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Abstract

An integrated approach for estimating the stock of human capital in the United States is developed which eliminates well known problems associated with both the cost and income based methods currently in use. Historical information on the cost of the educational investment made in base entrants (individuals who enter the full time labor force immediately following high school graduation) and the wage rate they receive upon entry into the work force is used to compute a rental rate for human capital. The human capital stock for other cohorts of the work force is then estimated using that rental rate and the reported earnings for each population subgroup. This method neutralizes the cost identification problems associated with the work of Kendrick and Eisner. It also allows a more realistic treatment of the depreciation and appreciation of human capital. When used to estimate a Cobb-Douglas production function of the U.S. economy for the period 1963-1988, this measure provided more explanatory power than hours of labor.

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AN ALTERNATIVE MEASURE OF THE HUMAN CAPITAL STOCK

Researchers attempting to measure the stock of human capital have based their estimates on either historical costs or expected incomes.[1,2] This paper develops a third, integrated method which eliminates some well documented problems associated with past estimates. New estimates of the stock of human capital in the United States are then constructed and used to examine the contribution of human capital to U.S. economic growth between 1963-1988.

Theoretical Concerns with Previous Measures of Human Capital

All estimates of the human capital stock must be constructed indirectly due to the absence of direct observations of the human capital stock. Some (Kendrick, 1976, and Eisner, 1989) have used a cost-based approach, assuming that the depreciated value of the dollar amount spent on those items defined as investments in human capital is equal to the stock of human capital. Others, for example, Jorgenson et al. (1983a, 1989) have used discounted future income to measure each individual's human capital stock.

Those choosing to follow the cost-based methodology face two major problems. First, since it is impossible to directly observe the change in human capital stock attributable to increases in particular types of spending, no objective method exists for separating those expenditures which should be considered investments in human-capital from those which should be considered consumption. There also is no way the marginal contributions of different types of investments in human capital can be identified.

Kendrick's work illustrates the difficulty. He began by assuming that all costs of raising children are human capital investments. That, in turn, forced inclusion of expenditures for necessities such as food and clothing in the spending used to derive his measure. Others (Bowman, 1962, Machlup, 1984) disagreed, arguing that basic expenditures should be considered consumption, not investment, unless one is raising slaves. Without direct observations of the human capital stock debates over what should be considered human capital investment cannot be resolved objectively.

Equally important, it is impossible to determine the productivity of different types of investments. Lacking empirical guidance analysts must subjectively allocate household spending into investment and consumption. Kendrick, for example, assumed that only one-half of medical expenditures was human capital investment. Although Eisner's work provides alternatives to some of Kendrick's more controversial assumptions, any cost based measure depends heavily on the researcher's explicit assumptions about the proportion of various household and public expenditures considered to be human capital investment.

Cost based estimates of the human capital stock are also dependent on the depreciation rate assumed. Typically, simple tax accounting rules have been chosen. Kendrick assumed that human capital depreciated according to a modified double-declining balance schedule, while Eisner chose the straight-line method. Neither allowed for appreciation, ignoring empirical evidence that showed human capital appreciating in the early stages of one's career, then depreciating later in life.[3]

The income approach, which relies on the relationship between earnings and human capital, fares little better. Here, increments to earned income are assumed to reflect additions to the nation's human capital stock. This approach requires a precise estimate of the human capital rental rate, something which again is unobservable. Further, defining the incremental addition to the human capital stock to be equal to the incremental income observed creates a strained definition of human capital investment, one where the actual level of investment is assumed to be equal to the return on investment.[4]

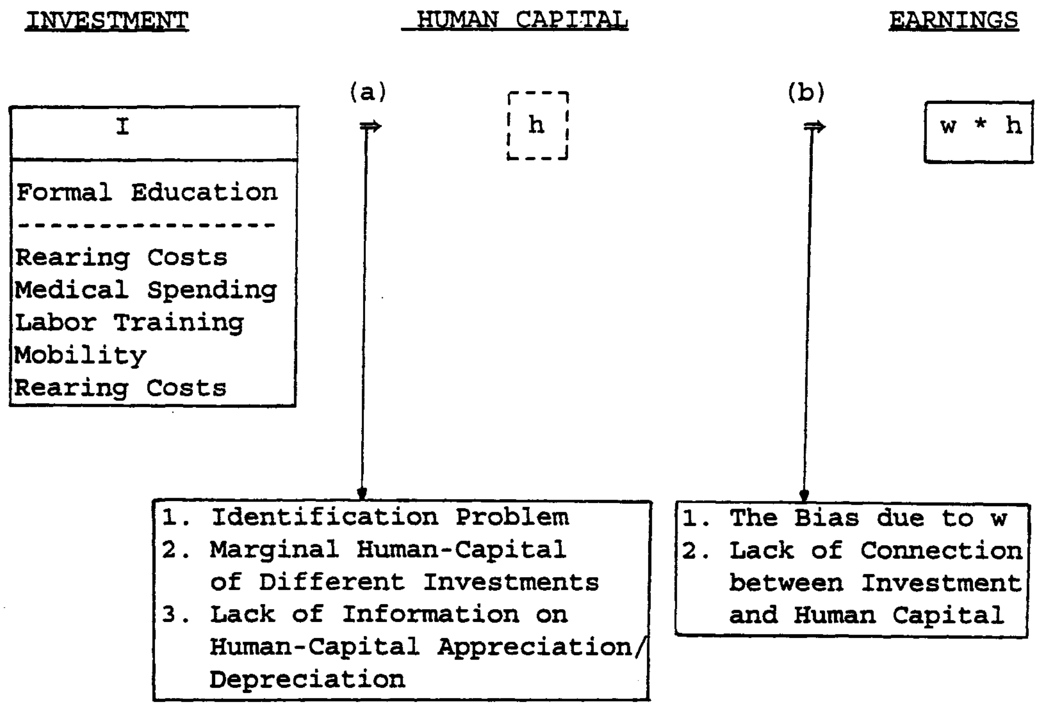
An Alternative Measure of the Human Capital Stock

A nation's aggregate human capital stock can be thought of in three ways. The first, potential human capital, is the human capital of all people, including those physically or mentally unable to work. A portion of potential human capital is never active in the labor market. Available human capital is that portion of the human capital stock attributed to individuals currently actively in the labor market working, seeking, or waiting for productive employment. Effective human capital is that which is not only available but currently being applied in production. This paper's focus is on effective human capital, the appropriate definition to use when examining productivity.

