974]. Even with an infinite geometric capacity depreciation schedule, though, *FV* and *CC* valuation estimates may diverge due to the existence of differential tax effects.

Consider the case with taxes in which capacity depreciation occurs at the geometric rate δ over an infinite service life; i.e., $d_t = \delta(1 - \delta)^{t-1}$. Simplification of equation (4) (the specifications for H and D from Appendix A show that for this case $H = D$, implying the discounting effect is suppressed) results in:

$$FV_s = CC_s\{1 - \nu - \tau(Z_s - Y_s)\}. \quad (6)$$

FV equals *CC* when taxes are absent or when new and owned used assets face the same tax treatment. *FV* and *CC* diverge, however, when new assets receive an investment tax credit (ν or *ITC*), or when depreciation tax savings (per unit of productive capacity) for new assets (τZ) differs from owned used assets (τY). Two asset bundles may be productively equivalent, they may yield identical pretax cash flows and, therefore, they may possess identical current costs. If they are subject to differential tax treatment, however, they will deliver different after-tax cash flows and their economic values will differ.[7]

Tax effects cause a divergence between *FV* and *CC* (and *HC*) because the specific price of new assets capitalizes the tax benefits received by new assets. This specific price is used in the current cost methodology as a benchmark for valuing owned used assets and adjustments are made for differences in current productive capacities. When the discounted tax benefits relative to current capacity are different for new assets than for owned used assets, however, the current specific price does not accurately reflect discounted after-tax cash flows for owned used assets.

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capacity depreciation schedule (as specified in Appendix A) with, say, a real interest rate of 3% shows $D = .8530$. For the owned used asset with five years of service remaining, $H = .9159$ (i.e., H equals 1/5 discounted at 3% for 5 years). The ratio of *FV* to *CC* for the used asset therefore equals .57.

[6] Two models which assume depreciation is endogenous and depends on utilization rates and maintenance expenditures as choice variables are Epstein and Denny [1980] and Kim and Moore [1988].

[7] A tax policy under which Y equals Z is when (1) the depreciable basis is indexed to inflation, and (2) tax depreciation and capacity depreciation each proceed along identical infinite geometric patterns at the rate δ. The U.S. Treasury Tax Reform Proposal of November 1984 suggested such a tax depreciation schedule, but it was not enacted. Under these conditions $c = p\,(r + (1 - \tau)\delta - \pi)/(1 - \tau)$ and *FV* equals *CC*.

In summary, the *FV* specification reduces to the *CC* model when, for assets of varying ages, effective tax rates are identical and discounted pretax cash flows are a constant proportion of current productive capacities. The specifications further reduce to the *HC* model when specific prices are constant. The primary difference among the three models arises from the information incorporated in the estimate of economic value. For all three, the capacity depreciation schedule is always exogenous. For *HC* and *CC*, however, this schedule is the only source of decline in an asset's economic value throughout its service life. For the *FV* model, on the other hand, the change through time in an asset's economic value is determined by the interaction between differential tax effects and capacity depreciation. Estimating the economic value of owned used assets with the *HC* or the *CC* model is tantamount to using the *FV* model with implicit acceptance of the assumptions required for reducing the model—incremental information about differential tax effects (and specific price changes) is ignored.

3. *Evidence on the Existence of Differential Tax Effects*

This section examines the extent to which new and owned used assets receive differential tax benefits. As established in the previous section, the existence of substantial differences in discounted tax benefits between new and owned used assets induces estimation error in the valuation estimates for the *HC* and *CC* models. The *FV* model, on the other hand, reduces this estimation error by taking into account only the specific tax benefits associated with an asset.

Our analysis focuses on three benchmark years (1973, 1976, 1980) and the types of industrial machinery and equipment required to be disclosed under FASB [1979] *Statement No. 33*. The selection of the sample is determined by two factors. First, data on observed transaction prices for used assets are readily available to us for 1973, 1976, and 1980 (Land [1974; 1977; 1981]). These three years represent economic environments with differing inflation rates, tax policies, and investment climates. Second, the entire gamut of industrial machinery and equipment in the corporate sector is selected for analysis because the assets are unlikely to be affected by unsystematic phenomena peculiar to any one industry or firm. The average age of owned corporate equipment is six years for 1973, 1976, and 1980 (U.S. Department of Commerce, Bureau of Economic Analysis [1987]), but the analysis, in theory, could be replicated for any age of asset or any level of aggregation (e.g., industry, firm, division, or specific asset type).

