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ABSTRACT

A study analyzed the contributions of education to U.S. economic growth during the years 1948 to 1973. By allocating the growth of the quality of labor input among the contributions of changes in the composition of the labor force by sex, age, education, employment status, and occupation, researchers were able to separate the contribution of education to economic growth from the contributions of other changes in the composition of the labor force. They concluded that investment in education is very large by comparison with labor market input, amounting to 5.13 times labor input in 1973. The rate of growth for investment is twice as high as that of labor input. Investment is highest for elementary education, next to highest for secondary education, and lowest for higher education. Another finding of the study is that while the value of investment per student in constant price rises for males and females with elementary and secondary education, this value peaked for college trained males in 1955 and for college trained females in 1950. (This study is one in a series on the relationship between education and productivity.) (MN)

THE CONTRIBUTION OF EDUCATION TO U.S. ECONOMIC GROWTH, 1948-1973

by

Dale W. Jorgenson

1. Introduction

The purpose of this paper is to analyze the contribution of education to U.S. economic growth during the years from 1948 to 1973. This remarkable quarter century has been dominated by a powerful upward thrust in the level of U.S. economic activity. In 1973 the output of the civilian economy stood at 1.306 trillion dollars of 1972; by contrast output in 1948 was only 498 billions. The increase in the level of economic activity from 1948 to 1973 was greater than the rise over the whole preceding course of American history.

The growth record of the U.S. economy over the period 1948-1973 is all the more striking in view of the experience of the two preceding decades. The years from 1929 to 1948 were dominated by the Great Depression of the 1930's and the Second World War. For this period Christensen and Jorgenson (1970) have estimated the rate of growth of the U.S. private domestic economy at 2.1 percent per year. For the period 1948-1960 the U.S. growth rate rose to 3.6 percent per year; from 1960 to 1973 the growth rate averaged 4.3 percent, more than double the average from 1929 to 1948.

In this paper we employ a novel perspective on postwar U.S. economic growth. We show that the driving force behind the massive expansion of the U.S. economy between 1948 and 1973 has been a vast mobilization of capital and labor resources. The most important single contribution to U.S. economic growth during this period was made by the growth in capital input. The contribution of capital input averaged 1.6 percent per year for the period 1948-1973. The contribution of labor input was another important source of U.S. economic growth, averaging 1.1 percent per year from 1948 to 1973.

Capital and labor inputs combined contributed 2.7 percent per year to the growth rate of 3.9 percent for the output of the U.S. civilian economy from 1948 to 1973. These two inputs accounted for more than two-thirds of the growth of output that took place. By contrast advances in the level of technology contributed only 1.2 percent per year to the growth of output, less than half the combined contributions of capital and labor inputs. Accordingly, we have emphasized the mobilization of capital and labor resources rather than advances in the level of technology in analyzing postwar U.S. economic growth.

The contribution of education to economic growth takes place through enhancement of the productivity of individual members of the labor force. Increases in hours worked through gains in employment contribute to the growth of labor input. In addition, labor input grows through increases in the proportion of hours worked by more productive members of the work force. We identify this component of growth in

labor input with growth in labor quality. In our approach the growth of labor input is the sum of growth in hours worked and growth in labor quality. Change in the educational composition of the labor force is a very important source of growth in labor quality. However, the contribution of education must be separated from the impact of changes in the composition of the labor force by sex, age, employment status, and occupation.

To implement our approach to the analysis of sources of U.S. economic growth we have developed a methodology based on an explicit model of production and technical change. This methodology is based on an aggregate production function giving output as a function of capital and labor inputs and time.[1] To identify the role of education in economic growth we represent labor input as a function of types of labor input that differ in marginal productivity. We combine the production function and labor input as a function of its components with necessary conditions for producer equilibrium. These conditions make it possible to identify the marginal product of labor input with the ratio of the wage rate to the price of output. Similarly, we can identify the marginal product of each type of labor input with the ratio of its wage rate to the wage rate of labor input as a whole.

To analyze the sources of U.S. economic growth and to identify the contribution of education we first allocate the growth of aggregate output between contributions of capital and labor inputs and changes in the level of technology.[2] We then separate the contribution of each input between growth in an unweighted sum of its components and growth in input quality.[3] Labor quality is defined as the ratio between the labor input index and the unweighted sum of hours worked. To identify the role of education we represent labor input as a function of types of labor input broken down by characteristics of individual workers such as sex, age, education, employment status, and occupation.[4] Utilizing this breakdown of labor input into its components, we allocate the growth of the quality of labor input among the contributions of changes in the composition of the labor force by sex, age, education, employment status and occupation. This analysis enables us to separate the contribution of education to economic growth from the contributions of other changes in composition of the labor force.

In Section 2 we analyze the sources of U.S. economic growth for the period 1948-1973. We show that the contribution of labor quality is a very important source of U.S. economic growth, accounting for 0.45 percent per year of a total contribution of labor input of 1.09 percent per year. The quality of labor input grows through increases in the proportion of hours worked by the more productive members of the labor force. In Section 3 we analyze the contribution of education to the growth of labor input in the U.S. economy. We show that the contribution of

education accounts for 0.67 percent per year of a total growth in the quality of labor input of 0.72 percent per year.

While the contribution of education to U.S. economic growth is obviously highly significant, our analysis of the sources of economic growth is subject to very important limitations. The most critical limitation is that educational investment in any year contributes to growth in the quality of the labor force in that year, but also enhances the productivity of individual workers in future years. A second limitation is that measures of labor input focus attention exclusively on market labor activities -- hours worked and wage rates of employed persons. Education also contributes to social welfare through nonmarket activities of individuals employed in the labor market and through the activities of individuals not participating in the labor market.[5]

In Section 4 we attempt to overcome some of the limications of our analysis of education as a source of economic growth by presenting a measure of investment in education. The most important innovations in our measure of investment in education are these: First, our concept of human capital is based on lifetime labor incomes for all individuals in the U.S. population.[6] Second, we incorporate both market and nonmarket activities into our measures of labor incomes. This makes it possible to provide measures of lifetime labor incomes for individuals employed in the labor market and for individuals not involved in the labor market.

Third, our measures of investment in education are based on a system of demographic accounts that includes accounts for school enrollment.[7] Fourth, we combine these accounts with economic accounts for the value of available labor time to obtain measures of investment in education for the U.S. economy as a whole.

To implement our methodology for analyzing the sources of U.S. eocnomic growth we have constructed a complete set of U.S. national accounts for capital and labor inputs as well as for output at the aggregate level. This system of accounts complements the existing U.S. national accounts for output developed by the Bureau of Economic Analysis (1977). Our accounts can be integrated with existing national accounts for capital formation and wealth in the form of nonhuman capital developed by Christensen and Jorgenson (1969, 1970, 1973a, 1973b). Similarly, to implement our methodology for measuring investment in education we have constructed a set of U.S. national accounts for capital formation through education. Our accounts can be integrated with a new system of U.S. national accounts developed by Jorgenson and Pachon (1982a, 1982b) that includes capital formation and wealth in the form of human capital.