We begin by noting the relationships between investment, human capital, and earnings. Those relationships are shown in Figure 1 where I is equal to formal and informal investments in human capital; h, human capital; w, the rental rate for human capital; and $w*h$ is equal to observed earnings. Investments in human capital establish the human capital stock, relationship (a), and based on the established human capital stock, an individual obtains his earning, relationship (b).

Cost based methods exploit the relationship between investment and human capital, relationship (a), to derive estimates of the human capital stock. The income approach uses the backward relationship (b), beginning with an assumption about the human capital rental rate being always equal to one.[5] Problems with each approach are listed at the bottom of the figure.

Figure 1 The Relationship between Investment, Human Capital and Earnings



The Fundamental Earnings Function

Economists postulate that individuals' earnings are a function of their human-capital stock.[6] We begin with a fundamental earning function specified as

(1) $$E^s_{i,j}=w_t h^s_{i,j},$$

where $E^s_{i,j}$ and $h^s_{i,j}$ are earnings and human capital stock, respectively, for an individual of sex s, age i, and educational level j, and w_t is the human-capital rental rate in year t. It is assumed that individuals' earnings in year t are based on their human capital stocks at the beginning of year t, which is also the human capital stock at the end of year t-1.

Since both the human capital stock and its rental rate are unobserved, it is necessary to standardize one of the unknown variables. We choose to standardize on the human capital stock of the base entrants, those who enter the labor force directly after graduating from high school. This is done using the historical cost method and relationship (a) above. Then, using the relationship between human capital stock and earnings, (relationship (b) above), a human capital rental rate can be estimated. That rental rate is assumed to be constant over all cohorts and all skill levels in a particular year. With it the implied human capital stock for other cohorts of the work force can be derived from their observed earnings.

Base entrants were chosen as the standardizing group for two reasons. First, since there has been no on the job investment in their human capital, issues surrounding the cost of labor training need not be dealt with, nor is it necessary to estimate the contribution of training after entry to the labor force to an individual's human capital stock. Second, the SAT (Scholastic Aptitude Test) provides a consistent measure of the distribution of the ability of high school graduates over time. The presence of this consistent measure of ability allows us to take account of changes in the human capital production function over time and across cohorts.

Estimating the Human Capital Stock of Base Entrants

We begin by choosing a base year and identifying the aggregate historical investment in the education of base entrants in that base year. The human capital stock of the cohort of base entrants is assumed to be equal to the total real investment over time in their education.[7] In this study all education through high school graduation is assumed to be general education. This allows investments in elementary and secondary school to be aggregated and treated as a single investment. The human capital stock of an average base entrant, with an average ability of all base entrants, in the base year is defined as the per capita educational expenditure on all members of that age cohort.

For average base entrants in years other than the base year, their human capital stock is computed based on the relationship between their expected ability level and the ability level of the average base entrants in the base year. If employers knew the exact amount of human capital that base entrants bring to the work place, the fundamental human capital equation (1) could be used to obtain a general rental rate for human capital. However, since employers lack precise information on new entrants abilities at the time hiring decisions are made, and since the human capital stock of base entrants cannot be expected to remain constant over time, an alternative measure must be found. We use estimates of the average SAT scores of entering base entrants as a proxy for the expected ability level of entry level workers.

Although SAT results are available for most years included in this study, the data have a severe self-selection bias since scores are available only for those who choose to take the test. An estimate of the unbiased ability distribution requires knowledge of the selection mechanism, the probability that high school seniors of each ability level will take the SAT. The method used to derive an estimate of the ability distribution is described below.

Suppose the probability that high school seniors of each level of ability will take the SAT can be found by

$$(2) \qquad \frac{P^a_{x,t}\, N^a_t}{P^p_{x,t}\, N_t} = c_{x,t}\text{, for all year t and ability level x,}$$

where $c_{x,t}$ is the probability that high school seniors with ability level x take the SAT in year t, $P^a_{x,t}$ is the proportion of students, with ability level x out of the number of students taking the SAT in year t, $P^p_{x,t}$ is the proportion of all high school seniors in year t with ability x, and N^a_t and N_t are the number of students taking the SAT, and the number of high school seniors in year t, respectively. Data for $P^a_{x,t}$, N^a_t and N_t are available on the *Digest of Education Statistics*.

The Educational Testing Service administered the SAT to a random sample of high-school-seniors in 1966, 1970 and 1974. The results from those tests provide information on $P^p_{x,t}$. Using (2) $c_{x,t}$ can be found. Since this norm test is not available annually, we use $c_{x,1966}$ for the years 1966 and 1967, $c_{x,1970}$ for the years from 1968 to 1972, and $c_{x,1974}$ for the others. It follows that $P^p_{x,t}$ can be solved for t other than 1966, 1970 and 1974.

Let x be the average of the Verbal and the Mathematics portions of the SAT scores. Assuming that the SAT is a sufficient measure of students' abilities, with $P^p_{x,t}$ in hand, the ability distribution of high school seniors can be estimated in any particular year. The characteristics of the ability distribution implies that probability density function can be estimated by a polynomial function, f(x). To ensure the probability accumulation function, F(x), passes through F(200)=0 and F(800)=1, the polynomial function must be characterized by

$$(3) \qquad F(200)=\beta_0+\beta_1(200)+\beta_2(200)^2+\beta_3(200)^3=0\text{ , and}$$

$$F(800)=\beta_0+\beta_1(800)+\beta_2(800)^2+\beta_3(800)^3=1\text{ .}$$

These two equations allow us to eliminate β_0 and β_1. The modified regression equation is

(4) $F(x)+(1/3)-(x/600)=(x^2-100x+160000)\beta_2+(x^3-840000x+160000000)\beta_3+\epsilon$,