The differential tax deductions between new and owned used assets are computed as described in Appendix A and summarized in table 1. The discounted tax depreciation deductions per dollar of new asset in 1973 (Z_{1973}) rely on tax depreciation schedules applicable to 1973 fixed asset expenditures. Likewise, discounted tax depreciation deduc-

TABLE 1

Differences in Tax Benefits between New and Owned Used Assets Standardized to Reflect Equivalent Productive Capacities

$s =$	1973	1976	1980
Discounted tax depreciation deductions per dollar of new asset:			
Z_s	70.30¢	68.81¢	63.34¢
Discounted tax depreciation deductions per dollar of six-year-old owned used asset:			
$Y_{s,6}$	44.63¢	34.44¢	26.10¢
Rate of the investment tax credit:			
v_s	5.6%	8.1%	6.1%
Statutory corporate income tax rate:			
τ_s	0.48	0.48	0.46
Per-dollar difference in discounted tax benefits between a new and a six-year-old owned used asset:			
$v_s + \tau_s (Z_s - Y_s) =$	17.92¢	24.60¢	23.23¢

All data sources are described in Appendix A.

Z_s equals the discounted sum of expected tax depreciation deductions for a $1 capital expenditure in new assets; tax schedules are those applicable to year s and the procedure is specified in Appendix A, equation (14).

$Y_{s,6}$ equals the discounted sum of remaining expected tax depreciation deductions for six-year-old owned used asset in year s; the table entry reflects deductions for assets possessing equivalent productive capacity as one dollar of new assets and the procedure is specified in Appendix A, equation (12).

tions per dollar of six-year-old asset in 1973 ($Y_{1973,6}$) are computed by relying on tax depreciation schedules applicable to 1967 fixed asset expenditures. New assets in 1973 offer discounted tax depreciation deductions that equal 70.30 cents per dollar of asset, substantially greater than the 44.63 cents of discounted tax depreciation deductions for the six-year-old owned used asset (adjusted for differences in productive capacity).[8] With a corporate income tax rate (τ) of 0.48 and an investment tax credit (v) of 0.056, the discounted tax benefits for new assets exceed by 18 cents the discounted tax benefits received by the productively equivalent six-year-old owned used asset. The differential tax benefits between new and six-year-old owned used assets in 1976 (based on 1976 and 1970 tax depreciation schedules, respectively) equal 25 cents and for 1980 differential tax benefits (based on 1980 and 1974 depreciation tax schedules, respectively) equal 23 cents.[9]

The estimates in table 1 establish that tax laws generally provide benefits that, per unit of productive capacity, are substantially greater for new assets than for owned used assets. As discussed in Scholes and

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[8] The adjustment for diminished productive capacity in the owned used asset assumes a 13-year straight-line capacity depreciation schedule. The sensitivity of the estimates to the assumed capacity depreciation schedule is examined in sections 4 and 5.

[9] According to Land [1974; 1977; 1981], the demand for used assets was high in 1973, low in 1976, and moderate in 1980. The demand for used assets for these three years is inversely related to the differential tax benefits between new and used assets.

Wolfson [1992], these differential tax benefits are capitalized into the specific price of new assets. The *HC* model (with the historical specific price less a depreciation component) and the *CC* model (with the current specific price less a depreciation component) ignore these differential tax benefits. In the next section, we examine the magnitude of differences among the *HC*, *CC*, and *FV* point estimates for three alternative capacity depreciation schedules.

4. Point Estimates of Specific Asset Values from the Valuation Models

In this section point estimates of asset values are constructed by the *HC*, *CC*, and *FV* valuation frameworks for industrial machinery and equipment.[10] Table 2 presents valuation estimates from the three models for each year throughout an asset's expected service life. The representative asset is acquired in 1973; it embodies one unit of productive capacity when new; and its acquisition cost is \$46.41 (the 1973 specific price index, p_{1973}, for industrial machinery and equipment).[11] Each of the three panels in table 2 assumes a different capacity depreciation schedule. As listed in the top row of each panel, the point estimate of asset value for this new asset is \$46.41 in 1973 regardless of which valuation model is utilized and irrespective of the capacity depreciation schedule; i.e., $HC_{1973,0} = CC_{1973,0} = FV_{1973,0} = p_{1973} = \$46.41$.