2. Sources of U.S. Economic Growth

In this section we allocate the growth of aggregate output between growth in capital and labor inputs and changes in the level of technology. We construct data on the rate of technical change by combining price and quantity data for value added, capital input, and labor input. We employ a translog quantity index of the rate of technical change, equal to the difference between the change in the logarithm of value added from period to period and a weighted average of changes in the logarithms of capital and labor inputs.[8] The weights are given by average shares of each input in value added for the two periods.

The starting point for our measure of the rate of aggregate technical change is a production account for the U.S. economy as a whole in current prices.[9] The fundamental accounting identity for the economy as a whole is that the value of output is equal to the value of input from the producers' point of view. The value of output excludes sales and excise taxes and includes subsidies received by producers. The value of input includes the value of primary factors of production incorporating supplementary payments and payroll taxes included in labor compensation and property taxes and other taxes on property compensation. Valuation from the point of view of the producer is intermediate between valuation at market prices and valuation at factor cost.

Given our definition of output and input from the point of view of the producer, the aggregate production account takes the form given in Table 1. The value of output from the point of view of the producing

AGGREGATE PRODUCTION ACCOUNT: CURRENT PRICES

REVENUE

1.		Gross domestic civilian product
2.	+	Services of consumers' durables
3.	+	Services of durables held by institutions
4.	+	Net rent on institutional real estate
5.	-	Federal indirect business tax and non-tax accruals
6.	+	Capital stock tax
7.	-	State and local indirect business tax and non-tax accruals
8.	+	Business motor vehicle licenses
9.	+	Business property taxes
10.	+	Business other taxes
11.	+	Subsidies
12.	=	Value of output from the point of view of the producing sector.

OUTLAY

1.		Income originating in business
2.	+	Income originating in households and institutions
3.	+	Income originating in civilian government
4.	+	Capital consumption allowances
5.	+	Business transfer payments
6.	+	Statistical discrepancy
7.	+	Services of consumers' durables
8.	+	Services of durables held by insitutions
9.	+	Net rent on institutional real estate
10.	+	Certain indirect business taxes (revenue account above, lines 6 + 8 + 9 + 10)
11.	=	Value of input from the point of view of the producing sector.

sector is equal to the sum of gross domestic civilian product, as defined in the U.S. national income and product accounts, the services of consumers' durables, the services of durables held by institutions, and net rent on institutional real estate. The value of indirect business taxes on output, net of subsidies, is excluded from the value of output from the point of view of the producing sector. The net value of these taxes is equal to the sum of federal and state and local business tax and non-tax accruals, less the federal capital stock tax, state and local business motor vehicle licenses, property taxes and other taxes, and federal subsidies.

As an accounting identity, the value of output is equal to the value of input from the point of view of the producing sector. The value of input includes income originating in business, households and institutions, and civilian government, as defined in the U.S. national income and product accounts. The value of input also includes capital consumption allowances, business transfer payments, the statistical discrepancy, and certain indirect business taxes on property and property compensation. Finally, the value of input includes the imputed value of services of consumers' durables and durables held by institutions and net rent on institutional real estate.

Revenue and outlay accounts are linked through capital formation and the corresponding compensation of capital services. To make this link explicit, we divide the value of input from the point of view of the producer between labor and property compensation. Property compensation also includes profits, rentals, interest, capital consumption

allowances, business transfer payments, the statistical discrepancy, the property compensation of self-employed, and direct taxes included in outlay on capital services, including business motor vehicle licenses, property taxes, and other taxes. Labor compensation includes the compensation of employees and the labor compensation of the self-employed.

The quantity of aggregate value added is the sum of the quantities of value added in all sectors:

$$V = \Sigma V_i .$$

We can define the price of value added for the economy as a whole p_V in terms of prices of value added in all sectors $\{p_V^i\}$:

$$p_V V = p_V \Sigma V_i ,$$

$$= \Sigma p_V^i V_i .$$

Value added for the economy as a whole is equal to the sum of value added over all sectors. The quantity index of value added, the corresponding price index, and value added in all sectors are presented for the period 1948-1973 in Table 2.

Table 2

AGGREGATE VALUE ADDED

YEAR	PRICE	QUANTITY	VALUE ADDED
1948	.535	498.420	266.613
1949	.527	497.007	261.742
1950	.544	539.467	293.227
1951	.582	578.305	336.845
1952	.599	597.858	358.356
1953	.600	621.816	372.991
1954	.617	620.042	382.434
1955	.622	664.014	413.164
1956	.633	692.491	438.434
1957	.645	707.485	456.351
1958	.667	705.689	470.376
1959	.674	748.836	504.652
1960	.689	771.174	530.978
1961	.695	788.039	547.613
1962	.706	828.168	584.367
1963	.708	867.460	614.488
1964	.722	914.627	660.355
1965	.743	967.928	719.641
1966	.773	1020.897	789.336
1967	.794	1049.774	833.063
1968	.823	1101.789	906.418
1969	.876	1134.840	993.783
1970	.904	1137.615	1027.976
1971	.948	1168.719	1108.318
1972	1.000	1233.220	1233.220
1973	1.065	1306.251	1391.316

Our next objective is to implement an index of productivity for the economy as a whole empirically. We assume that value added V can be expressed as a translog function of capital input K, labor input L, and time T. The corresponding index of productivity growth is the translog index of the rate of technical change $\bar{v}_T$:

$$\bar{v}_T = \ln V(T) - \ln V(T-1) - \bar{v}_K \left[\ln K(T) - \ln K(T-1)\right]$$

$$- \bar{v}_L \left[\ln L(T) - \ln L(T-1)\right] \quad ,$$

where weights are given by average shares of capital and labor inputs, $\bar{v}_K$ and $\bar{v}_L$, in value added for the economy as a whole:

$$\bar{v}_K = \frac{1}{2}\left[v_K(T) + v_K(T-1)\right] \quad ,$$

$$\bar{v}_L = \frac{1}{2}\left[v_L(T) + v_L(T-1)\right] \quad ,$$

$$\bar{v}_T = \frac{1}{2}\left[v_T(T) + v_T(T-1)\right] \quad ,$$

and:

$$v_K = \frac{p_K K}{p_V V} \quad ,$$

$$v_L = \frac{p_L L}{p_V V} \quad .$$

The value shares are computed from data on the quantities of value added, capital input, and labor input and the corresponding prices, p_V, p_K, and p_L.