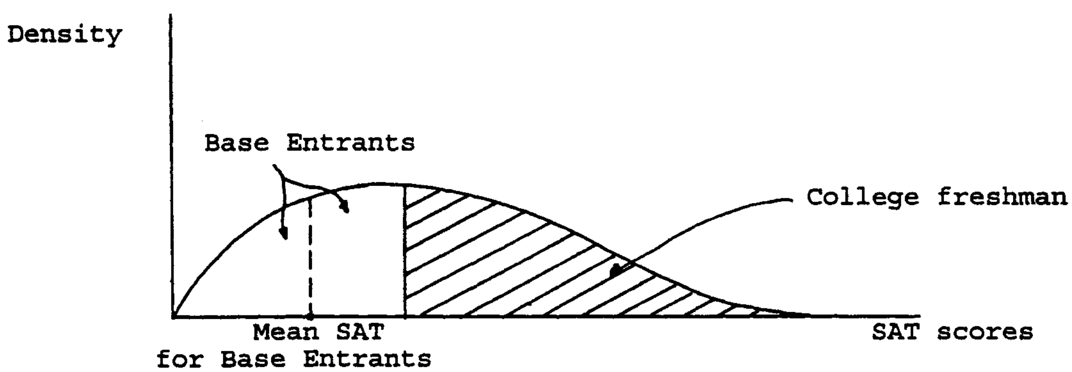
where ϵ is an error term. Therefore, $F(x)+(1/3)-(x/600)$ is the new dependent variable, and $x^2-100x+160000$ and $x^3-840000x+160000000$ are new regressors.

If we assume that (100-z)% of high school seniors enroll in college in year t, z% of seniors enter the labor force, the mean score of the base entrant is

(5) $x^b_t=\int_0^{x_z} f(x)xdx/F(x_z)$,

where x_z is the score that equates $F(x)=z/100$ (See Figure 2).

Figure 2 Mean SAT for the Base Entrants



Investment per capita for the high school graduates in 1988 (h^b_{1988}) is defined as the standard point. The human capital of average base entrants in, say, 1967 (h^b_{1967}) is derived from

(6) $h^b_{1967}=(x^b_{1967}/x^b_{1988})\times h^b_{1988}$.

The table below provides the regression results of ability distribution of high school graduates.

Table 1 Estimates of Ability Distribution Curves of High School Graduates by the SAT scores, 1966 to 1988

year	sex	β_2 (10^{-6})	β_3 (10^{-9})	$\bar{R}^2$
1966	M	3.043	-3.834	0.973
	F	-	-2.164	0.958
1968	M	2.968	-3.784	0.971
	F	-	-1.816	0.950
1970	M	3.032	-3.798	0.975
	F	-	-2.144	0.958
1972	M	5.849	-5.383	0.962
	F	4.741	-4.709	0.968
1973	M	7.050	-6.349	0.948
	F	7.120	-6.409	0.947
1974	M	6.659	-6.112	0.941
	F	6.528	-6.051	0.940
1975	M	4.102	-4.598	0.957
	F	3.909	-4.501	0.956
1976	M	2.324	-3.481	0.968
	F	1.847	-3.195	0.970
1977	M	2.418	-3.539	0.967
	F	1.522	-2.988	0.974
1978	M	2.332	-3.502	0.969
	F	1.030	-2.709	0.975
1979	M	2.050	-3.346	0.967
	F	1.195	-2.836	0.969
1980	M	1.623	-3.098	0.970
	F	3.442	-2.321	0.974
1981	M	1.760	-3.172	0.973
	F	-	-2.105	0.979
1982	M	2.332	-3.512	0.971
	F	-	-2.057	0.977
1983	M	2.465	-3.605	0.964
	F	-	-2.054	0.969
1984	M	2.049	-3.313	0.973
	F	-	-2.053	0.974
1985	M	2.889	-3.081	0.971
	F	1.486	-2.962	0.974
1986	M	2.747	-3.700	0.972
	F	1.229	-2.786	0.976
1987	M	1.488	-2.927	0.973
	F	-	-2.007	0.971
1988	M	2.412	-3.514	0.971
	F	-	-2.016	0.970

Note: Data are not available for 1967 and 1969.

The Rental Rate and the Human Capital Stock

Once the base entrants' human capital stock has been identified, earnings data can be used in equation (1) to determine w, the human capital rental rate. Since earnings are known for cohorts other than the base entrants, that rental rate can then be used in the fundamental earning function to determine the human capital stock of the remaining cohorts. This study divides the labor force by gender, age and educational level, (that is, male and female, age nineteen to sixty-four (forty-six groupings), and six educational levels, elementary, high school 1-3 years, high school graduate, college 1-3 years, college graduate, and 5 or more years of college).

The total human capital stock is the sum of the human capital stock of all cohorts. If $h^s_{i,j}$ is the human capital for the representative individual in cohort $G^s_{i,j}$, where s, i, and j indicate sex, age, and educational level, respectively, and the number of people in group $G^s_{i,j}$ is $N^s_{i,j}$, then the total human capital stock (H) is

(7) $$H=\sum_s\sum_i\sum_j N^s_{i,j}\cdot h^s_{i,j}.$$

Empirical Results

Data Sources

The model displayed in (7), requires data on $N^s_{i,j}$, number of individuals in $G^s_{i,j}$, and an estimate of $h^s_{i,j}$. The estimate of $h^s_{i,j}$ was obtained by using equation (1) which requires data on $E^s_{i,j}$, average earnings of $G^s_{i,j}$ and an estimate of w, the rental rate for human capital. The rental rate is determined from the real historical cost estimates of educational expenditures constructing the human capital stock of average base entrants in the base year and the earnings of those average base entrants in the base year. The necessary earnings data is available from *Money Income of Households, Families, and Persons in the U.S.*, Current Population Report, Series P-60. Expenditures on elementary and secondary education for base entrants in the base year (1988) were constructed from data in the National Income and Product Accounts.

Results

The procedure for finding the human capital rental rate is shown in Table 2.[8] The first two columns contain estimated annual mean SAT scores of average base entrants. Their derivation was illustrated in Figure 2. First, the distribution of the SAT scores was estimated for the whole cohort. The shaded area represents the proportion of high school graduates entering college. The mean SAT scores for the base entrants were then found from the remaining area.

Estimates of the human capital stock (colums 3 and 4) were obtained by choosing male base entrants in 1988 as the base and applying equation (6). The real earnings of each year's average base entrants in 1987 dollars are then standardized for differences in weekly hours of work. The human capital rental rates were obtained by dividing standardized real earnings by the human capital rental stock.