Panel A shows the evolution of the asset's value given that actual capacity depreciation occurs along a 13-year straight-line pattern. The *HC* estimate for this asset at the conclusion of its first year of service (year-end 1974) is constructed according to equation (1) and equals the historical acquisition cost multiplied by the remaining productive capacity; $HC_{1974,1} = \$42.84$. Each year the asset's value according to the *HC* model declines by 1/13th of the \$46.41 historical cost.

The specific price of new industrial machinery and equipment rises between year-ends 1973 and 1974 by over four dollars due to increasing prices characterizing this time period. Proponents of current cost accounting argue that a proper financial accounting of the firm's assets

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[10] *CC* and *HC* herein are analogous conceptually to the "current dollar net stock" and "historical dollar net stock" wealth estimates, respectively, published by the U.S. Department of Commerce, Bureau of Economic Analysis (henceforth BEA) [1987]. A discussion of the valuation of net assets by government agencies is presented by Young and Musgrave [1980]. Our modeling of *CC* and *HC* has benefited from discussions with Kenneth Rogers and John Musgrave at the U.S. Department of Commerce (Office of Business Economics and Bureau of Economic Analysis, respectively) and Charles Hulten at the University of Maryland.

[11] This specific price index is the nonfinancial corporate equipment deflator from the BEA [1987]. The BEA obtains these deflators primarily from the U.S. Department of Commerce, Bureau of Labor Statistics (henceforth BLS), where they are referred to as the Producer Price Indexes (henceforth *PPI*). The *PPI* typically are used by firms in their preparation of current cost disclosures and by researchers in their various analyses.

should make adjustments for specific price changes.[12] Making these adjustments shows that the *CC* point estimate of asset value at the conclusion of the first year of service is $46.77; $CC_{1974,1}$ equals the 1974 specific price of new assets ($50.67) multiplied by the remaining productive capacity (12/13ths). According to the *CC* model, the owned used asset after one year is more valuable than when new because the specific price changes for new assets (9.18%) exceeded the proportional decline in capacity depreciation (7.69%).

The effects of discounting and differential tax benefits are ignored in the *HC* and *CC* models but are incorporated into the *FV* model. When new in 1973, the asset's value of $46.41 is sustained by discounted tax benefits (depreciation tax savings plus the *ITC* sum to $18.26) and discounted pretax cash flow net of proportional taxes ($28.15). At the conclusion of this asset's first year of service, discounted tax benefits fall sharply because the *ITC* is removed from the expected return stream and the tax depreciation schedule is frontloaded.[13] The tax-adjusted fundamental value of the asset at the conclusion of its first year of service, $FV_{1974,1}$, equals the discounted sum of remaining after-tax cash flows and is $41.08.

The changes in asset value between year-ends 1973 and 1974 for the *FV*, *HC*, and *CC* models are −11.48%, −7.69%, and 0.78%, respectively. The point estimate from the *HC* model adjusts for capacity depreciation, but it is a biased measure of economic value for an owned used asset because it ignores the 9% cumulative increase in the specific price of new assets. The *CC* point estimate reflects capacity depreciation as well as specific price changes and is 9% greater than the *HC* point estimate. Both the *HC* and *CC* point estimates, however, ignore discounted differential tax benefits between new and owned used assets. The *FV* model accommodates these effects.

The remainder of table 2 indicates that the estimated value of an owned used asset depends on both valuation model and capacity depreciation schedule. The estimates in panel B assume actual capacity depreciation proceeds along a double-declining balance schedule (*DDB*) because the *DDB* schedule is the most widely utilized accelerated pattern in practice (see Shriver [1988]). The estimates in panel C assume actual capacity depreciation follows the decelerated "beta-decay" schedule developed by the U.S. Department of Labor, Bureau of Labor

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[12] Terborgh [1980] suggests that rather than indexing for specific price changes, it is more appropriate to index for changes in the general purchasing power of money.

[13] The *FV* model does not reflect the potential recapture of the *ITC* and accelerated tax depreciation. Auerbach and Kotlikoff [1983] estimate the benefits of churning pre-1981 investments so that tax depreciation schedules are reset to *ACRS* guidelines and find that no equipment would gain by transferring ownership and being brought under *ACRS*. Adjustment and transaction costs also mitigate the incentive to churn. Our modeling for the *FV* of owned used assets implicitly assumes no churning.