We assume that capital input and labor input can be expressed as translog functions of individual capital inputs $\{K_k\}$ and individual labor inputs $\{L_\ell\}$: [10]

$$\ln K(T) - \ln K(T-1) = \Sigma \bar{v}_{Kk} [\ln K_k(T) - \ln K_k(T-1)] ,$$

$$\ln L(T) - \ln L(T-1) = \Sigma \bar{v}_{L\ell} [\ln L_\ell(T) - \ln L_\ell(T-1)] ,$$

where weights are given by average shares of quantities of value added, capital input, and labor input in the value of the corresponding aggregates:

$$\bar{v}_{Kk} = \frac{1}{2} [v_{Kk}(T) + v_{Kk}(T-1)] , \qquad (k=1,2...p),$$

$$\bar{v}_{L\ell} = \frac{1}{2} [v_{L\ell}(T) + v_{L\ell}(T-1)] , \qquad (\ell=1,2...q),$$

and:

$$v_{Kk} = \frac{p_{Kk}K_k}{\Sigma p_{Kk}K_k} , \qquad (k=1,2...p),$$

$$v_{L\ell} = \frac{p_{L\ell}L_\ell}{\Sigma p_{L\ell}L_\ell} , \qquad (\ell=1,2...q).$$

The value shares are computed from data on capital inputs and their prices $\{p_{Kk}\}$ and labor inputs and their prices $\{p_{L\ell}\}$.

We next compare the rate of technical change and growth in capital and labor inputs as sources of growth in value added. We present annual growth rates for value added, capital input, and labor input for the period 1948-1973 in Table 3. The rate of growth of value added is the sum of the average rate of technical change and a weighted average of rates of growth of capital and labor inputs with weights given by the average value shares of the inputs. We present the share of capital input in value added in Table 3. The value share of labor input is equal to unity less the value share of capital input. Applying these weights to the rates of growth of the corresponding input identifies the contribution of each input to economic growth. We present the weighted growth rates of capital and labor inputs and the average annual rate of technical change in Table 3.

Value added grew rapidly throughout the period 1948-1973 with declines in 1949, 1954, and 1958 and a very low but positive growth rate in 1970. The declines lasted for a single year and were followed by sharp recoveries in 1950-1951, 1955, and 1959. Turning to the growth of capital input, we find that declines in value added during the period 1948-1973 were followed by reductions in the rate of growth of capital input one period later. By comparison with the growth of capital input, the growth of labor input was considerably more uneven. While the growth rate of capital input was positive throughout the period, substantial declines in labor input coincided with declines in value added in 1949,

Table 3

CONTRIBUTIONS TO GROWTH IN AGGREGATE OUTPUT 1948-1973

YEAR	VALUE ADDED	CAPITAL INPUT	LABOR INPUT	AVERAGE VALUE SHARE OF CAPITAL INPUT	CONTRIBUTIONS TO GROWTH IN AGGREGATE VALUE ADDED:		
					CAPITAL INPUT	LABOR INPUT	TECHNICAL CHANGE
1949	-.0028	.0630	-.0346	.3470	.0215	-.0226	-.0017
1950	.0819	.0375	.0390	.3610	.0137	.0247	.0434
1951	.0695	.0710	.0516	.3576	.0247	.0337	.0110
1952	.0332	.0555	.0262	.3492	.0198	.0165	-.0031
1953	.0392	.0340	.0175	.3470	.0118	.0114	.0160
1954	-.0028	.0389	-.0285	.3523	.0136	-.0186	.0020
1955	.0685	.0316	.0311	.3677	.0122	.0194	.0378
1956	.0419	.0530	.0211	.3648	.0193	.0139	.0086
1957	.0214	.0416	.0013	.3541	.0148	.0005	.0059
1958	-.0025	.0348	-.0278	.3572	.0121	-.0174	.0027
1959	.0593	.0153	.0356	.3675	.0061	.0223	.0308
1960	.0293	.0347	.0281	.3723	.0129	.0178	-.0014
1961	.0216	.0320	-.0101	.3720	.0115	-.0064	.0165
1962	.0496	.0234	.0374	.3714	.0088	.0229	.0178
1963	.0463	.0363	.0110	.3721	.0132	.0073	.0257
1964	.0529	.0350	.0263	.3748	.0134	.0163	.0231
1965	.0566	.0407	.0348	.3801	.0151	.0211	.0203
1966	.0532	.0549	.0424	.3801	.0210	.0265	.0055
1967	.0278	.0594	.0162	.3758	.0222	.0103	-.0046
1968	.0483	.0456	.0236	.3705	.0167	.0146	.0169
1969	.0295	.0469	.0259	.3655	.0172	.0162	-.0038
1970	.0024	.0470	-.0041	.3562	.0165	-.0025	-.0116
1971	.0269	.0305	.0031	.3518	.0107	.0015	.0146
1972	.0537	.0346	.0233	.3596	.0123	.0147	.0266
1973	.0575	.0469	.0421	.3621	.0171	.0273	.0130

1954, and 1958; declines in labor input also took place in 1961 and 1970. Finally, the pattern of technical change, like that of labor input, was relatively uneven with declines in the level of technology in 1949, 1952, 1960, 1967, and 1969-1970. Rapid growth in the level of technology is associated with recoveries in the growth of value added in 1950, 1955, and 1959. Rapid growth in the level of technology also took place during the period 1960-1966; this period was characterized by unusually rapid growth of value added, capital input, and labor input.

The average value share of capital input was very stable over the period 1948-1973, ranging from .3470 in 1949 and 1953 to .3801 in 1965 and 1966. Accordingly, the cyclical pattern relating growth in value added to the contributions of capital and labor inputs is virtually identical to the patterns relating growth in value added to growth in capital and labor inputs. Comparing the contributions of capital and labor inputs and the rate of technical change as sources of growth in value added, we find that the contribution of capital input was positive throughout the period from 1948 to 1973 and relatively even. By contrast, the contributions of labor input and the rate of technical change were negative for five and six of the twenty-five periods, respectively, and relatively uneven.

The contribution of capital input provides the largest single contribution to the growth of output in ten of the twenty-five periods from 1948-1973. The contribution of labor input provides the largest single contribution in four of these periods. Finally, the rate of technical change provides the largest contribution in ten periods. We

find that the contribution of capital input is greater than that of labor input in fourteen of the twenty-five periods. The contribution of capital input is greater than the rate of technical change in thirteen of the twenty-five periods. Finally, the contribution of labor input is greater than the rate of technical change in only eleven of the twenty-five periods.