The mean SAT scores in columns (1) and (2) fluctuate due to variations in the college enrollment rates of high school graduates as well as variations in ability over time. For example, college enrollment rates for males fell from more than 60 percent in 1969 to 53 percent in 1972 and 49 percent in 1974, then increased to 53 percent in 1975 (see the *Digest of Education Statistics*). Other things equal those low college enrollment rates imply a higher quality of base entrants, given the ability distribution, creating higher mean SAT scores in 1972 through 1974 for base entrants. Since the human capital stock of base entrants depends on their ability level, higher SAT scores yield a larger initial stock of human capital. Human capital rental rates for both males and females reached their peaks in 1978 and then declined. Females' rental rate increased 58% from 1963 to 1988, while males' rental rate increased only 15.8% in the same period.

Employers cannot observe how much human capital base entrants posses. It is reasonable to assume a close connection between the SAT scores of base entrants and entry level wages set by employers. In Tables 3A and 3B the rental rate labeled SAT(1) is derived from current base entrants, and the rental rates labeled SAT(3) and SAT(5) were obtained from the moving averages of three-period and five-period SAT scores, respectively. Rental rates obtained using the simple method, using only total educational expenditures per base entrant, without ability adjustment, to represent a base entrant's human capital stock are also shown for comparison purposes. The rental rates of all the adjusted methods peaked in the late 1970s, between the first and second oil price shock. The rental rate obtained using the simple method declined continuously after 1965.

Table 2 Basic Information on Base Entrants to the Labor Force

DATA ARE BASED ON THE AVERAGE BASE ENTRANT

	Mean SAT		Human Capital		Real Earnings		Work	Adj Earnings		Rental Rate	
year	Male	Female	Male	Female	Male	Female	hours	Male	Female	Male	Female
	(score)		(hc)		(1987 dollars)		(hrs)	(1987 dollars)		($/hc)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1963	290	299	71960	74132	12510	8705	38.8	11189	7785	0.155	0.105
1964	281	296	69663	73409	13032	9214	38.7	11685	8262	0.168	0.113
1965	281	288	69618	71462	13316	9673	38.8	11909	8651	0.171	0.121
1966	278	293	68964	72559	13887	9917	38.6	12484	8915	0.181	0.123
1967	280	285	69477	70664	14359	10923	38.0	13112	9975	0.189	0.141
1968	283	289	70230	71667	14689	11111	37.8	13484	10200	0.192	0.142
1969	279	284	69229	70485	15163	11508	37.7	13956	10592	0.202	0.150
1970	286	283	70748	70208	14911	11940	37.1	13946	11167	0.197	0.159
1971	281	281	69613	69705	14927	11686	36.9	14037	10989	0.202	0.158
1972	305	314	75604	77834	15676	12456	37.0	14701	11682	0.194	0.150
1973	309	318	76595	78877	16236	12058	36.9	15268	11339	0.199	0.144
1974	309	316	76508	78193	14888	11432	36.5	14153	10869	0.185	0.139
1975	291	297	72123	73523	15664	12045	36.1	15057	11578	0.209	0.157
1976	295	288	73164	71320	16373	12529	36.1	15738	12043	0.215	0.169
1977	287	289	70983	71531	16297	12552	36.0	15708	12099	0.221	0.169
1978	288	287	71370	71006	16501	12703	35.8	15994	12312	0.224	0.173
1979	288	288	71318	71405	16356	12388	35.7	15898	12041	0.223	0.169
1980	293	280	72517	69249	15526	11366	35.3	15262	11173	0.210	0.161
1981	279	276	69108	68456	14272	11266	35.2	14069	11106	0.204	0.162
1982	292	279	72222	69083	13662	11113	34.8	13622	11082	0.189	0.160
1983	286	277	70966	68531	12743	10768	35.0	12633	10675	0.178	0.156
1984	275	278	68085	68977	12618	10767	35.2	12439	10614	0.183	0.154
1985	277	275	68580	68164	12504	10525	34.9	12433	10464	0.181	0.154
1986	282	284	69779	70248	12697	10862	34.8	12660	10831	0.181	0.154
1987	273	274	67663	67936	12595	11158	34.8	12559	11126	0.186	0.164
1988	278	265	68902	65570	12357	10905	34.7	12357	10905	0.179	0.166

1. The computation of "Mean SAT" and "Human Capital" is shown in the text. They are adjusted by the ability distribution. Their data sources are the *Digest of Education Statistics* and the *Money Income of Households, Families, and Persons in the U.S.*, respectively. Note that the measurement unit of human capital is defined as hc.
2. "Real Earnings" indicates the earnings for nineteen-year-old base entrants and is derived from the *Money Income of Households, Families, and Persons in the U.S.* by using linear interpolation.
3. Data on "Work hours" per week are from the *Economic Report of the President*.
4. "Adj Earnings" (adjusted earnings) for year t is derived from

$$\text{real earning for year t} * \frac{\text{work hrs for year t}}{\text{work hrs for 1988}}.$$

5. Rental rates are obtained by dividing columns (8) and (9) respectively by (3) and (4).
6. Rounding will cause what appears to be identical SAT scores to produce slightly different levels of human capital.

Table 3A Alternative Estimates of Human Capital Rental Rates for Males.

Year	Simple	SAT(1)	SAT(3)	SAT(5)
		($/hc)		
1963	0.498	0.155	0.155	0.155
1964	0.555	0.168	0.165	0.164
1965	0.524	0.171	0.169	0.168
1966	0.510	0.181	0.180	0.177
1967	0.505	0.189	0.189	0.187
1968	0.510	0.192	0.194	0.193
1969	0.510	0.202	0.200	0.200
1970	0.488	0.197	0.199	0.199
1971	0.470	0.202	0.201	0.200
1972	0.467	0.194	0.204	0.206
1973	0.471	0.199	0.206	0.210
1974	0.445	0.185	0.185	0.191
1975	0.460	0.209	0.200	0.202
1976	0.454	0.215	0.212	0.209
1977	0.431	0.221	0.218	0.212
1978	0.420	0.224	0.222	0.219
1979	0.409	0.223	0.223	0.220
1980	0.392	0.210	0.212	0.211
1981	0.338	0.204	0.198	0.197
1982	0.292	0.189	0.191	0.190
1983	0.238	0.178	0.178	0.177
1984	0.211	0.183	0.176	0.175
1985	0.195	0.181	0.179	0.177
1986	0.192	0.181	0.184	0.180
1987	0.190	0.186	0.183	0.181
1988	0.179	0.179	0.179	0.179

1. Table 3A is derived by dividing adjusted earnings by human capital stock.
2. The human capital stock constructed by the simple method is the aggregation of educational investments.
3. The human capital stocks estimated by SAT(1), SAT(3), and SAT(5) are obtained by assuming that the wages of base entrants are paid based on the abilities of the current mean SAT score, the moving averages of three-period, and of five-period, respectively.

