

Value, Surplus, and Capital Investment

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September, 1984

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I am grateful to Patric Hendershott and Dale Jorgenson for showing interest and providing comments about my work. I am indebted to the Honeywell Corporation and the Boston College School of Management for financial support. Any errors are my responsibility.

Over the past twenty years the economic profession has accepted the user cost of capital as an important determinant of capital investment behavior.¹ The user cost became popular after Dale Jorgenson demonstrated that it could systematically relate policy parameters to market variables. Since Jorgenson's pioneering research, numerous studies have utilized his framework in order to explain investment fluctuations.

The objective of this paper is to provide insights about real investment incentives by applying the user cost of capital in an asset valuation model. Section I presents a framework that links asset values to the user cost. The resultant valuation model is used in various applications in section II. First, replacement value estimates are produced. Second, estimates of capital stock duration are derived and discussed. Third, an investment function is presented and estimated. A brief summary concludes the paper.

I. The rational valuation model

The capitalized value of an asset is the fair market price paid for rights to the asset's income stream. Several government agencies, et al., produce time series estimates of the value of a new but otherwise homogeneous unit of capital by sampling transaction prices in the capital goods market. Unfortunately though, it is not so easy to establish the value of "old" capital. The lack of extensive markets trading vintage capital means that it is not possible to directly discern the

value of an aggregate stock comprised of vintage capital; only inferences may be made. The first objective of this study is to make inferences about the value of vintage capital. This is done by taking the observed price of new capital and unraveling it into a description of the income stream that new assets are expected to generate. The early portion of new capital's income stream temporally overlaps with the remaining portions of vintage capital's income stream. Because of homogeneity it is possible to compute the vintage capital's value by summing the overlapping portion of the stream. In other words, this model provides a conditional estimate of a stock's value by measuring the stock's discounted marginal income stream. This measure is consistent with the definition that a stock's value is equal to the sum of the open market values that each unit comprising the stock would fetch if sold in competitive capital markets. A model to compute the stock's expected capital income stream is described below.

Begin with the price of new capital. Given competitive demand for capital goods, investors will invest until the net present value of the marginal investment is zero. This equilibrium can be described as²

$$(1) \quad q(s) = \int_0^{\infty} e^{-rt} p(s+t) F'(s+t) [1 - \int_0^t h(v) dv] dt$$

where

q : unit price of capital

p : unit price of output

F' : marginal physical product of capital

r : discount rate

$h(v)$: the percent of original productive capacity

lost at the v 'th moment after acquisition

Suppose a stock is comprised of capital that has an infinite life and never depreciates. In this case, $h(v)=0$ for every v . Each capital unit, whether new or vintage, is capable of generating a discounted return stream equal to

$\int_0^{\infty} e^{-rt} p(s+t) F'(s+t) dt$ and would have identical capitalized value in competitive markets. Adding together the capitalized value of all units in the capital stock yields the replacement value, RV , as

$$(2) \quad RV(s) = \int_0^{\infty} e^{-rt} p(s+t) F'(s+t) \int_0^{\infty} I(s-u) du dt$$

where $I(s)$ is the real investment at time s . The real capital in place at time s may be computed as the sum of all prior investments. The integral du represents that summation and equals $K(s)$. The integral dt represents the discounted path of expected returns through time and equals $q(s)$. In equation 2 du and dt are independent and $RV(s)=q(s)K(s)$. Notice that 2 captures only the income stream attributable to the stock in place as of time s . Future increases in the income stream brought about by later capital expansions are capitalized at the time of expansion and have no effect upon the value of capital already in place.

More generally capital may have a less than infinite life and may not retain its original productive efficiency. In order to modify equation 2 to reflect this change the sum of all previous investments must be allowed to reflect the expirations

and capacity depreciation that have occurred. Let L be the productive service life of capital. The stock $K(s)$ is a weighted sum of the real investments $I(s)$ back through $I(s-L)$.³ The weights represent the proportion of real capital surviving until the reference point s . The proportion of capital surviving u periods after its acquisition

is $1 - \int_0^u h(v)dv$. Given the maintained hypothesis that the capacity depreciation schedule is invariant to time, the quantity of capital that shall exist u periods in the future but which is in place today (time 0), may be computed as

$$K(0,u) = \int_0^L I(u-t) [1 - \int_0^t h(v)dv] dt$$

and the replacement value of the stock is

$$(3) \quad RV(s) = \int_0^L e^{-rt} p(s+t) F'(s+t) \int_t^L I(s+t-u) [1 - \int_0^u h(v)dv] du dt$$

Equation 3 cannot generally be reduced to qK because the du and dt integrals are not independent. In essence, 3 computes replacement value as follows. Past investment flows are depreciated to arrive at the quantity of capital in place at the current period, s . That quantity is multiplied by the current value marginal product to arrive at the present value of current capital income. Next, the model calculates the quantity of real capital that will exogenously persist until the following period and multiplies that quantity by that period's value marginal product. The resulting term is discounted and added to the previous income term. The process is repeated. The current capital stock is depreciated into the future and each period's

quantity of capital is multiplied by that period's expected value marginal product. The term is discounted back to the present where it contributes to current replacement value.

Equation 3 can serve as the basis for a valuation procedure because many of its required variables are recorded data series. The real investment series $I(s)$ is widely measured for a large number of assets and the series $h(v)$ is exogenous and can be estimated as the weights in a mortality distribution. All that remains is to collect the value marginal product series. Jorgenson has shown that the value marginal product is estimable and that its best proxy is the user cost of capital.

In the presence of income taxes, depreciation deductions, exogenous depreciation, inflation, and inflation induced excess taxes on accounting inventory profits, the user cost is given by

$$(4) \quad pF' = \frac{q(r-\pi)[1-c-\tau S(1-bc)]}{(1-W)[1-\tau(1+zm\pi)]}$$

The undefined terms are

π : the expected inflation rate

c : the effective rate of the investment tax credit

b : the proportion of the tax credit that must be deducted from the depreciation base

τ : the marginal tax rate on business income

S : the present value of tax depreciation deductions

z : the percent of inventories accounted by first-in-first-out (FIFO) inventory accounting procedures

m : the cost-of-goods sold per dollar of output

W : $= \int_0^{\infty} e^{-(r-\pi)v} h(v) dv$

Capital stock replacement value estimates are derived and discussed in the next section and related to several aspects of investment activity.