TABLE 2

Evolution of an Asset's Value according to Alternative Valuation Models and Capacity Depreciation Schedules

Year-End	Specific Price of New Assets	Remaining Productive Capacity	*HC*	*CC*	*FV*
PANEL A: Straight-Line Capacity Depreciation					
1973	$46.41	100.00%	$46.41	$46.41	$46.41
1974	50.67	92.31	42.84	46.77	41.08
1975	59.43	84.62	39.27	50.29	37.66
1976	64.39	76.92	35.70	49.53	33.57
1977	68.44	69.23	32.13	47.38	28.67
1978	73.26	61.54	28.56	45.08	24.00
1979	78.92	53.85	24.99	42.50	20.10
1980	85.43	46.15	21.42	39.43	17.53
1981	94.56	38.46	17.85	36.37	12.39
1982	101.33	30.77	14.28	31.18	9.86
1983	101.71	23.08	10.71	23.47	6.47
1984	102.18	15.38	7.14	15.72	2.29
1985	101.98	7.69	3.57	7.84	.77
PANEL B: Double-Declining Balance Capacity Depreciation					
1973	$46.41	100.00%	$46.41	$46.41	$46.41
1974	50.67	84.62	39.27	42.88	40.13
1975	59.43	71.60	33.23	42.55	35.95
1976	64.39	60.58	28.12	39.01	31.41
1977	68.44	51.26	23.79	35.08	26.65
1978	73.26	43.38	20.13	31.78	22.43
1979	78.92	36.70	17.03	28.97	19.00
1980	85.43	31.06	14.41	26.53	16.86
1981	94.56	26.28	12.20	24.85	12.49
1982	101.33	22.24	10.32	22.53	10.47
1983	101.71	18.81	8.73	19.14	7.55
1984	102.18	15.92	7.39	16.27	3.48
1985	101.98	13.47	6.25	13.74	1.63

Statistics (henceforth BLS) [1979] in constructing capital estimates for corporate equipment.[14]

The *FV* model is less sensitive than *HC* or *CC* to differences in capacity depreciation schedules. For example, according to the *HC* model the asset concluding its sixth year of service at year-end 1979 retains

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[14] Lately, the BEA has begun to make available two series for capital estimates. Their "wealth" series assumes a straight-line capacity depreciation pattern. Their "multiproductivity" series assumes the beta-decay schedule developed by the BLS [1979].

TABLE 2 — *continued*

Year-End	Specific Price of New Assets	Remaining Productive Capacity	*HC*	*CC*	*FV*
PANEL C: Decelerated Capacity Depreciation					
1973	$46.41	100.00%	$46.41	$46.41	$46.41
1974	50.67	97.96	45.46	49.64	42.34
1975	59.43	95.65	44.39	56.85	40.32
1976	64.39	93.02	43.17	59.90	37.57
1977	68.44	90.00	41.77	61.59	33.46
1978	73.26	86.49	40.14	63.36	29.20
1979	78.92	82.35	38.22	64.99	25.82
1980	85.43	77.42	35.93	66.14	24.25
1981	94.56	71.43	33.15	67.54	17.98
1982	101.33	64.00	29.70	64.85	15.78
1983	101.71	54.55	25.31	55.48	11.02
1984	102.18	42.11	19.54	43.02	4.99
1985	101.98	25.00	11.60	25.50	1.88

All data sources are described in Appendix A.

In all cases the representative asset is purchased at year-end 1973 and depreciated over a 13-year service life.

The specific price index for new assets is the nonfinancial corporate equipment deflator from the BEA [1987].

The remaining productive capacity equals original capacity minus accumulated capacity depreciation; specifications for the alternative capacity depreciation schedules are presented in Appendix A for the variable *d.*

Entries in the *HC, CC,* and *FV* columns represent the point estimates of asset value according to the respective valuation models. Reading down one column, within each panel, shows how the point estimate of asset value changes as the asset ages. Point estimates are constructed from the valuation models specified in equations (1), (2), and (3), respectively.