Table 3B Alternative Estimates of Human Capital Rental Rates for Females.

Year	Simple	SAT(1)	SAT(3)	SAT(5)
		($/hc)		
1963	0.346	0.105	0.105	0.105
1964	0.392	0.113	0.112	0.112
1965	0.381	0.121	0.118	0.118
1966	0.364	0.123	0.123	0.122
1967	0.384	0.141	0.139	0.137
1968	0.386	0.142	0.142	0.141
1969	0.387	0.150	0.149	0.148
1970	0.391	0.159	0.157	0.156
1971	0.368	0.158	0.156	0.155
1972	0.371	0.150	0.161	0.162
1973	0.350	0.144	0.150	0.154
1974	0.342	0.139	0.139	0.144
1975	0.353	0.157	0.150	0.152
1976	0.347	0.169	0.162	0.158
1977	0.332	0.169	0.167	0.161
1978	0.323	0.173	0.172	0.168
1979	0.310	0.169	0.169	0.167
1980	0.287	0.161	0.158	0.157
1981	0.267	0.162	0.159	0.157
1982	0.238	0.160	0.160	0.158
1983	0.201	0.156	0.155	0.153
1984	0.180	0.154	0.154	0.153
1985	0.164	0.154	0.152	0.152
1986	0.164	0.154	0.156	0.156
1987	0.168	0.164	0.161	0.161
1988	0.158	0.166	0.160	0.159

1. Table 3B is derived by dividing adjusted earnings by human capital stock.
2. The human capital stock constructed by the simple method is the aggregation of educational investments.
3. The human capital stocks estimated by SAT(1), SAT(3), and SAT(5) are obtained by assuming that the wages of base entrants are paid based on the abilities of the current mean SAT score, the moving averages of three-period, and of five-period, respectively.

Estimates of effective human capital stocks in the United States from 1963 through 1988 are given in Table 4A through 4D. The effective human capital stock estimated by the simple method increased more sharply than others over the study period due to the significant decrease in the human capital rental rate. Observed declines in the effective human capital stock during the oil shocks of the mid 1970s and early 1980s were expected since recessions are accompanied by higher unemployment and effective human capital counts only employed individuals.

When differences in the ability levels of base entrants were considered the effective human capital of males working full-time increased by less than 100 percent over the study period. For females, however, the human capital stock associated with full time workers grew by nearly 200 percent. The total effective human capital stock, including both full and part time workers, increased by about 135 percent for females and by 75 percent for males. As would be expected the increased participation of females in the full time labor force during that period had a major impact on the effective human capital stock.

In this study human capital is measured in units of "hc", not in dollars. This measurement unit meets the consistency requirement noted by Layard (1973).[9] It should be noted that although 1987 dollars are used as the measurement unit for the average base entrant in the base year (1988), 1987 dollars should not be used as a measurement unit for other students and other years because the human capital stock for the students other than the average base entrants in 1988 are adjusted to reflect their SAT scores. One dollar invested in students other than the average base entrant in 1988 does not produce the same unit of the human capital as accrues to the average base entrant in 1988. Similarly, 1987 dollars cannot be used as the measurement unit in years other than 1988.

Table 4A Estimates of Effective Human Capital by the Simple Method

	MALE			FEMALE			Total
Year	Full-time	part-time	total	Full-time	part-time	total	
			(billions of hc)				
1963	1363	240	1603	370	256	626	2229
1964	1328	232	1560	356	248	604	2164
1965	1465	256	1721	404	282	686	2407
1966	1621	285	1906	446	312	758	2664
1967	1804	308	2112	497	352	849	2961
1968	1876	326	2203	513	375	888	3091
1969	1937	388	2324	549	381	930	3255
1970	2056	412	2467	604	433	1037	3504
1971	2197	416	2613	675	478	1153	3766
1972	2394	439	2833	722	508	1230	4063
1973	2482	446	2927	790	561	1352	4279
1974	2462	493	2954	828	582	1410	4365
1975	2355	558	2913	807	621	1428	4341
1976	2478	570	3049	869	680	1549	4598
1977	2721	612	3332	976	729	1705	5037
1978	2942	620	3562	1081	812	1893	5455
1979	3014	625	3639	1193	1037	2230	5868
1980	2916	546	3462	1281	664	1946	5408
1981	3308	648	3956	1392	730	2122	6078
1982	3726	814	4540	1650	819	2469	7009
1983	4749	948	5697	2111	1086	3197	8894
1984	5675	1012	6687	2514	1131	3645	10332
1985	6514	1153	7667	2933	1269	4202	11869
1986	6935	1176	8111	3141	1306	4447	12558
1987	7224	1181	8405	3280	1318	4598	13003
1988	7660	1184	8845	3640	1377	5018	13862

1. The effective human capital stock is the human capital stock which actually participates production activity.
2. Individuals who work 35 hours or more per week and 50 weeks or more per year are defined as full-time workers.
3. Part-time workers are assumed to work on average one half the time that full-time workers do.