II. Value processes

A. Replacement Value

Replacement value is the summation of discounted future values. The replacement value formula, presented in continuous time in equation 3, can be written in discrete time as

$$(5) \quad RV_s = \sum_{t=0}^L (1+r)^{-t} (pF')_{s+t} \left\{ \sum_{u=t+1}^L I_{s+t-u} [1 - \sum_{v=0}^u h_v] \right\}$$

Empirical estimates are constructed according to equation 5, given substitution of 4, and an assumption that tax, inflation, and structural rates are expected to remain constant. The sample set consists of two assets, plant and equipment, in ten U.S. manufacturing industries over the 1958-76 annual sample period (19 years). The data used to generate these twenty time series (two assets per industry, ten industries) is described in the Appendix.

Column 1 of table 1 presents the sum of the replacement value series over all assets and industries. These estimates are unusual for a capital stock series because they decline several times (1961-62, 1963-64, 1970-71). Typical capital stock estimates, such as those published by the Bureau of Labor Statistics (hereinafter BLS), are measures of replacement cost (RC) and are computed as the product of cumulated non-depreciated capital times current supply price (i.e., $RC(s) =$

$q(s)K(s))$.⁴ The steady increases in capital's supply price have resulted in an RC series that is monotonically increasing.⁵ Conversely, the RV estimate may have declined even though the real stock increased. This occurred whenever there was a sufficiently large drop in capital's value marginal product; such was the case in the downturns observable in column 1.

Column 2 of table 1 presents the ratio of replacement value to replacement cost. The ratio shown is the aggregate ratio obtained by summing over all ten industries; i.e., the numerator and denominator are each the sum of 20 individually constructed series, ten plant plus ten equipment. The decline of 48 percentage points over the 16 years 1961-76 is evidence that replacement cost has grown considerably faster than replacement value.⁶ These results indicate that in 1976 replacement cost is \$29.4 billion greater than replacement value.

The fundamental distinction between replacement cost and replacement value is their sensitivity to static versus dynamic incentives. Replacement cost is directly sensitive to the supply and demand schedules for capital goods and output. Replacement value is directly sensitive to the distribution of returns across time.⁷

B. Duration

The rational valuation model can reflect not only the differences among alternative stock's values but also the differences in the timing with which the returns are expected. A summary measure of a return stream's intertemporal distribution is its duration. Duration is the weighted average maturity of a return stream, where the weight applied to each period is equal to the proportionate contribution of that period's return to the asset's total present value. Streams with a short duration generate a large proportion of their present value in the near future whereas long duration streams generate proportionately more in the remote future. The generalized notion of duration was conceived and described by J.R. Hicks in Value and Capital.⁸ Therein, he established that an asset's elasticity of capitalized value with respect to the discount ratio is equal to that asset's duration.

The importance of Hicks' duration can be easily illustrated. The net present value of an investment alternative is comprised of the difference between a discounted receipt stream and a discounted expenditure stream. Each component stream has its unique duration. Suppose that at a given discount rate the investment's net present value equals zero. Now say the discount rate rises. The sign of the change in net present value depends upon the relative durations of the component streams. If the duration of the receipt stream is greater than the expenditure stream's, net present value falls

and investment (in that alternative) is stifled. Conversely, if the expenditure stream's duration is greater than the receipt stream's, net present value rises and a commitment towards the investment path is more attractive.

It is possible to generate estimates of capital stock duration by modifying equation 3. The duration of a capital stock, denoted as DUR, is given by

$$(6) \quad \text{DUR}(s) = \int_0^L \frac{t}{RV(s)} e^{-rt} p(s+t) F'(s+t) \left\{ \int_t^L I(s+t-u) \left[1 - \int_0^u h(v) dv \right] du \right\} dt$$

This equation in discrete form, given substitution of 4, is estimable. For the moment though, impose the restrictive conditions under which replacement value reduces to replacement cost (described in footnote 4). The equation can be solved as

$$(7) \quad \begin{aligned} \text{DUR}(s) &= \frac{p(s) F'(s) I(s)}{RV(s)} \int_0^\infty t e^{-(r-\pi)t} \left\{ \int_t^\infty e^{a(t-u)} \left[1 - \int_0^u \delta e^{-\delta v} dv \right] du \right\} dt \\ &= \frac{1}{r+\delta-\pi} \end{aligned}$$

where a is the rate of real capital accumulation and δ is the rate of depreciation. This result is slightly more constrained than Hicks' finding that duration equals $1/r$ for constant perpetual streams. Given the exponential restrictions on price, rate and accumulation paths used to derive 7, duration is independent of the path of capital accumulation. In actuality, real investment paths are volatile, one of the restrictive conditions implicit in 7 is violated, and actual empirical estimates of duration depend upon the capital accumulation path;

relatively new stocks have a longer duration than old stocks, *ceteris paribus*.

Duration estimates are computed annually (1958-76) for two assets (plant and equipment) in each of ten industries using the discrete analogue to formula 6. Column 1 of table 2 presents a measure of duration for each industry. The number presented is an arithmetic average computed over the 19 annual observations of duration for each industry; each industry's annual observation is a weighted average of the plant and equipment durations. The magnitude of the duration estimates is roughly consistent with what might be expected in light of equation 7.⁹ The range of estimates is from 4.41 to 5.92 years, a spread of 34%. Some of the interindustry variation is a result of differences in the assumed industry specific service lives for equipment, but not all of it. Eventhough plant service life is 28 years in all industries and all assets are depreciated by straight line, the 1975 estimates of plant duration (not shown) range from 6.76 years (SIC 36) to 8.13 years (SIC 30), a spread of 20%. The correlation coefficient (1975, cross-section, ten industries) between plant duration and the plant user cost is -0.81. It seems that interindustry differences in duration are primarily a result of differences in industry user costs and capital accumulation paths.