We have allocated the sources of growth in value added among growth in capital and labor inputs and the rate of technical change. We next decompose the rate of growth of capital input between rates of growth of capital stock A and quality of capital stock Q_K. Similarly, we decompose the rate of growth of labor input between rates of growth of hours worked H and quality of labor hours Q_L. Using indexes of the quality of capital stock and hours worked, we can decompose the rate of growth of value added as follows:[11]

$$\begin{aligned} \ln V(T) - \ln V(T-1) &= \bar{v}_K [\ln Q_K(T) - \ln Q_K(T-1)] \\ &+ \bar{v}_K [\ln A(T-1) - \ln A(T-2)] \\ &+ \bar{v}_L [\ln Q_L(T) - \ln Q_L(T-1)] \\ &+ \bar{v}_L [\ln H(T) - \ln H(T-1)] + \bar{v}_T . \end{aligned}$$

The rate of growth of value added is the sum of a weighted average of the rates of growth of capital stock and hours worked, a weighted average of the rates of growth of quality of capital stock and hours worked, and the rate of technical change. In Table 4 we present weighted average of growth of the quality of capital stock and hours worked for the period 1948-1973. We also present weighted rates of growth of capital stock and hours worked for the same period.

We find that the growth of capital quality is an important source of growth of capital input, but that it is dominated by the growth of capital stock. Both components of the growth of capital input have positive rates of growth throughout the period 1948 to 1973. The slowdowns in the growth of capital input in 1950, 1955, 1959, and 1971 were associated with declines in rates of growth of both capital stock and its quality. Growth in the quality of hours worked is an important source of growth of labor input, with positive rates of growth in every year from 1948 to 1973, except for 1961 and 1972. By comparison the growth in hours worked is considerably more erratic with declines in 1949, 1954, 1957-1958, 1961, and 1970. Only the decline in hours worked that took place in 1957 failed to coincide with a decline in labor input. The growth of hours worked exceeded the growth of the quality of hours worked as a source of growth in labor input in seventeen of the twenty-five periods from 1948 to 1973.

Table 4

CONTRIBUTIONS TO GROWTH IN AGGREGATE INPUT AND THE AGGREGATE RATE OF TECHNICAL CHANGE, 1948-1973

YEAR	QUALITY OF CAPITAL STOCK	CAPITAL STOCK	QUALITY OF HOURS WORKED	HOURS WORKED
1949	.0093	.0122	.0004	-.0230
1950	.0058	.0079	.0085	.0161
1951	.0107	.0140	.0077	.0259
1952	.0083	.0115	.0126	.0038
1953	.0041	.0076	.0052	.0062
1954	.0053	.0083	.0032	-.0218
1955	.0038	.0073	.0011	.0183
1956	.0073	.0119	.0042	.0097
1957	.0051	.0097	.0066	-.0060
1958	.0044	.0076	.0033	-.0208
1959	.0013	.0047	.0048	.0175
1960	.0042	.0086	.0140	.0037
1961	.0036	.0078	-.0032	-.0031
1962	.0025	.0063	.0110	.0118
1963	.0043	.0089	.0016	.0056
1964	.0033	.0100	.0060	.0103
1965	.0040	.0110	.0019	.0191
1966	.0073	.0137	.0079	.0186
1967	.0080	.0141	.0047	.0055
1968	.0055	.0111	.0043	.0103
1969	.0055	.0116	.0005	.0156
1970	.0052	.0113	.0067	-.0092
1971	.0029	.0077	.0011	.0004
1972	.0027	.0095	-.0038	.0186
1973	.0051	.0119	.0034	.0239

We have analyzed the sources of growth of aggregate value added in the U.S. economy over the period 1948-1973 on the basis of annual data from the aggregate production account presented in Tables 3 and 4. Next we summarize these data for the period as a whole and for six subperiods — 1948-1953, 1953-1957, 1957-1960, 1960-1966, 1966-1969, and 1969-1973 — in Table 5. The first part of this table provides data from Table 3 on growth in output and inputs. The second part summarizes data from Table 3 on the contributions of capital input, labor input, and the rate of technical change to the growth of output from Table 3. The third part presents decompositions of both the contribution of capital input into components associated with capital quality and capital stock and the contribution of labor input into components associated with labor quality and hours worked. The final part contains a decomposition of the rate of aggregate technical change into components associated with rates of sectoral technical change and the reallocations of value added, capital input, and labor input among sectors.

For the period 1948-1973 aggregate value added grew at 3.85 percent per year, while capital input grew at 4.18 percent per year, indicating that the ratio of capital input to output has risen during the period. By contrast labor input grew at only 1.73 percent per year while the rate of aggregate technical change averaged 1.25 percent per year. The average annual rate of growth of value added reached its maximum at 4.67 percent during the period 1960-1966, grew at an average annual rate of 4.42 percent in 1948-1953, and fell to a minimum of 2.87

Table 5

AGGREGATE OUTPUT, INPUTS, AND PRODUCTIVITY: RATES OF GROWTH, 1948-1973

VARIABLE	(AVERAGE ANNUAL RATES OF GROWTH)						
	1948-1973	1948-1953	1953-1957	1957-1960	1960-1966	1966-1969	1969-1973
VALUE ADDED	.0385	.0442	.0323	.0287	.0467	.0352	.0351
CAPITAL INPUT	.0418	.0522	.0413	.0283	.0371	.0506	.0398
LABOR INPUT	.0173	.0199	.0063	.0120	.0236	.0219	.0161
CONTRIBUTION OF CAPITAL INPUT	.0151	.0183	.0147	.0103	.0138	.0187	.0142
CONTRIBUTION OF LABOR INPUT	.0109	.0127	.0038	.0076	.0146	.0137	.0103
RATE OF TECHNICAL CHANGE	.0125	.0131	.0136	.0107	.0182	.0028	.0107

Table 5 (Concluded)

AGGREGATE OUTPUT, INPUTS, AND PRODUCTIVITY: RATES OF GROWTH, 1948-1973

VARIABLE	1948-1973	(AVERAGE ANNUAL RATES OF GROWTH)					
		1948-1953	1953-1957	1957-1960	1960-1966	1966-1969	1969-1973
CONTRIBUTION OF CAPITAL QUALITY	.0052	.0076	.0054	.0033	.0042	.0063	.0040
CONTRIBUTION OF CAPITAL STOCK	.0098	.0106	.0093	.0070	.0096	.0123	.0101
CONTRIBUTION OF LABOR QUALITY	.0045	.0069	.0038	.0074	.0042	.0032	.0018
CONTRIBUTION OF HOURS WORKED	.0063	.0058	.0001	.0001	.0104	.0105	.0084

percent per year during the period 1957-1960. The average annual rate of growth of capital input reached a maximum of 5.22 percent from 1948-1953, grew at 5.06 percent per year during the period 1966-1969 and fell to a minimum of 2.83 percent per year in 1957-1960. The rate of growth of labor input reached its maximum during the period 1960-1966 at 2.36 percent per year, grew at 2.19 percent per year during the period 1966-1969, and fell to a minimum of .63 percent per year in 1953-1957.