Table 4B Estimates of Effective Human Capital Using the Adjusted Method With Ability Represented by SAT Score

	MALE			FEMALE			Total
Year	Full-time	part-time	total	Full-time	part-time	total	
			(billions of hc)				
1963	4363	766	5129	1218	844	2062	7192
1964	4391	768	5160	1239	865	2105	7264
1965	4489	784	5273	1270	887	2158	7430
1966	4569	804	5373	1322	926	2248	7621
1967	4827	825	5653	1353	958	2311	7963
1968	4986	867	5854	1391	1018	2409	8263
1969	4995	867	5861	1414	981	2395	8256
1970	5089	1019	6108	1484	1064	2548	8656
1971	5118	969	6087	1574	1115	2689	8776
1972	5751	1055	6806	1785	1258	3043	9849
1973	5864	1053	6916	1923	1366	3289	10205
1974	5921	1185	7106	2035	1431	3467	10573
1975	5186	1228	6414	1811	1394	3205	9619
1976	5227	1203	6430	1786	1398	3185	9615
1977	5303	1192	6495	1917	1431	3348	9844
1978	5515	1163	6678	2016	1515	3531	10209
1979	5531	1147	6678	2192	1905	4097	10775
1980	5428	1017	6445	2278	1181	3459	9904
1981	5492	1076	6568	2290	1201	3490	10058
1982	5774	1262	7036	2447	1214	3660	10697
1983	6356	1269	7626	2729	1403	4132	11758
1984	6543	1167	7710	2937	1321	4258	11968
1985	7004	1239	8243	3134	1356	4490	12733
1986	7348	1246	8594	3350	1393	4743	13337
1987	7390	1208	8598	3368	1354	4722	13320
1988	7660	1184	8845	3464	1311	4775	13619

1. The effective human capital stock is the human capital stock which actually participates production activity.
2. Individuals who work 35 hours or more per week and 50 weeks or more per year are defined as full-time workers.
3. Part-time workers are assumed to work on average one half the time that full-time workers do.

Table 4C Estimates of Effective Human Capital using the Adjusted Method When Ability is Represented by Three-Period Moving Average of SAT Scores

	MALE			FEMALE			Total
year	Full-time	part-time	total	Full-time	part-time	total	
			(billions of hc)				
1963	4370	768	5138	1220	846	2066	7204
1964	4472	782	5254	1248	871	2119	7373
1965	4548	796	5344	1300	908	2208	7552
1966	4607	820	5427	1323	927	2250	7677
1967	4827	834	5662	1373	971	2344	8006
1968	4947	863	5810	1393	1019	2412	8222
1969	4935	989	5924	1425	989	2415	8339
1970	5049	1009	6058	1499	1074	2573	8631
1971	5146	977	6123	1587	1124	2710	8833
1972	5486	996	6482	1668	1175	2843	9324
1973	5670	999	6669	1843	1309	3152	9821
1974	5910	1148	7059	2042	1436	3477	10536
1975	5407	1267	6675	1897	1460	3357	10032
1976	5291	1235	6527	1865	1460	3325	9852
1977	5395	1246	6641	1936	1446	3382	10023
1978	5561	1192	6753	2027	1524	3551	10304
1979	5534	1159	6693	2193	1906	4099	10792
1980	5379	1012	6391	2325	1205	3530	9921
1981	5651	1111	6762	2335	1225	3560	10322
1982	5709	1251	6960	2445	1213	3659	10619
1983	6350	1280	7629	2740	1409	4149	11778
1984	6780	1215	7995	2937	1321	4258	12253
1985	7080	1267	8347	3158	1366	4524	12871
1986	7259	1254	8514	3303	1373	4676	13189
1987	7513	1238	8751	3416	1373	4789	13540
1988	7660	1184	8845	3595	1360	4954	13799

1. The effective human capital stock is the human capital stock which actually participates production activity.
2. Individuals who work 35 hours or more per week and 50 weeks or more per year are defined as full-time workers.
3. Part-time workers are assumed to work on average one half the time that full-time workers do.

Table 4D Estimates of Effective Human Capital using the Adjusted Method When Ability is Represented by Five-Period Moving Average of SAT Scores

	MALE			FEMALE			Total
year	Full-time	part-time	total	Full-time	part-time	total	
			(billions of hc)				
1963	4382	770	5152	1224	847	2071	7223
1964	4483	784	5268	1251	873	2124	7392
1965	4560	796	5356	1304	910	2214	7570
1966	4661	820	5481	1334	934	2269	7750
1967	4881	834	5715	1393	986	2379	8094
1968	4962	863	5826	1403	1026	2429	8255
1969	4938	989	5927	1438	998	2436	8363
1970	5038	1009	6047	1510	1082	2592	8639
1971	5159	977	6136	1600	1133	2733	8869
1972	5431	996	6427	1658	1168	2826	9254
1973	5563	999	6562	1798	1277	3075	9637
1974	5737	1148	6886	1960	1378	3338	10224
1975	5350	1267	6618	1871	1440	3312	9929
1976	5367	1235	6603	1911	1496	3406	10009
1977	5543	1246	6789	2010	1501	3511	10301
1978	5653	1192	6845	2085	1567	3652	10497
1979	5592	1159	6752	2213	1923	4135	10887
1980	5403	1012	6415	2342	1214	3557	9972
1981	5672	1111	6783	2362	1239	3601	10384
1982	5726	1251	6977	2484	1233	3717	10694
1983	6408	1280	7687	2773	1426	4200	11887
1984	6812	1215	8028	2944	1325	4269	12297
1985	7159	1267	8425	3170	1371	4541	12967
1986	7396	1254	8650	3305	1374	4679	13330
1987	7570	1238	8808	3425	1376	4801	13609
1988	7660	1184	8845	3618	1369	4987	13831

1. The effective human capital stock is the human capital stock which actually participates production activity.
2. Individuals who work 35 hours or more per week and 50 weeks or more per year are defined as full-time workers.
3. Part-time workers are assumed to work on average one half the time that full-time workers do.

Advantages Over Current Methods of Measuring Human Capital

This integrated approach to measuring human capital draws from the strengths of both the cost and income methods, while producing estimates which avoid many of the weaknesses of the prior measures. More specifically, by using the cost approach to define only the human-capital stock of the average base entrants, by assuming that the human-capital rental rate is constant over all cohorts, and by applying that general human capital rental rate to the earnings of each group in each cohort to estimate the human-capital stock, the problem of identifying the proportion of investment in items such as training and medical care which should be considered investments in human capital are avoided.

Since only educational investments are considered to contribute to the human capital stock of base entrants it may appear that this method understates the human capital stock. This, however, is not so. Consider medical spending. Since higher medical spending is associated with a higher probability of survival and improved health status, and that is reflected in higher aggregate earnings for the cohort over time, our estimates of effective human capital for the cohort will increase. Actually, this method treats medical spending more appropriately than do the cost based measures. Adding medical spending to the base-entrant's human capital would be double counting.[10]

Similarly base entrants are new workers in the labor force, workers who have not received any labor training. While aggregate labor-training data exists, it is very difficult to specify which groups in which cohorts are beneficiaries. Such restrictions on data availability make it likely that relationship (b) is more reliable than (a) in Figure 1. With regard to mobility, individuals will move to other places if they believe they will find better jobs or higher wages.