Column 2b of table 2 presents each industry's duration (weighted average of plant and equipment) for 1975. Comparison with column 1 reveals that the ordering of industries by

magnitude of duration is not stationary over time. Eventhough there is interindustry covariation of duration across time, there is relative movement and reordering. In light of the role of duration as a link between risk and return, such relative motion may have economic significance.¹⁰

It should be expected that when the discount rate is instantaneously raised the discounted value of every future period's expected return will fall. Total present value will unequivocally decline. Furthermore, because distant returns are affected proportionately more than near returns duration will unequivocally shorten. Table 2 confirms this. Columns 2a and 2b present, respectively, the 1975 replacement value (plant plus equipment) and duration computed for each industry using the historic discount rate. Columns 3a and 3b present, respectively, the same measures given simulated 20% rises in the discount rates. The direction of changes is as expected, both replacement value and duration fall.¹¹

Of course, the replacement values shown in column 3a are not those that would be expected to actually result if there were a 20% rise in the discount rate. These numbers are not equilibrium values; not even in a partial equilibrium setting. In column 3a we have affected the discount rate, and hence the user cost, but not the value marginal product. The analysis of what happens given a change in the discount rate is logically incomplete. In order for the discount rate to remain at its higher level the value marginal product must be allowed to adjust to the new user cost.

Columns 4a and 4b present RV and DUR given a 20% rise in the discount rate and complete movement of the value marginal product towards the new user cost, thereby restoring equilibrium.¹² Again, a rise in the discount rate unequivocally results in a decline in duration, more or less to the same magnitudes as shown in column 3b. Yet eventhough the discount rate has risen, terminal replacement values are not necessarily less than their initial values. In two industries, SIC 29 and 33, equilibrium replacement values do fall from their initial (column 2a) values. In most industries though, equilibrium replacement values rise. In these cases capitalized value is positively related to the equilibrium discount rate.

The sensitivity of equilibrium replacement value to discount rate fluctuations depends upon the user cost's elasticity with respect to the discount rate, hereinafter denoted as η_c . Given simple conditions of constant prices, infinite lived and nondepreciating capital, the sign of $\partial RV / \partial r$ is the same as the sign of $(\eta_c - 1)$; for elasticities greater than unity equilibrium RV moves in the same direction as the equilibrium discount rate. Given complex conditions of taxes, finite lived capital, and volatile capital accumulation paths, the critical value of η_c at which $\partial RV / \partial r$ changes signs is a complex function of parameter and variable values. Regardless, in this sample set a 20% contemporaneous rise in equilibrium discount rates raises RV in some industries while lowering it in others. A shock to a common, economy-wide component of discount

rates tends to increase the capitalized value of some stocks while decreasing others.

C. Investment

The first step in measuring a stock's replacement value is to specify its expected return stream. Equation 5 defines a return stream that is L periods long. Because the stream is comprised of expected values it reflects all available information about the anticipated future. After having been specified, the stream may be discounted in order to compute the stock's capitalized value. If the stream spanning the interval s through $s+L$ is discounted back to time s ,¹³ the resulting discounted sum is $RV(s)$. Notice though, that from the aforementioned return stream it is possible to compute the value that capital in place at s is expected to have at any point during the capital's life; i.e., its value at any time $s+j$, for $0 < j < L$. That present value is equal to the sum of the returns over the interval $s+j$ through $s+L$, discounted back to $s+j$. One may use a derivative of 5 for that computation. The capital in place at time s is expected to have a replacement value at $s+j$ equal to

$$(8) \quad RV_{s,j} = \sum_{t=0}^{L-1-j} (1+r)^{-t} (pF')_{s+t+j} \left\{ \sum_{u=t+1+j}^L I_{s+t+j-u} \left[1 - \frac{u-1}{v} h_v \right] \right\}$$

Equation 8, given substitution of 4, can be used to generate a sequence of L estimates of replacement value. The series of estimates computed from 8 as j is incremented from 0 to $L-1$ is herein referred to as the replacement value sequence for time s .

Column 1a of table 3 presents the replacement value sequence for structures in the paper products industry in 1974. The most recent addition to that stock was $I(1973)$; the stock in place as of 1974 was comprised of some new undepreciated capital and was therefore expected to be productive for L periods; in this case 28 years. (See appendix for data description.). All entries in 1a are generated from equation 8 with $s=1974$. The top entry is $RV(1974)$ and is computed from equation 8 with $j=0$; or equivalently, from equation 5. The second entry is $RV(1974,1)$ and is the value that the same stock, i.e., capital in place as of 1974, is expected to have one period in the future. It is computed from 8 with $j=1$. The bottom entry is $RV(1974,27)$ and is computed from 8 with $j=27$; it is the value capital in place in 1974 is expected to have in 2001.

The value of the stock at time s is equal to the sum of the discounted value of all expected capital services. As time passes from s to $s+1$ capital services are extracted. The worth of those services is $c(s)K(s)$, where c is the user cost of capital. Because the real stock in 1974 contains 3648 million units of capital and the user cost of capital is .1786 dollars per unit, the extraction of capital services in 1974 represents a loss in capitalized value by 1975 of \$651 million ($=3648 \times .1786$). The deletion of this entry from the return stream naturally leads to a reduction in the capitalized value of the stream, but not by the full amount because there is an offsetting positive effect. In $RV(1974,1)$ each entry in the

return stream is discounted less than it was in RV(1974) because as of 1975 each future return is one period closer to the discounting point of reference.¹⁴ This effect tends to increase capitalized value by \$448 million. Hence, the net value change is \$-0.2 billion (=\$448-651 million), or a fall of 3.76% off the initial replacement value (=\$0.2/5.4 billion).¹⁵

The situation can be elucidated further. Capitalized value is the discounted sum of value marginal products.

$$RV(s) = \sum_{t=0}^{L-1} (1+r)^{-t} p(s+t) F'(s+t) K(s,t)$$

Simple and perfect equilibrium implies equality of user cost and value marginal product. Therefore,

$$RV(s) = \sum_{t=0}^{L-1} (1+r)^{-t} c(s+t) K(s,t)$$

The value next period is expected to change to

$$RV(s,1) = \sum_{t=0}^{L-2} (1+r)^{-t} c(s+t+1) K(s,t+1)$$

The change in value from time s to s+1 is

$$\begin{aligned} (9) \quad \Delta RV_{0,1} &= RV(s,1) - RV(s) \\ &= \frac{-c(s+L-1)K(s,L-1)}{(1+r)^{L-1}} + \sum_{t=0}^{L-2} \frac{c(s+t+1)K(s,t+1) - c(s+t)K(s,t)}{(1+r)^t} \end{aligned}$$

For expositional ease say that the periodic flow of capital services has equal value such that $c(s+t)K(s,t)$ is constant across every t. On that condition 9 can be reduced to

$$\begin{aligned} (10) \quad \Delta RV_{0,1} &= \frac{-c(s+L-1)K(s,L-1)}{(1+r)^{L-1}} \\ &= \frac{-c(s)K(s)}{(1+r)^{L-1}} \end{aligned}$$

For infinite lived capital, such as perpetuities, the discount ratio is zero [$=(1+r)^{-\infty}$] and the value will not change so long

as expectations, etc., remain unchanged. For finite lived assets, capitalized value will change with the passage of time, falling to zero upon the asset's expiration. The value may monotonically or exponentially fall to zero, or it may rise and then fall; ultimately though, it must fall to zero. The value change is the net result of two opposing and potentially unequal effects. Each effect may be viewed from two opposing yet equivalent perspectives.