54% of its historical acquisition cost assuming straight-line capacity depreciation (i.e., $HC_{1979,6} \div HC_{1973,0}$ is .54 for panel A), 37% assuming *DDB* capacity depreciation, and 82% assuming decelerated capacity depreciation. Those three ratios for the *CC* model (i.e., $CC_{1979,6} \div CC_{1973,0}$ for panels A, B, and C) are 92%, 62%, and 140%. For the *FV* model the ratios are 43%, 41%, and 56%. The spread between the highest and lowest ratios is smaller for the *FV* model than for the *HC* or *CC* models.

The robustness of the *FV* model arises from its equilibrium-preserving nature. For example, the capacity depreciation schedule is incorporated into the user cost framework and determines equilibrium pretax cash flow. An acceleration in the assumed capacity depreciation schedule implies that the pretax cash flow stream will be declining more rapidly. For a new asset to deliver discounted pretax cash flow plus discounted tax benefits equal to the specific price of new assets (a necessary condition for zero net present value marginal equilibrium), the pretax cash flow (and user cost) must be larger than otherwise. Hence, for the *FV* model an acceleration in the assumed capacity depreciation schedule is matched by an equilibrium-preserving increase in pretax cash flow, thereby making the *FV* point estimate a fairly robust indicator of economic value across alternative capacity depreciation schedules.[15]

5. Comparison of Point Estimates of Specific Asset Values from the Valuation Models with Observed Fixed Asset Prices from Active Secondary Markets

In this section the point estimates of owned used asset values from the alternative valuation models are compared to the observed prices of used industrial machinery and equipment from active secondary markets for the benchmark years 1973, 1976, and 1980. By assuming that the accuracy of a point estimate is greatest when it equals the used asset's observed market price (the market criterion for expected after-tax cash flows), we are able to determine the extent that the *FV* point estimates reduce the bias induced by discounting and tax effects.[16]

The market price data are obtained from pricing guides prepared by expert used asset dealers and appraisers (Land [1974; 1977; 1981]). The experts compiled new, used, and salvage price data for the benefit of purchasing agents. The data include observed transaction prices obtained from contracts, auctions, and recent sales. The experts have been buying and selling these assets for many years and, therefore, the data are assumed to be accurate and reliable.

The data base includes the standard specifications of industrial machinery and equipment owned by business enterprises in the corporate sector subject to FASB [1979] *Statement No. 33* disclosure requirements. More specifically, the data base contains observed prices for 4,875 assets from the BLS [1979] major asset categories of electrical machinery ($N = 994$), metalworking machinery ($N = 765$), general purpose machinery ($N = 1,851$), special industry machinery ($N = 832$), and miscellaneous industrial machinery and equipment ($N = 433$) (see Shriver [1987]).

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[15] Likewise, the *FV* point estimate is fairly insensitive to the estimation of the discount rate r. As shown in equation (6), *FV* depends on the difference $Z - Y$, both of which are discounted sums, and therefore errors in r tend to cancel.

[16] Used asset prices obtained from secondary markets may be downward biased estimates of the economic value of owned used assets because of (1) potential distressed or damaged items, (2) alternative (secondary) uses for the asset, and (3) asymmetric information between buyers and sellers (the "lemons" problem). These problems generally do not exist for industrial machinery and equipment transactions because of multiple time periods and identifiability of the sellers (Heal [1976]), quality certification by middlemen (Viscusi [1978]), and prior experience in operating a similar type of asset and access to independent professional opinion about the asset's condition and quality (Hulten and Wykoff [1981]).

Prior research indicates that the *CC* estimates of new assets may be overstated because of substitution bias and inadequate adjustments for technological or quality change (see Shriver [1987], Swanson and Shriver [1987], and Hall and Shriver [1990]). To deal with this potentially confounding effect, we matched the new and used assets over the three time periods according to standard engineering specifications and operating capacity. This matching, based on the Land [1974; 1977; 1981] classification methodology, was reviewed by industrial engineers and appraisers and is assurance that the new and used prices reflect assets with equivalent embodied technology.

Prior research also indicates that *CC* estimates of owned used assets may be overstated because of the "double counting of inflation" inherent in conventional depreciation methods (see Beaver and Landsman [1983] and Shriver [1988]). To mitigate this confounding effect, we incorporated identical depreciation methods and useful lives into the capacity depreciation schedules utilized to generate the point estimates of specific asset values for each valuation model. Consequently, the differences between the *CC* and *FV* point estimates may be attributed to discounting and tax effects (and, for *HC*, attributable also to the effects of specific price changes).

