STOCKS AND DEPRECIATION OF HUMAN CAPITAL: NEW EVIDENCE FROM A PRESENT-VALUE PERSPECTIVE

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Responding to a perceived growing interest in human wealth estimates, this paper offers a framework for measuring the aggregate stock of human capital and then implements the procedure for the United States male population age 14 to 75. Unlike previous estimates of human wealth that are based upon historical or resource costs, these estimates measure the capital stock as the discounted present-value of expected lifetime returns. In the estimation, returns are equated with earnings data from the 1970 U.S. Census 15 percent Public Use Sample for out-of-school males, adjusted for employment and survival probabilities, adjusted for an assumed exogenous growth in future earnings, and discounted at 7.5 percent.

We provide cross-sectional estimates of individual stocks of human capital by age and educational attainment, as well as expected lifetime wealth profiles for individuals by level of education. These individual profiles can be used to obtain direct estimates of age-specific depreciation which suggest human capital is subject to significant and prolonged appreciation before nearly straight-line depreciation begins around middle age. This finding is all the more significant since resource-cost estimates of human capital which must assume a depreciation pattern to obtain stocks have always imposed a much faster rate much sooner.

Finally, an aggregate estimate of the stock of human capital for all males is supplied and its sensitivity to the choice of the discount rate, tax laws, and expected exogenous growth is analyzed. This seemingly-conservative stock estimate is then compared to a much lower resource-cost estimate offered recently by John Kendrick. A discount rate over 20 percent would be needed to equate the two measures. In trying to reconcile the two figures, we raise some new questions about the validity of both approaches for human capital accounting.

The publication of John Kendrick's *The Formation and Stocks of Total Capital* [8] is but the most recent example of a growing interest by economists in developing national wealth estimates for the United States to complement the existing and widely available flow estimates of income, consumption and investment. This interest in stock estimates is in part a response to progressing theoretical work on "permanent-income" hypotheses, in part an attempt to either document or dispel concern over an impending capital shortage, and in part a by-product of recent welfare-motivated attempts to expand conventional income and product accounts to include the services of all types of capital—physical, human, and intangible.

What is particularly paradoxical about this renewed concern over stocks is that it has sparked so little interest in improving estimates of human wealth. The few existing estimates of human capital stocks, which now include Kendrick's comprehensive effort [8], have employed a resource-cost approach to capital valuation—that is, the summation of all past investment costs. In a recent issue of this *Review* Mary Jean Bowman argued for a more forward-looking (but as yet underemployed) measure of human capital:

> The total human capital stock embodied in a man who has completed his schooling could in principle be measured as the discounted value of his

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expected future stream of earnings . . . This seems a logical way of valuing the human capital stock. [3]

While several recent U.S. Census Bureau publications have attempted to estimate lifetime incomes by this present-value approach, we shall argue that these studies have misspecified the returns to human capital and have failed to explore the implications of their results for the accumulation and depreciation of human capital.

This paper represents a preliminary attempt to apply the present-value approach to human capital valuation using earnings data for males obtained from the 1970 Census. Our seemingly conservative present-value estimates, when compared to the still lower resource-cost estimates of Kendrick, raise some new questions about the validity of each approach. Our estimates also permit us to make some novel inferences about human capital depreciation that appear to be at odds with either the *ad hoc* assumptions of depreciation conventionally used by resource-cost accountants, or the mathematically convenient yet economically untenable depreciation patterns used by human capital theoreticians.

The outline of the paper is as follows: Section II reviews the theoretical basis of human capital valuation by a present-value approach. Section III discusses modifications necessary to implement the theory using cross-sectional data. Section IV presents the results of human capital stock and depreciation estimates for the male population in 1969 and contrasts them with the resource-cost approach estimates. Section V summarizes our findings and outlines proposals for future research.

II. Theoretical Basis

It is a fundamental principle of capital theory that in a competitive equilibrium the value of a capital asset can be determined both as the "backward" measure of accumulated cost of resources expended on producing that asset and also as the "forward" measure of the discounted flow of future yields accruing to that asset. In a world of complete certainty, perfect capital markets and no externalities, one measure is equally as "good" as the other; but it is primarily because these conditions are very seldom satisfied that both measures are of interest. Indeed it is quite probable that the two approaches may give widely different estimates of the value of the capital stock. Which of the two measures is the "correct" one depends in large part on the uses to which the estimates will be put. But it seems reasonable that a dynamic economy interested in assessing its future productive capacities would be more interested in the forward-looking present-value approach than in the historical-cost approach.

In practice the choice of which method to use often turns on the relative availability of data. Estimates of physical capital stocks have almost universally been prepared from a cost approach. This choice of the "backward" measure is determined as much by the general availability of capital expenditure data as it is by the paucity of information on future period returns to capital.[1]

[1]Goldsmith [6], Denison [4], and Kendrick [8] are among the classics in the resource cost approach to physical capital valuation. For an interesting attempt to value physical capital from a present value approach, see Mendelowitz [9].