Causing a decline in capitalized value is the extraction of embodied capital services. On the one hand, the supplier of the services, or more precisely the capital itself, suffers a gross loss of $c(s)K(s)$. On the other hand, the producer, as recipient of the services, realizes a gross return of $p(s)F'(s)K(s)$.

Causing an increase in capitalized value is the pressing forward of embodied capital services towards the present. On the one hand, the capital itself accrues value in the form of market interest. On the other hand, the producer has to pay market interest on capital.

Insofar as the gross return exceeds interest there is a change in capitalized value. On the one hand, the magnitude of the change is computed in equation 9 by directly measuring the change in the value of the embodied return stream. On the other hand, the surplus, SUR, may be computed as the producer's gross return less market interest due on capital; a change given by

$$\begin{aligned}
 \text{SUR} &= p(s)F'(s)K(s) - r[RV(s) - c(s)K(s)] \\
 &= (1+r)c(s)K(s) - r \sum_{t=0}^{L-1} (1+r)^{-t} c(s+t)K(s,t) \\
 &= \frac{c(s)K(s)}{(1+r)^{L-1}} \\
 &= -\Delta RV
 \end{aligned}$$

Capital provides a surplus equal in magnitude but opposite in sign to the change in capitalized value.¹⁶ The market interest portion of the gross return can be earned from any equal-valued investment of the same risk class; efficient markets assure that. The surplus, i.e., the gross return net of market interest, is born from the real investments made during previous periods and uniquely depends upon the intrinsic character of the capital stock under question. Foregone real returns sacrificed through earlier investments are being released from the capital within which they had been embodied.

Each value change implicit in column 1a represents a return. Hence, the entire column represents a sequence of returns, or rather, a return stream.¹⁷ As suggested in section IIB, investment incentives may be related to the intertemporal distribution of returns. That section describes a procedure for computing a summary measure of a return stream's intertemporal distribution; the elasticity called duration. That measure is inappropriate for this situation because the aforementioned procedure discounts every periodic return before measuring that period's contribution to duration. In section IIB duration is computed for the gross return stream; i.e., for $\int c(t)K(s,t)dt$. Because that stream contains interest, it is appropriate to discount by the interest rate before computing the weight that each period contributes to duration; because of discounting, the sum of the duration weights is unity.

The return stream implicit in column 1a is net of interest.

It is inappropriate to discount by the rate of interest.¹⁸ Given a stream such as this the share that each period contributes to total benefit is the proportionate share of that period's return to the stock's total current value. These shares are weights that may be used to compute a summary measure of the surplus stream's intertemporal distribution. Herein, that measure is referred to as the real average period, RAP, and it is given by

$$(11) \quad \text{RAP}(s) = \frac{L-1}{j \sum_{j=1}^{L-1}} j \left\{ \frac{\text{RV}(s, j-1) - \text{RV}(s, j)}{\text{RV}(s)} \right\}$$

The weight applied to each period is the ratio in brackets. Notice the sum of all weights equals unity.

Because there are L elements in the replacement value sequence, there are L-1 value changes. The series of value changes that can be computed from the replacement value sequence for time s is herein referred to as the value change sequence for time s. Column 1b of table 3 presents the proportionated value change sequence for 1974. Each entry is a ratio with numerator equal to that period's value change and denominator equal to the stock's initial value; the column lists the weights from equation 11 with s=1974. For example, the entry in the third row of 1b is derived as $[\text{RV}(1974, 1) - \text{RV}(1974, 2)] / \text{RV}(1974)$; or $3.98\% = (5202 - 4987) / 5405$. Column 2b presents the replacement value sequence for 1975. Thus, 2b is analogous to 1a except that the point of reference is 1975 instead of 1974; $\text{RV}(1975)$ contains $I(1974)$ and reflects expectations based upon available information through 1975. Column 2a is the proportionated value

change distribution for 1975 and is analogous to 1b; 2a is derived from 2b and is a listing of the weights from equation 11 for $s=1975$. The interesting comparison is between analogues 1b and 2a.

The two columns represent different intertemporal distributions of returns. In 1b the earlier returns are weighted more heavily than they are in 2a. This is obvious because the sum of each column is unity. Thus, the relatively heavy weights given early returns in 1b is compensated by the relatively light weights given remote returns; notice 1b is greater than 2a until the twelfth period, at which point there is an overtaking. The shift of intertemporal distributions is also reflected by a change in the real average period; RAP is 11.5 years for 1b and 12.4 years for 2a. Between 1974 and 1975 the value change distribution tilted (upon the RAP) towards the remote future. Equilibrium surpluses expected from structures in the paper products declined for near periods and increased for remote periods.

I assume the incentive to invest is positively related to the size of near term surpluses. Thus, if conditions were such that the real average period declined, near-term expected surpluses would increase, and the incentive to invest would increase. Stability arises because induced investment drives up the subsequent real average period, thereby relieving pressure for continued investment. A steady state condition is where the natural decline in RAP brought about by depreciation induces

just enough capital investment to push RAP back to its initial position.¹⁹

When stocks adjust costlessly and instantaneously investment flows are dependent upon the one-period return capital is expected to provide; i.e., investment is a function of only the most immediate surplus, as in $qI=f(\Delta RV_{0,1})$. When there are adjustment costs or installation lags, investment flows are dependent upon the surpluses expected to occur during several subsequent periods, such as in $qI=f(\Delta RV_{0,1}, \Delta RV_{1,2}, \dots, \Delta RV_{m-1,m})$ where m is the number of periods for which adjustment constraints are effective.