Table 3 presents the comparison of the observed prices with the six-year-old point estimates from the alternative valuation models for three patterns of capacity depreciation. Both the point estimates and the observed prices are formulated as the ratio of "six-year-old used asset price ÷ current specific price of a new asset" in order to ascertain the retention of value by a used asset relative to a new one. This relative retention of value formulation also facilitates the comparison of assets with varying values.

The observed retention of value ratio from the actual transaction data for a six-year-old asset equals 0.33, 0.32, and 0.34 in 1973, 1976, and 1980, respectively. These descriptive statistics constitute the sample mean retention of value ratios for the 4,875 industrial machinery and equipment assets contained in the used asset data base and serve as the environmental criteria for the point estimates from the *HC*, *CC*, and *FV* models.

The point estimates of owned used asset values are generated by the alternative valuation models as described previously. Inspection of the *HC* retention of value ratios in table 3 reveals the *HC* point estimates are at their highest level of accuracy when generated by the straight-line (*HC-SL*) capacity depreciation schedule. The estimates are significantly different from the market price criteria at the 0.01 significance level for all three years,[17] but are within 3 percentage points of the observed ratios for both 1976 and 1980. In contrast, the *HC* point estimates

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[17] All inferential statistical tests are based on a two-tailed large sample test for a population mean.

TABLE 3

Comparison of Point Estimates from the Alternative Valuation Models with Observed Asset Prices (Land [1974; 1977; 1981]) from Active Secondary Markets

	Retention of Value Ratios for a Six-Year-Old Asset in: 1973	1976	1980
Observed prices:			
Mean used price ratios for the sample of 4,875 standard specifications of industrial machinery and equipment (see Shriver [1987])	.33	.32	.34
99% confidence interval	.32–.34	.31–.33	.33–.35
Point estimates assuming double-declining balance capacity depreciation:			
Historical Cost (*HC*)	.30	.24	.22
Current Cost (*CC*)	.37	.37	.37
Fundamental Value (*FV*)	.30	.27	.26
Point estimates assuming straight-line capacity depreciation:			
Historical Cost (*HC*)	.43	.35	.32
Current Cost (*CC*)	.54	.54	.54
Fundamental Value (*FV*)	.31	.28	.27
Point estimates assuming decelerated capacity depreciation:			
Historical Cost (*HC*)	.66	.54	.49
Current Cost (*CC*)	.82	.82	.82
Fundamental Value (*FV*)	.39	.36	.32

Both the point estimates and the observed prices (Land [1974; 1977; 1981]) are formulated as the ratio of "six-year-old used asset price ÷ current specific price of a new asset." All of the point estimate retention of value ratios are significantly different from the market price retention of value ratios at the 0.01 significance level, based on a two-tailed large sample test for a population mean.

assuming decelerated capacity depreciation substantially overstate the market price ratios by 15 to 33 percentage points, and assuming accelerated capacity depreciation the market price ratios are understated by 3 to 12 percentage points.

The *CC* point estimates are at their highest level of accuracy when generated by the accelerated (*CC-DDB*) capacity depreciation schedule. Even though the estimates are significantly different from the market price criteria at the 0.01 significance level for all three years, they always are within 5 percentage points for each year. In contrast, the *CC* point estimates assuming the straight-line (*CC-SL*) and the decelerated capacity depreciation schedule overstate the market value ratios by 22 and 50 percentage points, respectively.

These findings are consistent with the Lim and Sunder [1991] analytical properties of estimators. They conclude that the relative valuation accuracy of *HC* and *CC* models is not based on theory but is dependent on the relative magnitudes of parameters that characterize the economy at a particular time. For instance, the *HC-SL* combination may yield a statistically more accurate estimate than *CC-SL* of the economic value of owned used assets in an environment when estimation errors are large relative to specific price changes. In contrast, the *CC-DDB* combination may be superior to the *HC-DDB* combination when specific price changes are large relative to estimation errors.

The *FV* point estimates of owned used asset values presented in table 3 are significantly different from the market price criteria at the 0.01 significance level, but always are within 8 percentage points (and most are within 5) of the observed retention of value ratios. The *FV* model accounts for changes in economic value attributable to capacity depreciation, specific price changes, and the effects of discounting and differential tax effects. Consequently, the *FV* point estimates contain reduced estimation error and generally are more accurate than the *HC* and *CC* point estimates.