But, new high school graduates typically posses only general ability, not highly specific skills and the demand for employees with general skills is usually met locally. Rearing costs of children are considered as consumption, and not included. Furthermore, this integrated approach, like the income approach requires no prior assumptions about depreciation or appreciation rates. Appreciation or depreciation of the human capital stock is determined automatically by changes in the earnings of each cohort. Finally, this method proposes a more realistic method of estimating the rate of return on human capital than the simple assumption in the income based approach.

Revised Estimates of the Aggregate Production Function

The revised estimates of the human capital stock presented in tables 4A-4D were used to estimate a Cobb-Douglas production function, which incorporates both physical capital and human capital. The results from that exercise offer a partial check on the appropriateness of this alternative human capital measure. The human capital measure used is that of effective human capital, the aggregate human capital from everyone who participates in production activities. Since it incorporates both quantity and quality the labor input in this model does not need to be separated into hours of labor and a quality proxy, as done by Mankin et al. (1992) and Lau et al. (1993).

The traditional two-factor Cobb-Douglas function remains appropriate. That is, $Y=K^{\alpha}H^{\beta}\epsilon$,[11] where Y is real national income, K is physical capital, H is human capital, α and β are coefficients with $0\leq\alpha,\beta\leq1$, and ϵ is economic shock or disturbance. The logarithm functional form is

$$(8) \qquad \ln Y = \alpha \ln K + \beta \ln H + \ln \epsilon.$$

The production function was estimated using data from the period 1963 - 1988 with all monetary variables expressed in 1987 dollars. National income and physical capital are taken from series published by U.S. Department of Commerce .[12]

Results are tabulated in Table 5, where ln1H, ln3H and ln5H are the logarithms of the effective human capital stock generated by the adjusted method with current, three-year moving average and five-year moving average SAT scores as the adjustment factors. The other human capital measure, lnSH, is the logarithm of the human capital stocks derived from the simple method. lnLT is the logarithm of labor time.[13] An adjustment for serial correlation has been made.[14] The Durbin-Watson values in Table 5 show that the serial correlations are not significant.[15] A regression of national income on capital and hours of labor, also adjusted for serial correlation, is included for comparison purposes.

The human capital stock estimates based on the adjusted ability distributions have plausible interpretations and significant explanatory power in the aggregate production function, while t-values were not significant for the human capital measure without an ability adjustment.

Table 5 Estimates of the U.S. Aggregate
Production Function, 1963-88,
After Adjustment for Serial Correlation

	Coefficient	t-value	$\bar{R}^2$	D-W
lnK	0.47	5.75	0.985	1.29
ln1H	0.45	5.82		
lnK	0.39	5.06	0.986	1.39
ln3H	0.52	7.09		
lnK	0.36	4.96	0.988	1.5
ln5H	0.55	8.14		
lnK	0.45	0.56	0.982	1.25
lnSH	0.07	0.82		
lnK	0.54	11.58	0.993	1.31
lnLT	0.29	8.62		

D-W is the Durbin-Watson value

The addition of a measure of labor quality extended the explanatory power of the production function on income share to input factors. The traditional production function (the last model in Table 5) explains 83% (54%+29%) of the income share, while the first three models explain about 91% (the sum of coefficients of logarithms of physical capital and human capital) of income share. Moreover, the introduction of labor quality expands the role of labor input in production activity, from 29% to 45% or more. It implies that the traditional production function is likely to overstate the role of physical capital while understating that of labor input.

Conclusions

This study describes an alternative approach for measuring human capital, one which avoids the major drawbacks of the cost and income approaches by observing the whole sequence of human capital investment through earnings. Our model requires fewer assumptions about what defines an investment in human capital, removing a major source of differences among those using the cost approach. The change of wages, along with that of the human capital rental rate, reflects a proper depreciation and appreciation in human capital. Hence, the depreciation and appreciation defined in this approach does not follow the one used in physical capital as the cost approach implies. In addition, this measure rules out the possible bias resulting from the neglect of the variation of the human-capital rental rate between genders and over time. The generated measurement of human capital was shown to enhance the explanatory power of the aggregate production function and increase the role played by the labor input.

Notes

1. The number of years of schooling is also used to represent the human capital stock, but it lacks a quality element. It is also impossible to compute the return on human capital investment using this measure.

2. See Bowman (1962), pp. 73-79, Harbison and Myers (1964), pp.24-26, and Dhesi (1979), pp.30-36, for other indicators of human capital stock.

3. Evidence on the decline in real earnings as people age can be found in Mincer (1958), page 294; and in Mincer (1974), page 66 . However, this evidence is constructed on cross-sectional data analysis. Polachek and Siebert (1993) assert that earnings reach a peak at about age fifty-five, and then decline.

4. Increments of lifetime income, due to education, births and immigration, are defined as the country's investments of the human capital (see Jorgenson and Pachon, 1983b, pages 32 and 59). But, it is an axiom in economics that investment is a cost concept and income, a return concept. Mixing both concepts creates confusion.

5. This should not be confused with Jorgenson's version of the income approach. Jorgenson's version, which can also be called the forward looking approach, aggregates the future discounted income as a measure of an individual's human capital stock.

6. These economists include Becker (1964), Ben-Porath (1967), Moreh (1973), Haley (1973,1976), Heckman (1976), Klevmarken and Quigley (1976), Rosen (1976), Mincer (1979), Carliner (1982), Theeuwes et al. (1985), Johnes (1993), and Polachek and Siebert (1993).

7. Use of a base year to set the human capital stock is similar to the use of a base year to adjust for inflation. The choice of base year will affect the

absolute size of the human capital stock, but it does not change the relationship over time between the human capital stock in any one year and that in any other year. The use of a base year for human capital stock measurement simply standardizes the human capital measure on the ability distribution over time.

8. For those years without an available SAT distribution, the estimate of the latest (early) year will be used.

9. Layard noted "We are of course free to measure human capital in whatever units we like, but the same units must be used to measure the change in the stock and its initial level." Layard (1973), page 1014.