The regressions presented in table 4 relate the nominal gross investment time series to the first surplus series,²⁰ $\Delta RV_{0,1}$, adjusted for inflation. More precisely, the independent variable is the adjusted first surplus series, ΔRV^* , where

$$\Delta RV^*(s) = RV(s) - \frac{RV(s,1)}{1 + \pi}.$$

$RV(s,1)$ is divided by $1+\pi$ so that it is dollar-wise conformable with $RV(s)$. Table 4 presents estimated coefficients for plant investment regressed on its adjusted surplus series, for equipment investment regressed on its adjusted surplus series, and for plant and equipment total investment regressed on the sum of their adjusted surplus series. The bottom row presents regression results for the aggregated ten industry sample. The t -statistics with respect to 0 are in parentheses below the coefficients.

An overview of the empirical feasibility of the investment

function may be gleaned from the regression presented in the lower right corner of table 4; the dependent and independent variables are each the sum of twenty industry/asset specific series. The slope coefficient is highly significant, resulting in a relatively high goodness-of-fit statistic.²¹ The slope being greater than unity indicates that value inflows building up the stock were, on average, greater than the economic decay in value attributable to changes in the capitalized stream of vintage assets.

The asset specific aggregate regressions are also relatively good-fits; the adjusted first surplus is a significant series in both cases. The slope coefficient for equipment, at 1.65, is much greater than unity; plant's, at 0.60, is much less. The magnitude of the divergence from unity is implausible. These estimated equations are biased by specification errors.²² There is certainly specification error within the user cost. For example, structural rates should be asset specific, but in this study the discount rate is specific only to the industry, not asset, and rates of expected inflation are the same across all industries/assets. Increased sophistication of the user cost, empirically and theoretically, will likely result in the convergence of slope estimators toward more plausible levels.

As a final exercise several policy changes are simulated. The significance of the simulation is not the magnitude of the reported effects, but rather that the model can easily reflect

the impact of policy changes as a change in the forward expectations scheme. Table 5 presents the impact on investment if, in 1974, investors had perceived the following to be immediate and permanent changes: the tax rate declined two percentage points; the usage of FIFO accounting declined forty percent; the effective investment tax credit for plant and equipment increased two percentage points; and the depreciable tax life of all property decreased twenty percent.²³

A general observation from table 5 is that the responsiveness of investment to policy changes is not uniform across industries. The simulated tax package increased structures investment in the Primary Metals industry by only 4.1%, far less than the 10.2 or 9.7% stimulant realized in the Food Products or Petroleum industries. In a similar fashion the impact on equipment investment is varied across industries; the stimulant to equipment investment in the Paper Products industry is thrice as large as that in Rubber & Plastics. Comparison of columns 2a and 2b shows that eventhough the stimulant to an industry's plant investment is always less than to its equipment investment, the industry stimulated most "plant-wise" is not necessarily the one benefitting the most "equipment-wise". Not all industries/assets fare equally well under changes in the law.

III. Summary

This study presents a valuation model that computes an asset's replacement value as the discounted sum of its expected user cost stream. The valuation model allows inferences about the intertemporal distribution of expectations, returns, and other constraints.

The model is used to compute asset duration in ten manufacturing industries. It is shown that replacement values are not necessarily inversely related to equilibrium discount rates.

An investment function is introduced. It is examined and estimated. The empirical results, although crude, hint that the model may be able to provide insights about the impact of policy and structural shocks upon the allocation of a nation's resources among its different sectors and markets.

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APPENDIX

The twenty time series of replacement value estimates are generated with the data described below.

q: The industry and asset specific investment deflators were supplied by the Bureau of Labor Statistics (BLS).

I: The BLS also presents real gross investment flows.

π : The expected inflation rate is equal for all industries and asset types and is the annual average of the quarterly series presented in Hendershott and Hu (1981).

c: The effective rate of the investment tax credit is equal in all industries. For structures there is no allowance. The source for the rate for equipment is the SSRC-Penn-MIT quarterly econometric model (hereinafter SSRC).

b: Upon the institution of the investment tax credit in 1962 it was necessary to deduct the entire credit from the cost of the asset before computing depreciation for tax purposes. This requirement was permanently repealed by the 1964 Long Amendment. Therefore, b equals 1 in 1962 and 1963, and 0 otherwise.

τ : The industry-wide income tax rate is a weighted average of the economy-wide marginal corporate tax rate τ_{COR} and the economy-wide non-corporate rate τ_{NCOR} . The weights by which they are combined are the industry specific percentages of total industry depreciation deductions in the corporate and non-

corporate sectors respectively, as published in the IRS Statistics of Income. τ COR is the annual average of the quarterly tax rates presented in Hendershott and Hu (op. cit.). Following Hendershott and Hu (1980), τ NCOR is calculated as the weighted average of the marginal effective tax rate paid by the top half of the income distribution. The weights are the share of total adjusted gross income in the respective marginal tax bracket, as published in the Statistics of Income.

S: The present value of tax depreciation deductions is a weighted average of the tax savings resulting from a \$1 investment as depreciated by straight-line, sum-of-the-years' digits, and double-rate declining balance with a switch to straight-line after the midpoint of the asset's tax life. The weights are based upon data presented in the SSRC model and R. Coen. The tax life of structures is from the SSRC and is the same in all industries whereas the industry specific equipment tax lives are from Coen's table three.

z: The percent of inventories accounted by the FIFO (first-in first-out) method is computed from the industry sample on the COMPUSTAT tapes following a procedure similar to that used by vonFurstenberg, Malkiel, and Watson (hereinafter vFMW).

m: This variable has numerator equal to the cost of producing a unit of output and denominator equal to the output market price. It is computed from the industry sample on the COMPUSTAT tapes as well as inventory data from the Bureau of Economic Analysis.

h: Unless noted otherwise depreciation is assumed to follow a straight-line path. Hence h, which measures the amount of capacity lost during a period, is equal to $1/L$.²⁴

L: This study uses productive service lives that are derived from those in the BLS study. The BLS reports a service life for equipment and structures at the three-digit level. Herein, the service life at the two-digit industry level is set to the simple arithmetic average of the service lives at the component three-digit level. That works out to 28 years for structures in all industries and between 12 and 16 years for equipment.