Perhaps because of its wide acceptance in physical capital valuation, the cost approach has also been the method employed in the surprisingly few attempts at valuing human capital stocks. According to this cost approach, the value of human capital embodied in an individual is the sum of parental-financed rearing costs, and all past direct expenditures on schooling and formal training as well as the sizeable opportunity costs of students and trainees.

While the severe lack of data on expected future earnings of physical capital has understandably hampered the application of the present-value approach to physical capital valuation, the same excuse for its underemployment in valuing human capital appears rather strained. Indeed the services of human capital are continually priced in the market! It is rather surprising then that there has been no comprehensive attempt to valuing human capital from a present-value approach. The remainder of this section discusses the application of the present-value approach to computing the value of human capital embodied in the individual.[2]

According to the present-value approach to capital valuation, the total value of human capital embodied in an individual is the discounted stream of future returns that will accrue to the individual, his employer, his family and society in both market and nonmarket capacities over his lifetime. In a world of perfect certainty this value at time t would simply be:

$$PV_t^i = \sum_{j=t}^{N^i} \frac{R_j^i}{\prod_{k=t}^{j}(1+r_k^i)} \tag{1}$$

where R_j^i is the return in year j on the human capital of individual i, r_k^i is the rate at which individual i discounts returns received in year k, and N^i is the date of death of i.

Unfortunately neither R^i nor N^i is known very often with certainty. While uncertainty complicates the present-value calculation, the approach is still applicable so long as the individual formulates expectations over the future unknown variables.

Equation (1) is revised as follows:

$$PV_t^i = \sum_{j=t}^{N} \frac{R_j^{i*} \cdot P_{jt}^i}{\prod_{k=t}^{j}(1+r_k^i)} \tag{2}$$

where

R_j^{i*} = the expected returns in year j of individual i, conditional on i being alive at j.

P_{jt}^i = probability at date t that individual i will still be alive at date j.

N = feasible upperbound on life.

All expectations are held as of date t. This model leaves unspecified the manner in which the individual formulates his expectations regarding future returns as well as the nature of the returns themselves. Both issues must be resolved.

In many ways the second question—the nature of the returns—is really the more troublesome of the two, but also the one more often casually dismissed.

[2]Ideally, of course, we would like to have prices for *future* services of human capital, but because no such futures markets exist, we will have to settle for making inferences about future prices from observations on current and past market prices.

Human capital provides a plethora of benefits both in and out of the market. Of course personal earnings are the most directly observable returns to human capital. However, to the extent that some human capital embodied in an individual is firm-specific, then it is well known that not only the individual but also his employer captures part of the returns. But how can we separate these returns from the returns to the firm's other factors? To make matters worse, some returns to human capital are not even priced in the market: one of the primary benefits of schooling is certainly the greater efficiency and adaptability displayed by the more educated in performing a myriad of non-market chores such as child rearing, personal finance and homemaking, health investments, search activities, and even additional human capital investments. Furthermore, the highly educated are not only more efficient "producers", but also more ambitious consumers: a quite significant return to education must be the inherent broadening of the consumption possibilities available to the "educated" individual.

Several recent Census Bureau studies conducted by H. Miller, *et al.* [11, 13, 14] have constructed lifetime income estimates from a present-value approach. These estimates have limited the returns to human capital to market returns and have approximated these returns by income data. While a fuller specification of returns would be desirable, at least if returns are to be limited to the observed market valuation of human capital, then *earnings* as opposed to income seems to be a superior variable. Income data as collected by the Census Bureau includes not only earnings (wages, salaries and proprietor's income), but also property income, interest, dividends, and transfer payments. It is difficult to see how these last four items can be properly construed as returns to human capital. Our initial human capital estimates presented in Section IV follow the Census Bureau in restricting returns to market valuation, but we employ earnings instead of income data.

If we equate returns with earnings, then equation (2) must be revised to include the possibility that the individual might not be receiving market returns. Now estimate the individual's value at date t as:

$$PV_t^i = \sum_{j=t}^{N} \frac{E_j^{i*} \cdot P_{jt}^i \cdot W_j^i}{\prod_{k=t}^{j}(1+r_k^i)} \tag{3}$$

where we have replaced expected returns R_j^{i*} by expected earnings if alive and employed E_j^{i*}, and W_j^i is the conditional probability that individual i if alive will be in the labor force *and* employed in year j.

Our first question concerning the formation of expectations of future returns to human capital can now be modified to ask: how can we approximate the individual's expectations of future earnings? There have been a few attempts at estimating lifetime earnings from cross-sectional data (see Miller [10], and Weisbrod [15]). The basic notion is that an individual of age t with a certain vector of identifying characteristics (perhaps sex, race, education, occupation, ability . . .) will base his expectation of earnings n years from now on the observed earnings of people $t+n$ years old now who share his basic characteristics. It is well known, however, that these cross-sectional estimates invariably underestimate actual future earnings. The reason, of course, is that estimates based on a cross-section fail to take account of secular economic growth. If we are to use such data to generate a time series of future earnings, then we must modify the cross section by a series of expected growth rates in annual earnings. The use of growth-adjusted cross-sectional earnings data to estimate an individual's expected future earnings will mean that we can revise equation (3) as follows:

$$(4) \qquad {}_mPV_t^i = \sum_{j=t}^{N} \frac{{}_mE_j^i(\prod_{k=t}^{j}(1+x_k^i)) \cdot P_{jt}^i \cdot W_j^i}{\prod_{k=t}^{j}(1+r_k^i)}$$

where i is the vector of identifying characteristics of an individual, ${}_mPV_t^i$ is the present value in year m of a type i individual of age t, ${}_mE_j^i$ is the observed cross-sectional earnings in year m of a type i individual j years old, and x_k^i is the rate of growth in earnings for type i individuals expected to occur in the kth year of life.