To analyze the sources of U.S. economic growth for the period 1948-1973, we next consider the contributions of capital and labor inputs, and the rate of technical change as sources of growth in value added. For the period as a whole the contribution of capital input averaged 1.51 percent per year, the contribution of labor input averaged 1.09 percent per year, and the rate of technical change averaged 1.25 percent per year. Capital input is the most important source of growth in four of the six subperiods -- 1948-1953, 1953-1957, 1966-1969, and 1969-1973. Technical change is the most important source of growth during the two subperiods 1957-1960 and 1960-1966. Our overall conclusion is that capital input is the most important source of growth in value added, technical change is the next most important, and labor input is the least important. This conclusion is supported by our analysis of growth for the period as a whole, by data for subperiods given in Table 5, and by the annual data presented in Table 3.

In order to analyze the contributions of capital and labor inputs in more detail, we consider data on the contributions of capital stock and its quality and hours worked and their quality for the period as a whole and for the six subperiods presented in Table 5. For the period 1948-1973 the contribution of capital stock accounts for almost two-thirds of the contribution of capital input. This quantitative relationship between capital stock and its quality characterizes most of the period. The average contribution of capital quality reached its maximum at .76 percent per year in 1948-1953, averaged .63 percent per year during the period 1966-1969, fell to a minimum of .33 percent per year in 1957-1960 and averaged .40 percent per year in 1969-1973. The contribution of capital stock reached its maximum at 1.23 percent per year in 1966-1969, averaged 1.06 percent per year during the 1948-1953, and fell to a minimum of .70 percent per year in 1957-1960.

For the period as a whole the contribution of hours worked exceeded the contribution of labor quality. For the first half of the period the contribution of hours worked fell below the contribution of the quality of hours worked. For the last half of the period the contribution of hours worked accounts for almost two-thirds of the contribution of labor input. The average contribution of labor quality reached its maximum at .74 percent per year in 1957-1960 and declined steadily to a minimum of .18 percent per year in 1969-1973. The contribution of hours worked reached its maximum of 1.05 percent per year from 1966-1969, averaged 1.04 percent per year during the period 1960-1966 and only .01 percent per year during the periods 1953-1957 and 1957-1960.

We find it useful to provide additional perspective on our approach to measuring aggregate productivity by comparing our sources and methods with those of other studies of aggregate productivity. Our measure of the quantity of aggregate output is based on quantities of value added in each producing sector. Our measures of the quantities of aggregate primary factor inputs are based on all types of primary factor inputs. Finally, our measure of aggregate productivity is an index number constructed from data on prices and quantities of value added in all sectors, all types of capital input, and all types of labor input. This measure of productivity is based on a model of production and technical change for the economy as a whole with the quantity of value added represented as a function of capital input, labor input, and time.

For the U.S. economy as a whole Christensen and Jorgenson (1969, 1970, 1973a, 1973b) have employed an approach to productivity measurement that is broadly similar to ours. Their study of aggregate productivity covers the period 1929-1969 for the private sector of the U.S. economy. Christensen, Cummings, and Jorgenson (1978, 1980) have extended the estimates of Christensen and Jorgenson through 1973. As in our study, aggregate value added is defined from the producers' point of view, including the value of sales and excise taxes and including the value of subsidies. However, the quantity of value added is measured as an index of deliveries to final demand rather than the sum of quantities of value added over industrial sectors. The quantity of capital input is divided

among categories of the labor force broken down by educational attainment, but not by sex, age, employment class, or occupation.

The empirical results of Christensen, Cummings, and Jorgenson (1980) for the period 1948-1973 are very similar to ours. For this period their estimate of the average rate of growth of value added for the private domestic sector of the U.S. economy is 3.95 percent per year; by comparison our estimate of the rate of growth for the civilian sector of the U.S. economy is 3.85 percent per year. The two estimates are not precisely comparable since Christensen, Cummings, and Jorgenson do not include government sectors in their measure of value added. They estimate the average rate of growth of capital input at 4.16 percent per year for the period 1948-1973; our estimate for this period is 4.18 percent per year. These estimates are for the same sectors of the U.S. economy, since neither set of estimates includes capital input for the government sectors. Christensen, Cummings, and Jorgenson estimate the average rate of growth of labor input at 1.61 percent per year, while our estimate is 1.73 percent per year. Finally their estimate of the average rate of technical change is 1.33 percent per year, while our estimate is 1.25 percent per year. Again, the two estimates for labor input and the rate of technical change are not precisely comparable since we include labor input for the government sectors and they do not.

Christensen, Cummings, and Jorgenson (1979, 1980) have presented estimates of aggregate productivity for Canada, France, Germany, Italy, Japan, Korea, the Netherlands, and the United Kingdom as well as for the United States. Their estimates cover various periods beginning after 1947 and ending in 1973; the estimates cover the period 1960-1973

for all countries. Groes and Bjerregaard (1978) have developed comparable data for Denmark for the period 1950-1972. On the basis of the close correspondence between our results for the U.S. economy as a whole and those of Christensen, Cummings, and Jorgenson, we conclude that it is appropriate to compare our aggregate results with those for the other countries presented in their study.

Denison (1974) has provided estimates of aggregate productivity for the U.S. economy as a whole covering the period 1929-1969. Earlier, Denison (1967) presented comparable estimates at the aggregate level for Belgium, Denmark, France, Germany, the Netherlands, Norway, the United Kingdom, and the United States for the period 1950-1962. Walters (1968, 1970) has given estimates for Canada for the period 1950-1967 and Denison and Chung (1976) have given estimates for Japan for the period 1952-1971 that are closely comparable to Denison's estimates for the United States. A detailed comparison of the results of Christensen and Jorgenson (1969, 1970, 1973a, 1973b) and those of Denison (1967) is given by Jorgenson and Griliches 1972a,.1972b).

For the U.S. economy as a whole Kendrick (1961, 1973) has employed an approach to the measurement of value added through summation over the quantities of value added in all sectors with weights that change periodically. Similarly, his estimates of capital and labor inputs are constructed by summing the corresponding quantities over all sectors with periodcally changing weights. He also presents estimates of capital and labor inputs based on unweighted sums of the quantities for all industrial

sectors. Kendrick employs unweighted sums as a variant of his principal estimates, which are based on weighted sums with weights that depend on property and labor compensation by sector. Christensen and Jorgenson and Denison disaggregate capital and labor inputs for the economy as a whole by categories of capital stock and hours worked, but not by sector.