W: As soon as h, r, π , and L are known it is straight-forward to calculate W. Specifically,²⁵

$$W = \sum_{v=1}^L (1+r-\pi)^{-v} h_v$$

r: This study estimates an industry specific discount rate that is the industry's weighted average cost of capital. More precisely, $r = \alpha(1-\tau)i + (1-\alpha)f$ where f is the required return on equity, α is the debt/market value ratio, and $(1-\tau)i$ is the after-tax debt financing rate. A separate α , τ , i, and f are estimated for each period in the sample. All variables except i are industry specific. The debt rate, $i(t)$, is set to the A-rated industrial bond rate and the marginal tax rate, $\tau(t)$, is discussed above. The calculation of the debt to market value series, $\alpha(t)$, follows the procedure used by Gordon and Malkiel, Fullerton and Gordon, and vFMW, and relies upon the industry sample on the COMPUSTAT tapes and industry specific

financial ratios constructed by vFMW. The construction of the required return on equity series, $f(t)$, follows the procedure used by Fullerton and Gordon and is based upon the capital asset pricing model. An industry specific stock beta is computed using data from COMPUSTAT, Ibbotson and Sinquefeld, and the Center for Research in Security Prices (CRSP) return data. The expected excess market return is a long run average of historic market premiums.²⁶

FOOTNOTES

1./ A list of studies employing the user cost would likely number in the hundreds. Suffice it to say that staunch critic Martin Feldstein (1982) has written [p. 858]: "... I believe that the assumptions involved in the present model [Jorgenson's investment function] are far too restrictive and implausible for the model to be regarded as 'true' in any sense. It is however of some importance that, even within the highly constrained assumptions of the present model, the data provide clear support for a responsiveness of investment to changes in a correctly measured [user] cost of capital services..."

2./ There are several underlying assumptions embedded in equation 1. The more well-known are that the production function $Q=F(K,X)$ exists as does the marginal physical product of capital; capital is homogeneous with respect to productive capacity; the capacity depreciation path is exogenously determined and invariant to time; and the discounting of the income stream relies on an exponentially declining series of discount ratios.

3./ In fact $I(s)$ is not included in $K(s)$, but rather $[\lim_{\epsilon \rightarrow 0+}]I(s-\epsilon)$ is included. This technicality is accommodated in the discrete equations and the empirical work.

4./ Replacement cost and replacement value are identical given the conditions: the real stock will depreciate exponentially; capital has an infinite life; and the value marginal product is expected to proceed along an exponential

path. Because we maintain the hypothesis that depreciation is exogenous and invariant to time the first condition is satisfied iff historic investment has proceeded along an exponential path (Feldstein and Rothschild).

5./ The aggregate RC series (real and nominal, neither shown in table) in the denominator is monotonically increasing. The industry level RC estimates derived herein (20 series) were compared to those issued by the BLS. In linear regressions whose independent variable is the BLS capital stock estimate and whose dependent variable is the RC derived herein, the R-squareds are above .998 and the slope coefficients are near unity.

6./ Alternative theories exist on why the ratio of market value to replacement cost (Tobin's Q) had declined so significantly. See Patric Hendershott, M. Feldstein (1980), B. Malkiel, and F. Modigliani and R. Cohn.

7./ The user cost allows a modeling of forward expectations, and hence of future returns. This attribute of the user cost was noted by J.M. Keynes in The General Theory of Employment, Interest, and Money [pp. 66 and 69]: "User cost has, I think, an importance for the classical theory of value which has been overlooked ... [It] constitutes one of the links between the present and future."

8./ Hicks referred to an asset's duration as its "average period" (p. 186), apparently incognizant of an earlier study by Frederick Macaulay that applied the same measure to financial

bonds. In any event, the literature has coined the measure as "duration" in deference to Macaulay, even though his usage was restricted to bonds and he did not espouse the Hicksian connection to general equilibrium processes. Recent studies on duration are L. Fisher and R. Weil; J. Cox, J. Ingersoll, and S. Ross; and M. Hopewell and G. Kaufman

9./ J. Boquist, G. Racette, and Gary Schlarbaum have shown that the duration for common stocks with constant perpetual growth in dividends at the rate g is given by $\text{dur} = (1+r)/(r-g)$. Using this formula and plausible variable values the resultant duration estimates are substantially greater than what appears in table 2. This anomaly leads one to question how the duration of an industry's financial assets might be related to the duration of its real capital.

10./ Boquist, Racette, and Schlarbaum report four conclusions from their study on risk and duration. The first is that [p. 1360]: "Duration is a critical link in a dynamic relationship between risk and return."

11./ Haugen and Wichern have shown that for financial assets the ratio of Δ present value to Δr is equal to $\text{dur}[r/(1+r)]$. What follows is a comparison of the actual Δ in RV and the predicted Δ . The actual Δ is computed as $[(\text{col.3a} - \text{col.2a})/\text{col.2a}]$; the predicted as $\text{dur}(\Delta r)[r/(1+r)]$.

(SIC, actual Δ , predicted Δ): (33,6.4,10.3); (32,7.0,11.7); (26,7.2,12.2); (30,7.3,12.6); (22,8.0,13.7); (29,8.1,11.3); (28,8.1,13.5); (20,8.3,13.5); (36,8.4,14.6); (35,8.5,14.7).

Eventhough the magnitude of the predicted change overstates the actual change by roughly one-third, the rankings of industries by either measure are, with slight exception, the same.

12./ In the situation at hand equilibrium is attained while holding the optimal quantity of capital constant. That is plausible only if the demand for capital is perfectly inelastic while the supply of non-capital factor inputs is perfectly elastic. More general results cannot be attained in a partial equilibrium setting.

13./ In continuous time the stock $K(s)$ is comprised of the investment $[\lim_{\epsilon \rightarrow 0+}]I(s-\epsilon)$. The stock will continue to be productive, and hence will have value, until time $[\lim_{\epsilon \rightarrow 0}]s+L-\epsilon$. In discrete time, $\epsilon=1$.

14./ This attribute of value over time was described by Eugen Bohm-Bawerk in 1888 [page 343]:

In the first year of its use the owner realises the 'current' service with its value of 100 [TWD: in our case it is 651]. Naturally this service, thus consumed or rendered, comes off the value of the machine (which we may call the 'bearer of the use'), and the good suffers a loss of value. But this loss of value cannot be quite so great as the value of the service rendered and deducted. It is partly compensated by the increased value of the services that still remain embodied in the machine. That particular service which, at the beginning of the year of use, figured as 'next year's', and had a value of only 95.23 in present money, figures by the end of the year as 'this year's use';

it has advanced one year nearer maturity and grown into the full present value of 100. Similarly, the former third year's service has now become next year's, and its value has grown from 90.70 to 95.23: the fourth, fifth, and sixth year's services have passed into the rank and value of third, fourth, and fifth year's services.