One further issue of some importance is that of maintenance costs. If our valuation of human capital is to be strictly analogous to that of physical capital, then our earnings should really be net of maintenance expenses. Unfortunately, this raises some potentially unresolvable problems. How much of human consumption expenditure represents pure maintenance costs? How do maintenance expenditures vary over the lifecycle? In the literature, Weisbrod [15] has been virtually alone in attempting to implement such earnings deductions. We have opted to make no allowances for maintenance expenses. Given that consumption is the ultimate raison d'être of both investment and production, it seems reasonable to consider all consumption expenditure as an end in itself rather than as a means to an end.

This present-value formulation holds equally well in theory for both sexes. It is our assumption that all returns to human capital can be measured solely as market earnings that separates the men from the women: for males this operational assumption is troublesome enough, but for females it becomes nearly unworkable. We have calculated human capital stocks according to equation (4) only for males. Admittedly for both males and females expected returns deserve a more complete specification than we have as yet provided.

In addition to excluding the female population from our calculations, we also exclude males under the age of fourteen because of the difficulties of valuing this human capital that is still in the process of formation.

III. Data and Procedure

We have calculated the present value of future earnings for the male population for 1969 using summary census data for 1950 and 1970 and detailed cross-sectional census data available in the Public Use Sample of the 1970 Census, 15 percent questionnaire. This latter is an extremely large sample detailing personal and earnings characteristics of over 200,000 individuals. Excluding women, children under 14, military personnel, and inmates of health and correctional institutions, we still have a sample size of 64,967.

Our calculations are based upon the following assumptions:

1) *On average, individuals in the same age cohort with the same educational background can be treated as identical.* Thus we ignore such complicating factors

as ability and opportunity differences and deal only with the representative individual. We can therefore derive aggregate capital stocks from individual stocks by multiplying the capital stock of the representative individual by the total number of such individuals in the population.

The 1970 Public Use Sample provides both age and educational data on individuals by single years. This breakdown is too fine for our purposes. To avoid the problem of "empty cells" we have restricted our focus to males aged 14 to 75 and reduced the educational categories to six—0 to 8 years, 9 to 11 years, 12 years, 13 to 15 years, 16 years, and 17 or more years.

2) *All returns to human capital are monetary and accrue solely to the individual.* The Public Use Sample offers a frequency distribution of 1969 earnings in hundred dollar intervals up to "$50,000 or more" for all individuals aged 14 years and older. Interval midpoints were used for all earnings up to $50,000, while the mean of the "$50,000 or more" tail was inferred from published means for the entire sample.

Earnings consist of wages, salaries, and proprietor's income—all reported before taxes. If our procedure is to be strictly analogous to that of the valuation of physical capital, then we really want net (after tax) earnings. We have not (as yet anyway) corrected the data for expected future tax liabilities. Our before tax variable is appropriate only under the rather dubious assumption that taxes finance, dollar-for-dollar, publicly-provided final product to taxpayers.

Unlike previous studies with which we are familiar, we distinguish between reported earnings of those individuals still attending school and of those individuals out of school. Ignoring this distinction would bias downward our estimates of earnings of young full-time workers, many of whose cohorts are still in school and reporting relatively low earnings. Our projected earnings curves and wealth estimates of section IV are based solely upon earnings of individuals who have completed their schooling.

3) *Individuals engage in no post-school investment.* In other words, the observed earnings of two individuals of different ages with the same educational background differ only because of age-dependent effects—psycho-physical maturation or depreciation—and not because of differences in post-school activities. We explicitly rule out the possibility of formal on-the-job training. This is indeed a crucial assumption, and one of the first candidates for assumptions to be relaxed in further work.

4) *Earnings are subject to an exogenous growth trend of unspecified origin.* We assume that individuals hold expectations of this rate of growth of future earnings, and that it can be approximated as the annual rate of growth of constant dollar incomes for the twenty year period, 1949–69, as derived from census summary data [12]. We have calculated a growth rate for earnings of individuals in each educational category. The several Census Bureau estimates of lifetime incomes have employed a growth rate constant across all educational groups. This assumption has not been supported by post-war evidence: annual earnings of the highly educated have been increasing faster than earnings of the less educated, although post-1969 evidence suggests that this variance may now be less pronounced. (See Richard Freeman [5].)