10. Three reasons why physical quality improvement due to medical spending for base entrants can be neglected. First, the return of physical condition to healthy individuals is limited. Individuals at age nineteen are in the most healthy condition in their life cycle. Second, students who can graduate from high school are usually in healthy condition. Third, when medical spending improves an individual from unworkable to workable condition, this individual will be counted into the labor force, increasing the number of workers in the labor force.

11. An estimate of the production function with a constant term was obtained from using physical capital and labor hours as inputs. However, the coefficients for the constant term, logarithm of physical capital, and logarithm of labor hours, are -7.27, 0.18 and 1.15, respectively. The economic sense behind a production function implies a inappropriate specification of this model.

12. Physical capital is taken from Table A6, the gross fixed nonresident private capital in the *Fixed Reproducible Tangible Wealth in the United*

States, 1925-1989.

13. Labor hours are derived from the work hours per week (Table 2) multiplied by 52 and multiplied by the number of workers.

14. Table 5 was adjusted by the first-order autoregressive correction. That is, continue running the regression where a new dependent variable is derived from subtracting the predicted residual from the original regression, until the model converges. This procedure is automatically conducted by MicroTSP.

15. This regression does not have an intercept, the regular Durbin-Watson test is not proper. The critical value of D-W value was modified by Farebrother (1980).

Reference

Becker, G. (1964), Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education, Princeton: Princeton University Press.

Ben-Porath, Y. (1967), "The Production of Human Capital and the Life Cycle of Earnings," *Journal of Political Economy*, vol. 75, pp. 352-365.

Bowman, M. J. (1962), "Human Capital: Concepts and Measures," in *Economics of Higher Education*, ed. S. J. Mushkin, pp. 69-92. Washington, D. C.: Government Printing Office.

Carliner G. (1982), "The Wages of Older Men," *Journal of Human Resources*, vol. 17, pp. 25-38.

Dhesi, A. S. (1979), *Human Capital Formation and Its Utilization.* India: Sterling Publisher.

Eisner, R. (1985), "The Total Income System of Accounts," *Survey of Current Business*, vol. 65, pp. 24-48.

Eisner, R. (1988), "Extended Accounts for National Income and Product," Journal of Economic Literature, vol. 26, pp. 1611-1684.

Eisner, R. (1989), *The Total Incomes System of Accounts*. Chicago: University of Chicago Press.

Farebrother, R. W. (1980), "The Durbin-Watson Test for Serial Correction When There is no Intercept in the Regression," *Econometrica*, vol. 48, pp. 1553- 1563.

Haley, W. J. (1973), "Human Capital: the Choice between Investment and Income", *American Economic Review*, vol. 63, pp. 929-944.

Haley, W. J. (1976), "Estimation of the Earnings Profile from Optimal Human Capital Accumulation", *Econometrica*, vol. 6, pp. 1223-1238.

Harbison, F. and C. A. Myers (1964), *Education, Manpower, and Economic Growth.* New York: McGraw-Hill.

Heckman, J. J. (1976), "A Life-Cycle Model of Earnings, Learning, and Consumption," *Journal of Political Economy*, vol. 84, pp. s11-s44.

Johnes, G. (1993), *The Economics of Education*. MacMillan: London.

Jorgenson, D. W. and A. Pachon (1983a), "The Accumulation of Human and Non-human Capital," in *The Determinants of National Saving and Wealth*, ed. R. Hemming and F. Modigliani, pp.302-352. London: Macmillan.

Jorgenson, D. W. and A. Pachon (1983b), "Lifetime Income and Human Capital," in *Human Resources, Employment, and Development*, ed. P. Streeten and H. Maier, pp. 29-90. London: Macmillan.

Jorgenson, D. W. and B. M. Fraumeni (1989), "The Accumulation of Human and Non-human Capital," in Studies in Income and Wealth, vol. 52, *The Measurement of Saving, Investment, and Wealth*, ed. R. E. Lipsey and T. H. Stone, NBER, pp. 227-282, Chicago and London: University of Chicago Press.

Kendrick, J. (1974),"The Accounting Treatment of Human Investment and Capital," *Review of Income and Wealth*, vol. 20, pp. 439-468.

Kendrick, J. (1976), *The Formation and Stocks of Total Capital*, New York, Columbia University Press for NBER.

Klevmarken, A. and J. M. Quigley (1976), "Age, Experience, Earnings, and Investments in Human Capital," *Journal of Political Economy*, vol. 84, pp. 47-72.

Lau, L. J., D. T. Jamison, S. Liu and S. Rivkin (1993), "Education and Economic growth: Some Cross-Sectional Evidence from Brazil," *Journal of Development Economics*, vol. 41, pp.45-70.

Layard, P.R.G. (1973), "Denison and the Contribution of Education to National Income Growth: A Comment," *Journal of Political Economy*, vol. 51, pp. 1013- 1016.

Machlup, F. (1984), *The Economics of Information and Human Capital.* vol. 3, Princeton, Princeton University Press.

Mankin, N. G., D. Romer and D. N Weil (1992), "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, vol. 106, pp.407-437.

Mincer, J. (1958), "Investment in Human Capital and Personal Income Distribution," *Journal of Political Economy*, vol.66, pp. 281-232.

Mincer, J. (1974), *Schooling, Experience and Earnings*. New York: Columbia University Press for National Bureau of Economic Research.

Mincer, J. (1979), "Human Capital and Earnings," in *Economic Dimension of Education.* Washington, DC: National Academy of Education.

Moreh, J. (1973), "Human Capital: Deterioration and Net Investment," *Review of Income and Wealth*, vol. 19, pp. 279-302.

Polachek, S. W. and W. S. Siebert (1993), *The Economics of Earnings*. Cambridge University

Press: Cambridge.

Rosen, S. (1976), "A Theory of Life Earnings," Journal of Political Economy, vol. 84, pp. s45-s67.

Theeuwes, J., C. C. Koopmans, R. Van Opstal, and H. Van Reijn (1985), "Estimation of Optimal Human Capital Accumulation Parameters for the Netherlands," *European Economic Review*, vol. 29, pp. 233-257.

U.S. Department of Commerce, 1989 and earlier years, Current Population Report, series P-60, *Money Income of Household, Families, and Persons in the United States*. Washington D.C.

U.S. Department of Education, 1992 and earlier years, *Digest of Education Statistics*. Washington D.C.

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