It is interesting to note that some 50 years later Bohm-Bawerk's "bearer of the use" was to become Keynes' "user cost of capital".

15./ For the sake of clarity, consider the following example. In the year 2001 [=1974+27] the user cost was expected to have been \$0.833 [=0.1786(1+ π)²⁷] and the existing stock would have exogenously dwindled to 6.62 million capital units. The value of capital services were expected to have been \$5.51 million [=0.833(6.62)]. That entry on the return stream increases RV(1974) by only \$487,000 because it is discounted by (1+r)⁻²⁷. However, that same entry on RV(1974,27) is undiscounted and therefore contributes its full amount of \$6 million (5.51 rounded) to the stock's forward value. This entry is in the bottom row of col. 1a. Notice that because of this discounting effect RV(1974) is more robust to expectations assumptions about 2001 than is RV(1974,27); i.e., the upper rows in the table are more robust than the lower rows.

16./ Bohm-Bawerk points to this reverse imagery in his chapter conclusion, [p. 349]:

That, on the one hand, the value of the bearer of the use, and, on the other, its net return, are represented by such

figures that the former may be held equivalent to a money capital yielding, at the current rate of interest, exactly the same net return, is a coincidence which I have already explained. And, in virtue of this coincidence, it is, finally, as intelligible as it is justifiable that, in practical economic life which finds and adopts, as facts ready to its hand, the things which we try to explain, the net return of goods should be taken as foundation for acts of valuation. It is an abbreviated method which, practically, is quite appropriate, although it turns the relation of cause and effect exactly the other way.

17./ Given the conditions under which equation 10 is derived the value change sequence is identical to the term structure of discount ratios; i.e., $\Delta RV_{j-1,j} = (1+r)^{j-L}$.

18./ Irving Fisher examines the appropriateness of discounting return streams. In his appendix to Chapter XX, p. 537, he breaks the gross return stream [his "true income"] into its two components: market interest [his "alleged outgo of waiting"] and surplus [his "alleged net income"]. Within Chapter XX, p. 487, he provides an argument why the alleged outgo of waiting stream should not be discounted. The argument is, I believe, equally applicable to the discounting of the alleged net income stream: "The cost of waiting can neither be located in time, independently of the item waited for, nor can it, like any other item, be discounted, for it is itself the discounting. If we discount the discounting, we would have to

discount the discounting of the discounting and repeat the process indefinitely."

19./ That it is the change in average period (Hicks' nominal one or my real one) which is pertinent to explaining investment is emphasized by Hicks in his chapter "Interest and the Production Plan" [p. 223]: "The absolute length of the true average period has no significance whatsoever; it depends only in part upon the character of the production plan; it will be lengthened and shortened in an entirely arbitrary manner according as we calculate the average period of the plan at different rates of interest. Change in the average period is important, but not the length of the period itself."

20./ For each of two assets in ten industries a value change sequence may be constructed for every year in the 19 year sample period (1958-1976). From each time series it is possible to extract 19 observations of $\Delta RV_{0,1}$, 19 of $\Delta RV_{1,2}$, ..., and 19 of $\Delta RV_{L-2,L-1}$. The correlation coefficient (SIC 26: Plant) is .990 between unadjusted surpluses $\Delta RV_{0,1}$ and $\Delta RV_{1,2}$; .965 between $\Delta RV_{0,1}$ and $\Delta RV_{2,3}$; and .520 between $\Delta RV_{0,1}$ and $\Delta RV_{19,20}$. Using more than one surplus series in an investment equation introduces a problem of multicollinearity. The source of the problem is the dissimilarity between $RV(s,j)$ and $RV(s,j+1)$ arising because of constant rate assumptions.

21./ The Durbin-Watson statistic is 0.61, indicating serial correlation is a problem. Correction for first order serial correlation using the Cochran-Orcutt iterative technique

results in $qI = -2206 + 1.14\Delta RV^* + 0.75\epsilon_{-1} + \epsilon$. T-statistics are, left to right, 0.5, 5.4, and 4.8; the R^2 is .95.

22./ The Durbin-Watson for the aggregate plant regression is 0.94, indicating serial correlation among the residual errors; equipment's D-W equals 0.60. The slope coefficients, adjusted for first order serial correlation using Cochran-Orcutt's technique, are 0.61 (t-stat=5.9, $R^2=.89$) for plant and 0.60 (t-stat= 1.8, $R^2=.95$) for equipment. The evidence indicates some problem of omitted variables or equation specification.

23./ The proportional change presented in table 5 is computed as follows. For each asset $RV(1974)$ and $\Delta RV^*(1974)$ are computed using the historic data described in appendix A. Then the parameters are changed to reflect the tax package described above and new values RV^{tp} and ΔRV^{*tp} are computed. The induced change in investment is taken equal to $b(\Delta RV^* - \Delta RV^{*tp})$, where b is the respective slope coefficient from table 4. The proportional change in investment is the induced change divided by historic investment. Note that the aggregate induced change is the sum of the asset specific change in ΔRV^* multiplied by the slope coefficient from the aggregate regression.

24./ This study assumes that investments made at time 0 are not used until time 1. Because of this $h(1)$ is set to 0 in all cases.

25./ As the difference $r-\pi$ converges to zero, W gets infinitely large. Therefore, $r-\pi$ is constrained to be greater

than or equal to .02. This affects the calculation of W but not S. The constraint is binding for nine of the 190 observations of each asset.

26./ The twenty year moving average dropped precipitously in 1974. This is a result of 1954's unusually large excess return being replaced by 1974's unusually small one. For 1974-76 the expected premium is set equal to the average of 1970-73's expected premium.

Year	Replacement Value (\$ millions)	RV/RC
	-1-	-2-
1958	79989	1.24
1959	88181	1.33
1960	88473	1.32
1961	92365	1.35
1962	86763	1.25
1963	89568	1.26
1964	88033	1.20
1965	88441	1.15
1966	96724	1.15
1967	108559	1.15
1968	132694	1.26
1969	149412	1.28
1970	151647	1.17
1971	140500	.99
1972	142993	.96
1973	161940	1.02
1974	179447	.97
1975	190998	.88
1976	205367	.87

TABLE 1: Column 1 is the total replacement value of plant and equipment in 10 industries. Column 2 is the ratio of replacement value to replacement cost.