Assumptions 3) and 4) together imply that we can estimate the earnings of an individual of age t with s years of schooling n years from now from current cross-sectional data on earnings of persons aged $t+n$ with s years of schooling. In particular, if E^s_{t+n} is the observed earnings of an individual of age $t+n$ with s years of schooling then the expected earnings of a similarly schooled age t individual n years from now is $E^s_{t+n}(1+x^s)^n$, where x^s is the assumed annual rate of increase in earnings for individuals with s years of schooling.

Expected earnings in future years are weighted by probabilities of being alive in those years and probabilities of receiving earnings. The survival probabilities are derived from a 1969 life table and the probabilities of receiving earnings at different ages are computed from the Public Use Sample as the number of persons reporting earnings (by school enrollment, age and education) divided by total persons in that subgroup.

5) *Future earnings streams are discounted at a constant rate across all age and schooling categories.* Admittedly, different individuals have different rates of discount. However since we have very little *a priori* notion of their magnitudes, using one average rate seems to minimize the necessary guesswork. Our estimates presented in section IV use a rate of 7.5 percent—an average of the real rate of return on personal savings and the real rate paid on consumer loans.[3]

We view the choice of a discount rate from an individual rather than social perspective since a social discount rate implies knowledge of the opportunity cost of investment from society's view, given a social rate of time preference. Determining the opportunity cost alone is a complex task given our tax laws and wide range of benefits and costs accruing to a particular investment, but also we do not know what the social rate of time preference should be. Therefore, we view the question of an appropriate discount rate from an individual's viewpoint solely because it is a more manageable undertaking.

Our calculations of individual and aggregate human capital stocks follow directly from the above assumptions. We employ the following notation:

$_mPV^s_t$ = discounted present value for year m of expected earnings of a male of age t with s years of schooling.
$_mV^s_t$ = aggregate value of the human capital stock for year m of all males of age t with s years of schooling.
$_mE^s_j$ = observed earnings in year m of an out-of-school male of age j with s years of schooling
P_{tj} = probability that a male of age t will be alive at age j.
I^s_j = probability of receiving earnings during the jth year of life for a male with s years of schooling.
x^s = annual growth rate of earnings for males with s years of schooling.
r = constant annual rate of discount.
$_mN^s_t$ = number of males in year m of age t with s years of schooling.

[3]Juster [7] estimates the nominal rate on savings during the period as 4 percent and the nominal consumer finance charge as 15 percent. The 9.5 percent average of these two rates is reduced by an estimate of the average expected rate of inflation over the past 25 years of 2 percent to yield a 7.5 percent real rate of social discount. Becker [1] uses a rate of 8 percent in his age-wealth profiles.

The present value of earnings for year m of a representative individual of age t with s years of schooling is:

$$(5)\qquad {}_mPV_t^s = \sum_{j=t}^{75} \frac{{}_mE_j^s \cdot P_{tj} \cdot I_j^s (1+x^s)^{j-t}}{(1+r)^{j-t}}$$

Next, the value of human capital in year m of all males age t with s years of schooling is:

$$(6)\qquad {}_mV_t^s = {}_mN_t^s \cdot {}_mPV_t^s$$

The value of human capital in year m embodied in all males aged 14–75 with s years of schooling is:

$$(7)\qquad {}_mV^s = \sum_{t=14}^{75} {}_mV_t^s$$

Finally, the aggregate human capital stock in year m of males aged 14–75 is:

$$(8)\qquad {}_mV = \sum_s \sum_{t=14}^{75} {}_mV_t^s$$

where the schooling index is summed over the six educational categories.

IV. The Results

Cross-sectional and Time Series Wealth Profiles

Chart 1 plots individual age-wealth profiles by level of schooling for 1969 assuming a constant discount rate of 7.5 percent for all schooling categories, and an expected growth rate of earnings that varies with the level of schooling.[4]

It is important to understand both what these wealth profiles do and do not represent. For any level of schooling what they do show is the discounted present value of expected future earnings (wealth) as of 1969 of males aged 14 through 75. What they do *not* show are profiles through time of the wealth of males initially 14 years old in 1969. However, this second notion is also of interest and can be derived from the first. To see this, from equation 5 and suppressing the schooling index and survival and earnings probabilities, compare the discounted present-value of a 15 years old in 1969

$$(9)\qquad {}_{1969}PV_{15} = E_{15} + \frac{E_{16}(1+x)}{1+r} + \frac{E_{17}(1+x)^2}{(1+r)^2} + \ldots,$$

with the discounted present-value of a 15 year old in 1970 (who was, of course, 14 in 1969):

$$(10)\qquad {}_{1970}PV_{15} = E_{15}(1+x) + \frac{E_{16}(1+x)^2}{1+r} + \frac{E_{17}(1+x)^3}{(1+r)^2} + \ldots.$$

[4]These real growth rates were 1.625 percent for individuals with 0–8 years of school, 2.50 percent for 9–11 years, 2.625 percent for 12 years, 2.75 percent for 1–3 years college, and 3.25 percent for 4 years college and 5 or more years college.