6. *Conclusions*

We develop and test a tax-adjusted fundamental value (*FV*) model that incorporates information about differential tax benefits between new and owned used assets and specifies the effects of these differences on discounted after-tax cash flows. The results indicate that the accuracy (relative to used asset prices) of the *FV* point estimates of economic value is reasonably robust across three alternative capacity depreciation schedules. In contrast, the historical cost (*HC*) point estimates are at their highest level of accuracy when generated by a straight-line pattern, while the current cost (*CC*) point estimates are most accurate when generated by a double-declining balance pattern. The accuracy of the *HC* and *CC* models depends on the choice of capacity depreciation schedules.

The findings are relevant to the estimation of economic value for nontraded used assets in rate regulations, mergers and acquisitions, collateral for financial assets and liabilities, property tax assessments, appraisals, and the financial reporting of changing prices by business enterprises. These results and their implications, however, may be limited to the years, asset types, and level of aggregation selected for analysis in our study. Future research is needed to determine whether the *FV* model can accurately estimate, within alternative economic environments, the economic value of other types of assets (e.g., structures rather than equipment) or the economic value of assets at different levels of aggregation (e.g., total net fixed assets in an industry, firm, or division).

APPENDIX A

This appendix lists the notation and discusses data utilized in this study.

The input variables utilized in the *HC* and *CC* models are p_s and q_s (for new assets $s = 1973, 1976, 1980$, for six-year-old owned used assets $s = 1967, 1970, 1974$), and the d_j series ($j = 1, \ldots, 13$). There are unique annual observations for p_s and q_s. The d_j series utilized in one year is the same series utilized in all other years.

The input variables utilized in the *FV* model are p_s, q_s, ν_s, the d_j series, the $z_{s,j}$ series (s and j are defined above), r_t, τ_t, and π_t ($t = 1973, 1976, 1980$). The p_s, q_s, and d_j series utilized in the *FV* model are the same as the ones utilized in the *HC* and *CC* models. For the other input variables and series there are unique annual observations. The input variables as well as other intermediate variables mentioned in the text are described below.

π, *expected inflation rate*—For 1973 and 1976 the rate equals the end-of-year expected inflation rates presented by Hendershott and Hu [1981] and is 0.0498 and 0.0494, respectively. Sheng Cheng Hu graciously supplied an updated estimate for 1980 of 0.0800.

τ, *corporate tax rate*—The statutory corporate tax rate is 0.48 in 1973 and 1976 and 0.46 in 1980.

c, *user cost of capital*—This intermediate variable is constructed as:

$$c_s = \frac{p_s(r_s - \pi_s)\,(1 - \nu_s - \tau_s Z_s)}{(1 - D_s)\,(1 - \tau_s)}. \tag{7}$$

The real user cost (c/p) is the equilibrium pretax cash flow generated per dollar of real asset and is endogenously determined. For straight-line capacity depreciation it is 0.1894, 0.1887, and 0.1911 in 1973, 1976, and 1980, respectively; for double-declining balance it is 0.2291, 0.2279, and 0.2314; and for decelerated capacity depreciation it equals 0.1387, 0.1388, and 0.1394.

C, *expected pretax cash flow*—The present value at time s of the pretax cash flow expected from an asset concluding its *t*th year of service, denoted $C_{s,t}$, is constructed according to:

$$C_{s,t} = \sum_{j=1}^{\infty}(1 + r - \pi)^{-j}\,(1 - \tau)c_s q_{s-t}\,\{1 - \sum_{u=o}^{t+j-1} d_u\}. \tag{8}$$

d, *capacity depreciation schedule*—Three unique productive capacity depreciation schedules are utilized. For the straight-line schedule $d_j = 1/L$ for $j = 1, \ldots, L$ and $d_j = 0$ otherwise. The variable L is the asset service life. For double-declining balance $d_j = (2/L)(1 - 2/L)^{j-1}$ for $j = 1, \ldots, L - 1$, $d_L = (1 - 2/L)^{L-1}$, and $d_j = 0$ otherwise. For the decelerated beta-decay schedule $d_j = (L - (j - 1))/(L - \beta(j - 1)) - (L - j)/(L - \beta j)$ for $j = 1, \ldots, L$ with $\beta = 0.75$ and $d_j = 0$ otherwise.