SIC code	Average duration (1958-1976):	Actual, 1975		%Δr=.2		%Δr=.2	
		RV Duration		no adjustment		full adjustment	
		RV	Duration	RV	Duration	RV	Duration
	-1-	-2a-	-2b-	-3a-	-3b-	-4a-	-4b-
20	4.79	24732	5.75	22686	5.38	28659	5.37
22	4.61	9992	5.64	9195	5.29	11634	5.29
26	4.92	14729	5.63	13671	5.33	17241	5.32
28	4.88	35359	5.66	32486	5.32	40855	5.32
29	5.92	17639	6.90	16202	6.51	17486	6.50
30	4.85	8626	6.07	7999	5.74	9102	5.72
32	4.87	10677	5.78	9924	5.47	11757	5.44
33	5.35	29105	6.00	27239	5.71	28276	5.71
35	4.51	22937	5.37	20976	4.98	26035	5.00
36	4.41	17202	5.33	15753	4.95	19601	4.96

TABLE 2: Measures of industry duration (years) and replacement value (\$ millions).

Value of		:Current with respect to 1974:		Current with respect to 1975:	
current stock:					
j periods in :	RV(1974,j)	%ΔRV wrt	:	%ΔRV wrt	RV(1975,j)
the future :	\$millions	initial value:	:	initial value	\$millions
j =	-1a-	-1b-	:	-2a-	-2b-
0	5405	--	:	--	5424
1	5202	3.76	:	2.71	5277
2	4987	3.98	:	3.02	5114
3	4760	4.20	:	3.34	4932
4	4521	4.42	:	3.65	4734
5	4271	4.62	:	3.96	4520
6	4011	4.80	:	4.24	4290
7	3744	4.95	:	4.50	4046
8	3470	5.07	:	4.72	3790
9	3192	5.14	:	4.89	3525
10	2913	5.16	:	5.04	3251
11	2635	5.15	:	5.13	2973
12	2359	5.09	:	5.20	2691
13	2089	5.01	:	5.23	2407
14	1824	4.89	:	5.22	2124
15	1568	4.74	:	5.16	1844
16	1322	4.54	:	5.02	1572
17	1091	4.29	:	4.80	1312
18	876	3.97	:	4.50	1067
19	681	3.60	:	4.11	844
20	510	3.16	:	3.63	647
21	366	2.67	:	3.10	479
22	250	2.15	:	2.56	341
23	161	1.65	:	2.06	229
24	95	1.22	:	1.59	143
25	50	0.84	:	1.17	79
26	21	0.53	:	0.80	36
27	6	0.29	:	0.47	10

TABLE 3: Replacement value sequence for structures in Paper Products Industry, 1974 and 1975.

$$qI = a + b \Delta RV + \epsilon$$

SIC	PLANT				EQUIPMENT			Sum of P&E		
	a	b	R ²		a	b	R ²	a	b	R ²
20	-8.6 (0.3)	0.71 (18.3)	.95	:	-863.6 (4.1)	1.60 (11.0)	.87	-786.4 (4.7)	1.26 (16.3)	.94
22	31.8 (1.1)	0.58 (4.5)	.54	:	-93.0 (0.7)	1.08 (5.0)	.59	-46.3 (0.3)	0.94 (5.3)	.62
26	80.7 (2.8)	0.44 (4.9)	.58	:	-667.5 (2.8)	1.71 (7.9)	.78	-513.8 (2.2)	1.38 (8.2)	.80
28	113.5 (1.7)	0.61 (7.6)	.77	:	-1232.6 (3.0)	1.78 (9.1)	.83	-989.7 (2.3)	1.41 (9.4)	.84
29	-26.9 (0.3)	0.70 (5.9)	.67	:	-611.2 (4.7)	3.05 (9.1)	.83	-817.3 (4.7)	1.60 (11.2)	.88
30	20.8 (1.2)	0.96 (8.1)	.79	:	-104.5 (1.2)	1.46 (8.6)	.81	-68.8 (0.7)	1.33 (9.0)	.83
32	61.7 (3.7)	0.42 (8.3)	.80	:	-586.2 (2.4)	1.73 (5.4)	.63	-491.0 (2.7)	1.32 (7.9)	.78
33	289.2 (3.4)	0.29 (2.9)	.34	:	-968.3 (2.0)	1.62 (5.9)	.67	-514.6 (1.0)	1.13 (6.0)	.68
35	-6.1 (0.1)	0.79 (9.5)	.84	:	-466.6 (2.9)	1.40 (11.2)	.88	-437.7 (2.3)	1.20 (11.8)	.89
36	121.1 (3.1)	0.43 (5.1)	.61	:	-139.8 (1.1)	1.18 (9.1)	.83	15.2 (0.1)	0.93 (8.9)	.82
All ten	579.6 (1.8)	0.60 (9.9)	.85	:	-6090.0 (3.6)	1.65 (10.7)	.87	-4907.4 (2.9)	1.27 (12.3)	.90

TABLE 4: Ordinary least squares estimation of nominal gross investment on the adjusted first surplus series; results are by asset, by industry, or aggregated.

Industry		: Historic	:	%ΔInvestment		
		: Investment	:	because of policy		
		: (\$ millions)	:			
SIC		: Plant	Equipment	: Plant	Equipment	TotalP&E
Code	Description	: -1a-	-1b	: -2a-	-2b-	-2c-
20	Food Products	: \$818	\$2188	: 10.2%	18.4%	15.5%
22	Textile Products	: 275	894	: 6.5	8.6	8.2
26	Paper Products	: 327	1881	: 6.1	18.5	15.6
28	Chemicals & Products	: 941	4016	: 8.3	14.1	12.7
29	Petroleum & Coal	: 798	1047	: 9.7	21.8	16.1
30	Rubber & Plastics	: 336	1124	: 6.0	6.0	6.1
32	Stone, Clay, & Glass	: 296	1288	: 6.0	11.3	10.5
33	Primary Metals	: 760	2992	: 4.1	11.4	9.5
35	Nonelectrical Machinery	: 855	2457	: 8.2	10.0	9.6
36	Electrical Machinery	: 526	1900	: 5.7	9.0	8.2
All ten industries		: 5932	19787	: 7.7	13.2	11.6

TABLE 5: The impact of a simulated change in tax policy upon investment in plant and equipment; simulation applied to data current in 1974.