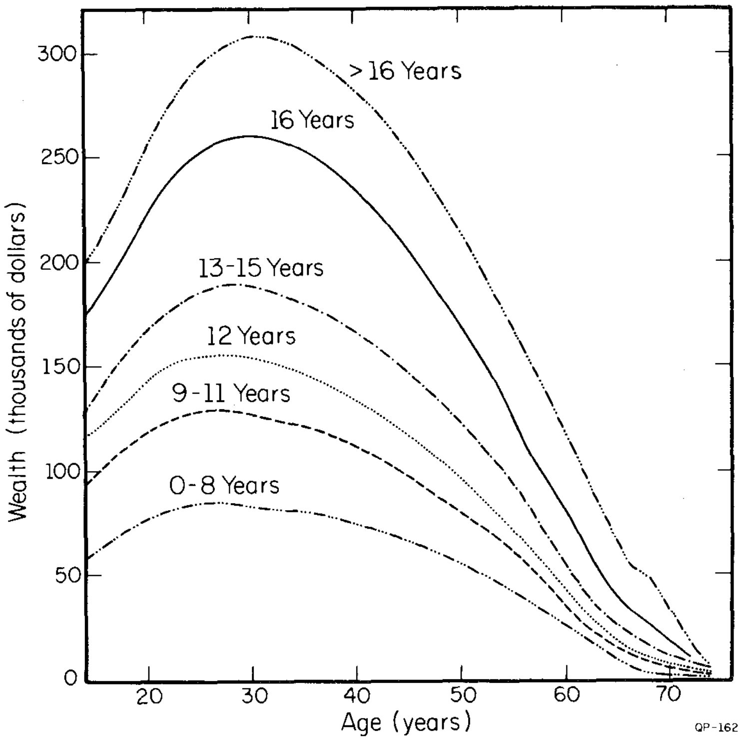

Chart 1. 1969 Cross-sectional Wealth Profiles of Males by Age and Level of Schooling

Equation (10) obtains because $E_t(t = 15, 16, 17 \ldots)$ refers to observed cross-sectional earnings in 1969. Now Chart 1 reports the present-value calculation of equation (9), not equation (10). But notice that

(11) $$_{1970}PV_{15} = (1+x)_{1969}PV_{15}$$

which says that (10) can be easily derived from (9). Or in general:

(12) $$_{m+a}PV^s_{t+a} = (1+x)^a{}_mPV^s_{t+a}$$

Using equation (12) and the figures underlying Chart 1 we can compute the time-profile of wealth (from year m to $m+a$) of an s-type individual initially t years old in year m.

Chart 2 plots lifetime profile of wealth by years of schooling for individuals 14 years old in 1969. Chart 3 plots cross-sectional earnings by age and educational attainment as derived from the Public Use Sample. Chart 4 then plots growth-adjusted cross-sectional earnings that can be viewed as a time-series of expected earnings streams for males 14 years old in 1969 for all relevant schooling groups. Both earnings charts are smoothed for presentation by a five-year-moving-average adjustment, although the wealth profiles were derived from unadjusted earnings.

Charts 1 and 2 reveal very clearly the strongly positive relation between education and expected wealth: additional schooling is associated with greater

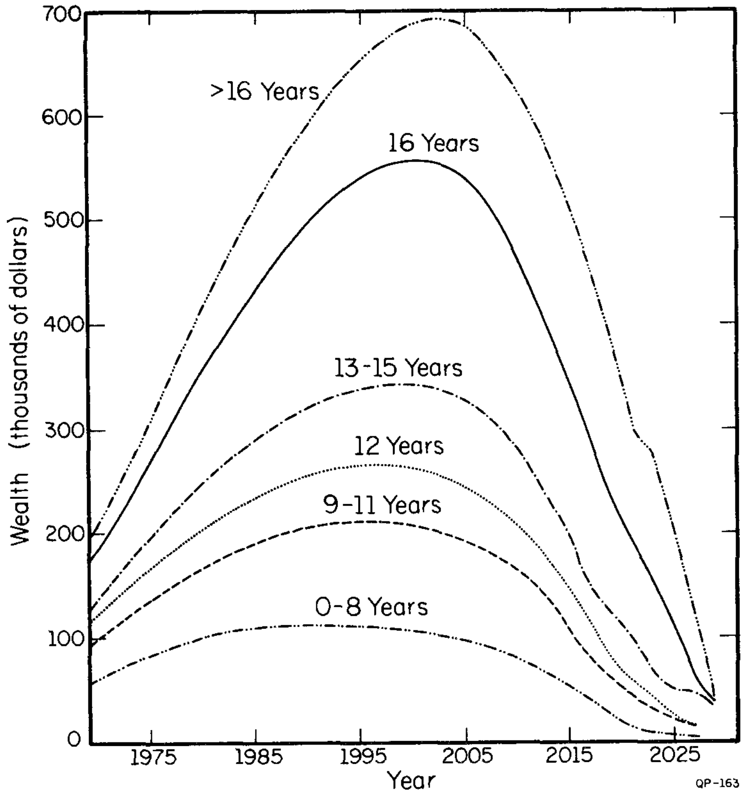

Chart 2. Projected Lifetime Wealth of Males Age 14 in 1969 by Level of Schooling

wealth at all ages. Also, the cross-sectional profiles in Chart 1 and the time-series profiles in Chart 2 show the same general pattern for all schooling groups of first rising and then gradually declining wealth. Wealth rises initially because expected earnings initially rise rapidly enough to offset the dampening effects of discounting. Indeed, the rate of discount crucially affects the shape of the wealth curves: a zero rate of discount would produce a continuously declining wealth profile, while an infinite discount rate would produce a wealth profile identical to the earnings profile.