D, *discounted productive capacity*—This intermediate variable is constructed according to:

$$D_s = \sum_{t=1}^{\infty} (1 + r - \pi)^{-t} d_t. \tag{9}$$

H, discounted productive capacity—This intermediate variable is pertinent to total net fixed assets, rather than a specific owned used asset, and is constructed according to:

$$H_s = \sum_{t=1}^{\infty} (1 + r - \pi)^{-t} \{\sum_{j=1}^{\infty} q_{s-j+1}\, d_{j+t-1}\} / K_s. \tag{10}$$

K, real quantity of assets—This intermediate variable measures the quantity of productive capacity in total net fixed assets and is constructed according to:

$$K_s = \sum_{t=0}^{\infty} q_{s-t} (1 - \sum_{j=0}^{t} d_j). \tag{11}$$

L, asset service life—Based on asset weights and service life data published in the *National Income and Products Accounts, L* is set to 13 years.

p, price of new assets—Fixed asset price indexes are from the U.S. Department of Commerce, Bureau of Economic Analysis (henceforth BEA) [1987], who in turn obtain them primarily from the Producer Price Index Series at the Bureau of Labor Statistics (BLS).

q, real investment—Real gross investment series are from the BEA.

r, weighted average financing rate—This rate is a weighted average of (after-corporate-tax) debt and equity financing rates, where the weight on debt is the debt ratio. The debt ratio is constructed from the Balance Sheets for the U.S. economy as the ratio of "Total Liabilities" to "Total Liabilities plus Market Value of Equities" (Board of Governors of the Federal Reserve System [1987]). The debt financing rate equals a high-grade corporate bond yield. The equity financing rate is based on a portfolio equilibrium between treasury bill yields, personal tax rates, and equity betas (data utilized in this equilibrium are based on Downs [1992]). The resulting weighted average (after-tax) financing rates equal 0.0765, 0.0817, and 0.1026 in 1973, 1976, and 1980, respectively.

v, investment tax credit—The rate of the investment tax credit is obtained from the *SSRC-MIT-PENN Quarterly Econometric Model* (Federal Reserve Board [1984]) and equals 0.0560, 0.0810, and 0.0610 in 1973, 1976, and 1980, respectively.

Y, discounted tax depreciation deductions—$Y_{s,t}$ is an intermediate variable representing the discounted tax depreciation deductions promised by the asset concluding its *t*th year of service at time *s* and is constructed according to:

$$Y_{s,t} = \sum_{j=1}^{\infty} (1 + r)^{-j} p_{s-t} q_{s-t} z_{s-t,t+j}. \tag{12}$$

Y_s is the discounted deductions per dollar of assets promised by the total net fixed assets at time *s* and is computed as the summation of $Y_{s,t}$ at time *s* across all age cohorts (t), as in:

$$Y_s = \sum_{t=0}^{\infty} Y_{s,t} / (p_s K_s). \tag{13}$$

$z_{s,j}$, *tax depreciation*—The series of weights $z_{s,j}$ ($j = 1, \ldots, L$) represent the proportion of a $1 fixed asset expenditure from time s that is deductible for tax purposes at time $s + j$. The series sums to unity and is recomputed annually. Tax lives are based on Coen [1975] and equal 12 years prior to 1971 and 10 years for 1971–80. The schedules reflect a combination of accelerated and straight-line procedures. The proportion of fixed asset expenditures depreciated by accelerated methods is taken from the *SSRC* (Federal Reserve Board [1984]) and rises smoothly from 0.7434 in 1961 to its maximum of 1.0 in 1970; thereafter it remains at unity. Half of all expenditures depreciated by accelerated methods are depreciated by sum-of-year's digits and half by double-declining balance with an optimal switch to straight-line at midlife. Expenditures not depreciated by accelerated methods are depreciated by the straight-line method. The half-life tax convention is used, which implies that the first year's allowable deduction is split in half and moved to the rear of the tax life. For 1971–80 the series of weights is identical in each year and equals .0955 (at the end of the first year of service), .1618 (second year, etc.), .1367, .1148, .0955, .0782, .0691, .0600, .0509, .0419, and .0955 (at the end of the eleventh year of service).

Z, discounted tax depreciation deductions for new investments—This intermediate variable represents the discounted deductions per dollar of new investment and is constructed according to:

$$Z_s = \sum_{t=1}^{\infty} (1 + r)^{-t} z_{s,t}. \tag{14}$$

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