3. The Contribution of Education

In the previous section we have presented a production account for the U.S. economy as a whole, including measures of aggregate value added, capital input, and labor input. We have utilized these data to allocate the growth of aggregate output among the rate of technical change and the contributions of capital and labor inputs. In this section we analyze the growth of labor input in greater detail in order to identify the contribution of education to U.S. economic growth. We assume that aggregate labor input can be expressed as a translog function of individual types of labor inputs, cross-classified by sex, age, education, employment status, and occupation. A measure of aggregate labor input can be constructed as a translog quantity index number.

For each of the components of labor input the flow of labor services is proportional to hours worked. Defining aggregate hours worked as an unweighted sum of its components, we can define the aggregate index of the quality of hours worked as an index that transforms aggregate hours worked into the translog index of aggregate labor input. This quality index reflects changes in the composition of aggregate hours worked by sex, age, education, employment status, and occupation. To analyze the sources of quality change in aggregate labor input, we introduce partial indexes of labor input, adding hours worked and the share of labor compensation over some characteristics of the labor force and constructing a translog index over the remaining characteristics.[12]

To analyze the sources of changes in the quality of aggregate labor input we introduce the contributions of each characteristic of labor input as the difference between the rate of growth of the corresponding partial index of labor input and the rate of growth of aggregate hours worked. For example, the contribution of education to the quality of aggregate labor input is defined as the difference between the rate of growth of a partial index of labor input constructed by adding hours worked and the share of labor compensation over all other characteristics of the labor force -- sex, age, employment status, and occupation -- and constructing a translog index over educational groupings.

In this section we begin by outlining the generation of data on labor input. To disaggregate labor input into components that differ in marginal productivity we measure wages along with hours worked for labor input broken down by characteristics of individual workers. A novel feature of our data on labor input is that we utilize data from both establishment and household surveys. We have controlled estimates of employment, hours worked, and labor compensation to totals based on establishment surveys from the U.S. national income accounts. On the basis of household surveys we have allocated these totals among categories of the work force cross-classified by characteristics of individual workers. The resulting estimates of hours worked and average compensation per hour provide the basis for our price and quantity indexes of labor input. Our data on labor input are cross-classified by the two sexes, eight age groups, five educational groups, two employment classes and ten occupational groups given in Table 6.[13]

Table 6

CHARACTERISTICS OF LABOR INPUT

SEX:

(1) Male

(2) Female

AGE:

(1) 14-15 years

(2) 16-17 years

(3) 18-24 years

(4) 25-34 years

(5) 35-44 years

(6) 45-54 years

(7) 55-64 years

(8) 65 years and over

EDUCATION:

(1) 1-8 years grade school

(2) 1-3 years high school

(3) 4 years high school

(4) 1-3 years college

(5) 4 or more years college

EMPLOYMENT CLASS:

(1) Wage and Salary Worker

(2) Self-Employed/Unpaid Family Worker

OCCUPATION:

(1) Professional, Technical, and Kindred Workers

(2) Farmers and Farm Managers

(3) Managers and Administrators, except Farm

(4) Clerical Workers

(5) Sales Workers

(6) Craftsmen and Kindred Workers

(7) Operatives

(8) Service Workers, including Private Household

(9) Farm Laborers

(10) Laborers, except Farm

Our first step in developing measures of labor input is to construct employment matrices cross-classified by sex, age, education, employment status, and occupation for each year on the basis of household surveys from the last three decennial Censuses of Population and the Current Population Survey. The resulting employment matrices are controlled to employment totals on the basis of establishment surveys from the U.S. national income and product accounts. Establishment surveys provide an enumeration of jobs rather than persons at work, while household surveys count only persons actually at work during the survey week. By using establishment-based estimates of the number of jobs and assigning to absent workers the average annual hours worked by individuals with comparable characteristics, we are able to estimate hours worked for each type of worker on an annual basis.

We estimate hours worked by workers cross-classified by demographic characteristics on the basis of household surveys. We adjust the resulting estimates to control totals from the U.S. national accounts. We define hours worked for each category of labor input as the product of employment, hours worked per week, and the number of weeks in the calendar year, fifty-two. Our measure of the quantity of labor input is hours worked for each cell of a matrix cross-classified by the characteristics of individual workers. The concepts employed in our estimates of labor input reflect the conventions used in the most recent Census of Population and in the Current Population Survey.

Our third step in developing measures of labor input is to construct labor compensation matrices for each year on the basis of the last three decennial Censuses of Population. The data provide estimates of average compensation per person rather than average compensation per job. To combine these data with estimates of the number of jobs from establishment surveys we first convert average compensation per person to average compensation per job. For this purpose we generate matrices of weeks paid per year for each category of workers. The average number of weeks paid per year, divided by fifty-two, provides an estimate of the number of jobs per person in each category. Labor compensation is the product of average compensation per person, the number of jobs per person, and the number of jobs. Estimates of average compensation per person and the number of weeks paid per year are based on household surveys, while estimates of the number of jobs are based on establishment surveys. Control totals for annual labor compensation are taken directly from the U.S. national income accounts.

To estimate average hourly compensation per person for employees we begin with data on wage and salary income from the last three decennial Censuses of Population. Differences in outlay on labor input per person reflect differences in marginal products among workers. However, the cost of labor input from the point of view of the producer also includes supplements, so that differences in wage and salary income must be adjusted to incorporate employers' contributions to social security and unemployment compensation and other supplements to wages

and salaries. The Census also provides data on total income and earnings. Total income includes property income and transfer payments; earnings include both property and labor income from self-employment.

Earnings reported by the Census for self-employed workers and income of unincorporated enterprises from the U.S. national income accounts include both labor and property income. We have divided income from unincorporated enterprises between labor and property components, assuming that after tax rates of return are the same for corporate and noncorporate business. Labor compensation is distributed among the self-employed on the basis of wage differentials among employees. To derive labor compensation per hour worked for each category of labor input, we divide total labor compensation by annual hours worked for each category. Average labor compensation per hour provides a measure of the price of labor input for each cell of a matrix cross-classified by the characteristics of individual workers.

Our final step in constructing data on labor input is to combine price and quantity data, cross-classified by sex, age, education, employment class, and occupation into price and quantity indexes of labor input. A novel feature of our approach is that we employ a translog quantity index of labor input. The change in the logarithms of labor input from period to period is a weighted average of changes in the logarithms of hours worked for the components of labor input. The weights are given by the average shares of each component in labor compensation for the two periods. We also derive a measure of total hours worked by adding hours worked across all categories of labor input. We define the

quality of hours worked as the ratio of labor input to hours worked. Changes in the quality of hours worked represent the differences between changes in an index of labor input with hours worked weighted by average labor compensation and changes in an unweighted index.