Comparing the time-series wealth and earnings profiles (Charts 2 and 4) notice that wealth always peaks well before earnings. At this point the reader might properly wonder if the evidence of these rising earnings profiles do not invalidate our earlier assumption of no post-school investment. What, other than on-the-job training, can account for such significant rises in earnings? Indeed these profiles do seem to suggest that our assumption is misguided: cross-sectional data used to predict future earnings for a cohort will be biased upward to the extent that older cohorts are receiving returns to post-school investments such as on-the-job training, health expenditure, and job search. But this is not to say that, for our assumption to be correct, the earning profile of a cohort must always be flat or declining. Indeed age-dependent maturation effects can be expected to produce at least a nominal upward income trend. The difficulty arises in separating

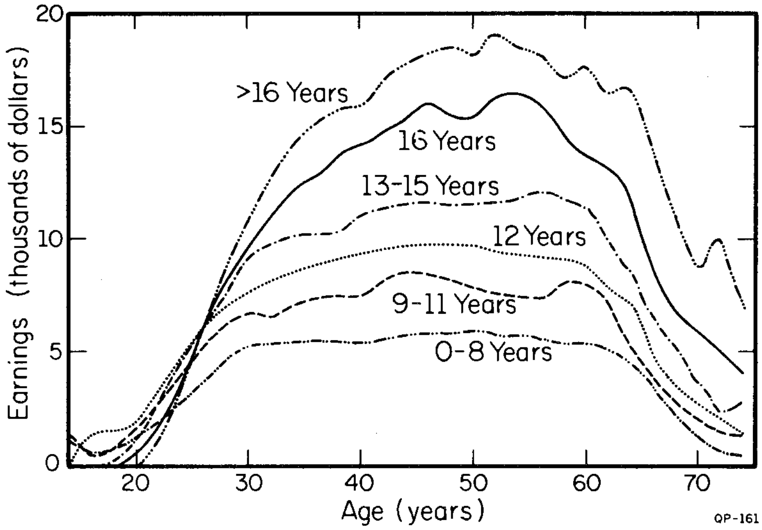

Chart 3. 1969 Cross-sectional Earnings of Males by Age and Level of Schooling

these age-dependent effects from the post-school investment effect which does not properly belong in an estimate of the *current* stock of human capital.

Depreciation

It is interesting to observe the variance in age at which wealth peaks across educational groups. Table 1 shows the age of maximum human wealth by years of schooling and assumed rate of discount. Generally, additional schooling postpones the peak in wealth. This variance is in large part the result of the very diverse earnings profiles of the different schooling groups. The less steeply rising the earnings profiles, the lower is the age at which wealth achieves its maximum. And Chart 4 suggests that earnings generally rise slower for the less educated. It is this promise of relatively high future earnings that forestalls the inevitable decline in wealth resulting from the limited number of periods of returns.[5]

Indeed it is the finite lifespan of the individual that is ultimately responsible for the depreciation of human wealth. In general, we know that the change in the value of wealth between two consecutive periods is the result of gross investment (I_t^s), depreciation (D_t^s) and capital revaluations (G_t^s). Formally, the change in the present value of wealth between years $m-1$ and m of an individual with s years of schooling is

$$(13) \qquad {}_mPV_t^s = {}_{m-1}PV_{t-1}^s + I_t^s - D_t^s + G_t^s.$$

However, our assumption of no post-school investment means that I_t^s is zero, and since we have no reason to assume that initial expectations will not be fulfilled, G_t^s is also zero. Equation (13) conveniently reduces to

$$(14) \qquad {}_{m-1}PV_{t-1}^s - {}_mPV_t^s = D_t^s$$

[5]The assumed rate of discount also affects the age of maximum wealth. The higher the rate of discount, *ceteris paribus*, the later is the age at which wealth peaks.