To construct an index of aggregate labor input we assume that aggregate labor input, say L(T), can be expressed as a translog function of its individual components, so that the translog quantity indes of aggregate labor input takes the form:

$$\ln L(T) - \ln L(T-1) = \Sigma \bar{v}_{L\ell}\left[\ln L_\ell(T) - \ln L_\ell(T-1)\right] ,$$

where weights are given by the average shares of the individual components in the value of aggregate labor compensation:

$$\bar{v}_{L\ell} = \frac{1}{2}\left[v_{L\ell}(T) + v_{L\ell}(T-1)\right] , \qquad (\ell = 1, 2 \ldots q),$$

and:

$$v_{L\,\ell} = \frac{p_{L\ell}L_\ell}{\Sigma p_{L\ell}L_\ell} , \qquad (\ell = 1, 2 \ldots q).$$

The value shares are computed from data on hours worked $\{L_\ell\}$ and compensation per hour $\{p_{L\ell}\}$ for each component of aggregate labor input, cross-classified by sex, age, education, employment class, and occupation of workers.

In quantifying the effect of changes in the composition of hours worked we begin with the recognition that the relationship between labor services and hours worked is not the same for all categories of labor input. For each of the components of aggregate labor input $\{L_\ell(T)\}$ the flow of labor services is proportional to hours worked, say $\{H_\ell(T)\}$:

$$L_\ell(T) = Q_{L\ell} \cdot H_\ell(T) , \qquad (\ell = 1, 2 \ldots q),$$

where the constants of proportionality $\{Q_L\}$ transform hours worked into flows of labor services. Each of the scalars $\{Q_{L\ell}\}$ is specific to a given category of labor input but is independent of time. It necessarily follows that the translog quantity index of aggregate labor input can be expressed either in terms of its components $\{L_\ell\}$ or in terms of the components of hours worked $\{L_\ell\}$ or in terms of the components of hours worked $\{H_\ell\}$:

$$\ln L(T) - \ln L(T-1) = \Sigma \bar{v}_{L\ell}\left[\ln L_\ell(T) - \ln L_\ell(T-1)\right] ,$$

$$= \Sigma \bar{v}_{L\ell}\left[\ln H_\ell(T) - \ln H_\ell(T-1)\right] .$$

We form the aggregate index of labor input from data on hours worked by workers cross-classified by sex, age, education, employment class, and occupation. Changes in the logarithms of hours worked for each component are weighted by average shares in the value of aggregate labor compensation.

The relation between aggregate labor input and aggregate hours worked is a function of the changing composition of aggregate hours worked. More precisely, it depends on the factor of proportionality that transforms aggregate hours worked into aggregate labor input. We can define aggregate hours worked, say H(T), as the unweighted sum of its components,

$$H(T) = \Sigma H_{\ell}(T) .$$

We can then define the aggregate index of the quality of hours worked, say $Q_L(T)$, as an index that transforms aggregate hours worked into the translog index of labor input:

$$L(T) = Q_L(T) \cdot H(T).$$

It follows that the growth rate of the aggregate index of the quality of hours worked can be expressed in the form:

$$\ln Q_L(T) - \ln Q_L(T-1) = \Sigma \bar{v}_{L\ell} \left[\ln H_{\ell}(T) - \ln H_{\ell}(T-1)\right] - \left[\ln H(T) - \ln H(T-1)\right] .$$

The quality index reflects changes in the composition of aggregate hours worked by workers classified by sex, age, education, employment class, and occupation.

The aggregate index of labor input, the corresponding price index, and the index of the quality of hours worked are presented for the period 1948-1973 in Table 7. Annual data for employment, weekly hours per person, hourly compensation, and total labor compensation and hours worked are also reported. The important conclusion to be derived from Table 7 is that forty-three percent of the average annual rate of growth of labor input is accounted for by a shift in the composition of hours worked. The remaining growth in labor input is due to growth in unweighted annual hours reported in the last column of Table 7. Labor input increases at an average rate equal to 1.73 percent per year. The aggregate quality and unweighted hours indexes increase at average annual rates equal to .74 and .99 percents, respectively.

Our next objective is to analyze the effects of changes in the composition of total hours worked For this purpose we consider the components of hours worked, say $\{H_{saecoi}(T)\}$, cross-classified by sex, age, education, employment class, occupation, and industry. Previously, we have used a single subscript ℓ to represent categories of labor input cross-classified by all characteristics except for industry. The subscript has represented 1600 categories of labor input. In our new notation labor input is cross-classified by two sexes represented by the subscript s, eight age groups represented by a, five education classes represented by e, two employment classes represented by c, ten occupational groups represented by o, and fifty-one industry groups represented by i. Similarly, we consider the shares of the components of labor input in the value of labor compensation for the economy as a whole, say $v_{saecoi}(T)$, cross-classified by sex, age, education, employment class, occupation and industry.

TABLE 7

AGGREGATE LABOR INPUT

YEAR	LABOR INPUT				EMPLOYMENT	WEEKLY HOURS PER PERSON	HOURLY COMPENSATION	HOURS WORKED
	PRICE	QUANTITY	OUTLAY	QUALITY				
1948	.330	531.760	175.676	.839	61639	39.3	1.39	126132
1949	.330	513.668	169.354	.840	60145	38.9	1.39	121752
1950	.346	533.910	184.967	.850	61688	38.9	1.48	124977
1951	.392	562.669	220.288	.861	64278	38.9	1.69	130137
1952	.402	577.204	232.060	.878	64981	38.7	1.77	130888
1953	.418	587.404	245.519	.885	65982	38.5	1.86	132154
1954	.427	570.791	243.599	.890	64533	38.0	1.91	127715
1955	.440	588.601	259.246	.892	66178	38.1	1.97	131392
1956	.468	601.721	281.856	.897	67730	37.9	2.11	133555
1957	.492	602.283	296.058	.907	67880	37.4	2.24	132181
1958	.511	586.070	299.483	.911	66416	37.0	2.34	128028
1959	.522	607.191	317.024	.918	68028	37.2	2.41	131678
1960	.533	624.684	333.009	.940	68742	37.0	2.52	132325
1961	.557	618.309	344.329	.935	68823	36.7	2.61	131684
1962	.572	641.354	367.153	.951	70127	36.8	2.74	134198
1963	.594	648.869	385.582	.954	70830	36.7	2.85	135415
1964	.617	666.053	411.233	.963	72332	36.5	2.99	137660
1965	.644	689.197	444.015	.966	74617	36.5	3.15	141988
1966	.683	719.392	491.534	.979	77717	36.2	3.36	146317
1967	.713	731.399	521.153	.986	79098	35.8	3.53	147633
1968	.767	748.674	574.124	.993	81010	35.6	3.83	150090
1969	.822	768.102	631.543	.994	83247	35.5	4.11	153844
1970	.876	765.146	670.183	1.004	83245	35.0	4.42	151636
1971	.931	767.025	714.139	1.006	83510	34.9	4.71	151767
1972	1.000	784.888	784.888	1.000	85885	34.9	5.02	156246
1973	1.086	819.269	889.484	1.005	89310	34.9	5.48	162217