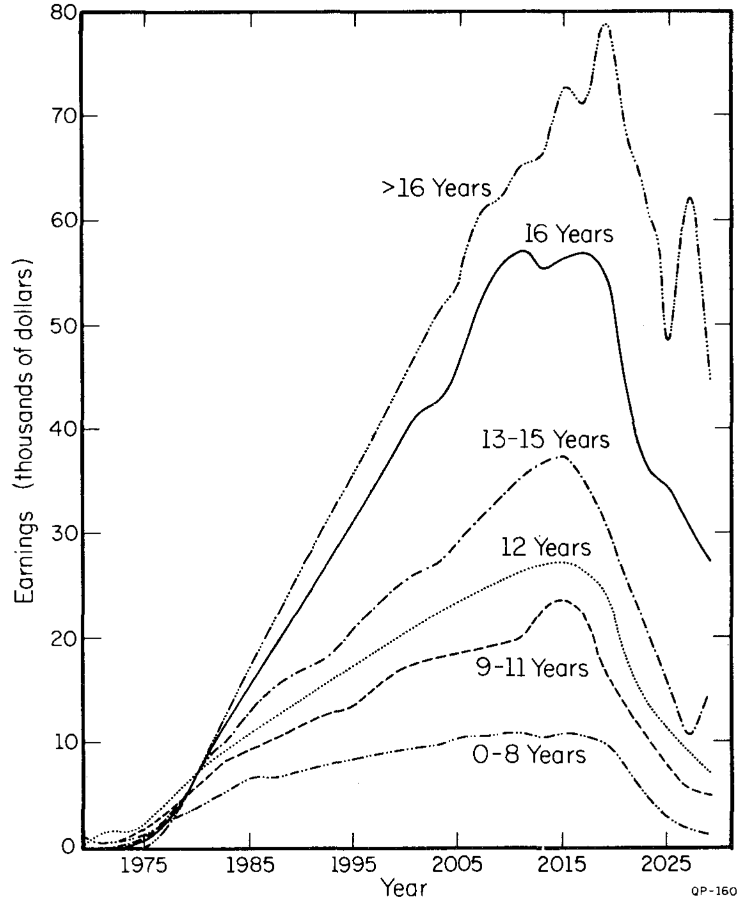

Chart 4. Projected Lifetime Earnings of Males Age 14 in 1969 by Level of Schooling

which allows us to estimate the implied patterns of depreciation for individuals 14 years old in 1969 directly from the time-series profiles of wealth in Chart 2. This represents a significant advantage of the present-value approach over the cost approach, which must assume an arbitrary depreciation pattern to derive stock estimates. What the wealth estimates in Chart 2 consistently reveal are first an

TABLE 1
AGE OF PEAK HUMAN WEALTH BY YEARS OF SCHOOL COMPLETED AND ASSUMED RATE OF DISCOUNT

Years of School Completed	Rate of Discount			
	2.5%	5%	7.5%	15%
0–8	26	33	40	42
9–11	30	39	41	47
12	30	37	41	49
13–15	30	39	43	51
16	34	42	44	49
17+	34	42	48	51

extended period of appreciation (or negative depreciation) followed by very nearly straight-line depreciation after the peak in wealth. Although these estimates cannot pinpoint the exact causes for the eventual depreciation, they do suggest that it appears to be much more a result of impending retirement rather than of any reduction in earnings potential.

The evidence of significant appreciation followed by straight line depreciation is all the more interesting because many writers have arbitrarily assumed other patterns of depreciation. Numerous articles presenting theoretical models of life cycle human capital accumulation, of which Ben-Porath's [2] is a classic, assume an exponential rate of depreciation, which begins immediately upon capital acquisition. Besides not allowing for an initial rise in value, the exponential rate produces a more rapid initial rate of decline than our evidence indicates. Kendrick assumes that human capital depreciation follows the double-declining balance method switched to straight-line when the latter begins to exceed the former. We believe that this misspecification seriously biases downward his human capital estimates. What is more important, though, is that Ben-Porath and Kendrick are only two writers out of many in the human capital area whose depreciation assumptions are not consistent with the evidence presented here.

Writers on human capital, however, have ample precedent for assuming a depreciation pattern that may not reflect economic depreciation, the change in value of an asset due solely to the passage of time. Kendrick notes that his assumed depreciation pattern is consistent with other assumptions about physical capital depreciation. The most widely used estimates of physical capital stocks, those prepared by the Bureau of Economic Analysis, have relied until very recently on depreciation patterns which show substantially greater initial depreciation than would result from a straight-line rate. A present-value study of physical capital could be worthwhile if only to indicate whether assumptions made about physical capital depreciation differ as greatly from the evidence as they do concerning human capital.

Aggregate Capital Stocks

Table 2 summarizes our estimates of the aggregate human capital stock for 1969 for all males age 14–75 and all levels of schooling. For the discount rate of

TABLE 2
AGGREGATE STOCK OF HUMAN CAPITAL, U.S. MALES 14–75, BY ASSUMED RATE OF DISCOUNT FOR 1969

Discount Rate	Capital Stock (Billions of dollars)
2.5%	14,395
5.0%	9,787
7.5%	7,148
10.0%	5,526
15.0%	3,807
20.0%	2,910

7.5 percent used in deriving the individual wealth profiles in Charts 1 and 2, the aggregate comes to $7,148 billion. The estimates indicate however just how sensitive this present-value method is to the assumed rate of discount. Nearly tripling the rate of discount to 20 percent reduced the estimated aggregate stock by approximately 60 percent, to $2,910 billion.

How do our estimates compare with those derived from the cost approach? The most carefully prepared of these estimates with which we are familiar are those derived by Kendrick [8]. Kendrick estimates the current-dollar aggregate net stock of human tangible and intangible capital, which he defines as all expenditures on education and training, health, mobility, and child rearing, embodied in all individuals of *both* sexes as $3,700 billion in 1969. His estimates are well below ours at a 7.5 percent rate of discount and even comparatively low at 20 percent considering his broader population base.

What can account for such a wide difference between Kendrick's cost-approach estimates and our moderate discount rate present-value estimates? Our estimates may be too high to the extent that they overestimate the expected growth in future earnings. The actual growth in real earnings thus far, in the recession-prone 1970s, has been substantially below our extrapolations for all educational groups. The annual growth rate in average weekly earnings in the private nonfarm sector from 1969 to 1974, deflated by the CPI, has been only 0.03 percent, down substantially from the 2 percent rate for 1949 to 1969. Furthermore, it is perhaps unreasonable to assume that there will continue to be a divergence among growth rates in earnings experienced by individuals with different amounts of schooling. This divergence may be only a temporary disequilibrium phenomenon. We have therefore recalculated the aggregate stock assuming a lower "equilibrium" growth rate that is constant across educational categories. At a 1 percent annual expected growth rate, the stock of male human capital is $5,932 billion. With zero expected growth it is $5,363 billion.

Our estimates might also be too high because they use earnings before taxes instead of after taxes. We have recalculated expected earnings by applying 1969 average tax rates to earnings data. Using these net earnings, a 7.5 percent discount rate, and the differential growth rates yields an aggregate capital stock estimate of $5,960 billion.

While our estimates may be too high to the extent that we have overestimated future earnings, Kendrick's estimates may be too low because they overstate the rate of depreciation of human wealth and understate the period of initial appreciation. Kendrick begins depreciating his stock of education and training capital at age 28, an age he justifies by reference to wealth profiles developed by Miller *et al.* [11]. These profiles are cross-sectional wealth estimates similar to our chart 1. But as we have argued, it is not these profiles but time-series wealth profiles that are appropriate for making inferences about depreciation. Chart 2 and Table 1 suggest that Kendrick's peak of 28 is at least ten years too early. Unfortunately we cannot readily reproduce Kendrick's estimates employing an initial stage of appreciation and a later peak followed by slower depreciation, because we do not have his underlying cost data by age cohort. However, Kendrick has published a "gross" capital stock estimate that is defined as the summation of all gross investment. This "gross" stock is $5,541 billion. This estimate incorporates no depreciation of capital, but neither does it incorporate any appreciation.

There is another fundamental difference between Kendrick's stock of human capital and our present-value estimates that underscores the attractiveness of our future-earnings potential approach. Kendrick's figures include only formal investment costs associated with schooling, on-the-job training, parental training, and health and mobility expenditures in the value of embodied human capital. Our estimates based on future earnings streams include not only the returns to formal investments, but also returns to occupational experience (learning by doing) and monopoly rents to native ability. These inevitable experience-induced labor productivity increases and ability rents cannot even be calculated from a cost approach since they are essentially costless, but represent a substantial expected return to human capital.

In the final analysis, there is no reason to believe that our two estimates must be approximately equal at a 7.5 percent rate of discount. Indeed, the internal rate of return that equates the cost and present-value estimates would be as high as 20 percent without any of the above adjustments to our estimates of expected returns and without depreciation adjustments to Kendrick's stocks. But 20 percent is a rate consistent with past estimates of returns to education. Becker [1] found private rates of return that vary from a low of 12.4 percent for college graduates to a high of 28 percent for high school graduates. Because capital markets are imperfect and because investment in education is a risky undertaking, there is no reason to assume the rate of return to education should equal the return to less risky investment or even the rate of discount.

V. Summary

Our study suggests the following conclusions:

(1) The present-value method of capital valuation appears to be a feasible approach for valuing human capital which can usefully complement the existing historical-cost estimates. We have implemented this approach by equating expected returns with market earnings derived from cross-sectional earnings data of out-of-school males adjusted by growth rates that vary with levels of education. Previous studies have used income instead of earnings data, ignored the distinction between the earnings of individuals in and out-of-school, and employed growth factors unrelated to educational attainment.

(2) Both cross-sectional and time-series wealth profiles (Charts 1 and 2) confirm the notion that education is positively associated with wealth at all ages.

(3) Time-series wealth profiles suggest that human wealth is subject to an initial lengthy period of appreciation followed by straightline depreciation. Historical-cost estimates of human capital have generally ignored (or at best, understated) this initial appreciation and then overstated the rate of depreciation.

(4) Aggregate male capital stocks derived from the present-value approach are much higher than stocks derived from the cost approach for discount rates in the neighborhood of 7.5 percent. The two approaches yield similar estimates at a discount rate around 20 percent.

Our approach suggests the need for the following extensions:

(1) Present-value estimates should be extended to females and the under-14 population.

(2) Returns to human capital should be broadened to include nonmarket benefits, particularly if the first goal is to be achieved.

(3) The assumption of no post-school investment is unrealistic. If cross-sectional earnings data are to be used to generate future earnings streams to current stocks, then that portion of earnings that represents returns to future on-the-job investment must be eliminated from the projected earnings stream. Unfortunately the problem has no obvious resolution.

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