Our analysis begins with the construction of "partial" indexes of labor input. We can define a partial index of labor input by adding hours worked and value shares over some characteristics of the labor force and constructing a translog index over the remaining characteristics. More specifically, we can define a <u>first-order index of labor input</u> corresponding to each characteristic of labor input by adding hours worked and value shares over all other characteristics of labor input and constructing a translog index over the single characteristic of interest. Since there are six characteristics of labor input --sex, age, education, employment class, occupation, and industry -- there are six first-order indexes of labor input. For example, the first-order index of labor input corresponding to sex, say L_s, can have its growth rate expressed in the form:

$$\Delta \ln L_s = \sum_s \bar{v}_s \Delta \ln H_s ,$$

$$= \sum_s \bar{v}_s \Delta \ln \sum_a \sum_e \sum_c \sum_o \sum_i H_{saecoi} ,$$

where:

$$\bar{v}_s = \frac{1}{2}\left[v_s(T) + v_s(T-1) \right] ,$$

$$v_s = \sum_a \sum_e \sum_c \sum_o \sum_i v_{saecoi} ,$$

and the Δ notation signifies first differences in the associated variable, for example:

$$\Delta \ln L_s = \ln L_s(T) - \ln L_s(T-1) .$$

The resulting first-order index corresponds to sex, but not to age, education, employment class, occupation, or industry.

We can define a second-order index of labor input corresponding to any two characteristics of labor input by adding hours worked and value shares over other characteristics and constructing a translog index. The second-order index corresponding to sex and age, for example, reflects changes in the composition of aggregate hours worked by sex and age, but not by education, employment class, occupation, or industry. There are fifteen second-order indexes of labor input generated by combinations of two of the six characteristics of labor input. All second-order indexes are defined in Table 8 together with the six first-order indexes.

Similarly, we can define third-, fourth-, fifth-, and sixth-order indexes of labor input corresponding to any three, four, five, or to all six characteristics of labor input. Continuing our example, the third-order index corresponding to sex, age, and education reflects changes in the composition of aggregate hours worked by these characteristics, but not by employment class, occupation, and industry. The fourth-order index corresponding to sex, age, education, and class of employment, reflects changes in the composition of aggregate hours worked by these four characteristics. Each fifth-order index captures compositional changes among all but the excluded characteristic. The twenty

third-order, fifteen fourth-order, and six fifth-order indexes are defined in Table 8 as is the single sixth-order index which reflects compositional shifts among all characteristics of labor input.

Special attention must be focused on the fifth-order index of labor input corresponding to all characteristics of labor input except industry. This index corresponds to the index of aggregate labor input L(T) defined above. Recall that the growth rate of the index can be expressed in terms of the components of hours worked $\{H_\ell\}$:

$$\ln L(T) - \ln L(T-1) = \Sigma \bar{v}_{L\ell} \left[\ln H_\ell(T) - \ln H_\ell(T-1)\right] .$$

In terms of our new notation, this expression has the equivalent form:

$$\Delta \ln L = \sum_s \sum_a \sum_e \sum_c \sum_o \bar{v}_{saeco} \Delta \ln H_{saeco} ,$$

$$= \sum_s \sum_a \sum_e \sum_c \sum_o \bar{v}_{saeco} \Delta \ln \sum_i H_{saecoi} .$$

To construct this index we add hours worked over industries to obtain hours worked cross-classified by all characteristics except industry. Similarly, we add value shares over industries, obtaining:

$$v_L = v_{saeco} = \sum_i v_{saecoi} .$$

This index must be contrasted with the sixth-order index of labor input corresponding to all six characteristics of labor input. This latter index reflects changes in the composition of labor input by industry as well as the five remaining characteristics.

TABLE 8

PARTIAL INDEXES OF LABOR INPUT

HOURS WORKED (ONE INDEX):

$$\Delta \ell n\, H = \Delta \ell n \sum_{s}\sum_{a}\sum_{e}\sum_{c}\sum_{o}\sum_{i} H_{saecoi}.$$

FIRST-ORDER (SIX INDEXES):

$$\Delta \ell n\, L_s = \sum_{s} \bar{v}_s\, \Delta \ell n\, H_s,$$

$$= \sum_{s} \bar{v}_s\, \Delta \ell n \sum_{a}\sum_{e}\sum_{c}\sum_{o}\sum_{i} H_{saecoi}.$$

SECOND-ORDER (FIFTEEN INDEXES):

$$\Delta \ell n\, L_{sa} = \sum_{s}\sum_{a} \bar{v}_{sa}\, \Delta \ell n\, H_{sa},$$

$$= \sum_{s}\sum_{a} \bar{v}_{sa}\, \Delta \ell n \sum_{e}\sum_{c}\sum_{o}\sum_{i} H_{saecoi}.$$

THIRD-ORDER (TWENTY INDEXES):

$$\Delta \ell n\, L_{sae} = \sum_{s}\sum_{a}\sum_{e} \bar{v}_{sae}\, \Delta \ell n\, H_{sae},$$

$$= \sum_{s}\sum_{a}\sum_{e} \bar{v}_{sae}\, \Delta \ell n \sum_{c}\sum_{o}\sum_{i} H_{saecoi}.$$

FOURTH-ORDER (FIFTEEN INDEXES):

$$\Delta \ell n\, L_{saec} = \sum_{s}\sum_{a}\sum_{e}\sum_{c} \bar{v}_{saec}\, \Delta \ell n\, H_{saec},$$

$$= \sum_{s}\sum_{a}\sum_{e}\sum_{c} \bar{v}_{saec}\, \Delta \ell n \sum_{o}\sum_{i} H_{saecoi}.$$

FIFTH-ORDER (SIX INDEXES):

$$\Delta \ell n\, L_{saeco} = \sum_{s}\sum_{a}\sum_{e}\sum_{c}\sum_{o} \bar{v}_{saeco}\, \Delta \ell n\, H_{saeco},$$

$$= \sum_{s}\sum_{a}\sum_{e}\sum_{c}\sum_{o} \bar{v}_{saeco}\, \Delta \ell n \sum_{i} H_{saecoi}.$$

SIXTH-ORDER (ONE INDEX):

$$\Delta \ell n\, L_{saecoi} = \sum_{s}\sum_{a}\sum_{e}\sum_{c}\sum_{o}\sum_{i} \bar{v}_{saecoi}\, \Delta \ell n\, H_{saecoi}.$$

To complete the set of partial indexes of labor input we add hours worked over all characteristics of the labor force to obtain an index of aggregate hours worked. This index does not reflect any change in the composition of labor input. The single index of aggregate hours worked is defined in Table 8 . There is a total of sixty-four partial indexes of labor input, corresponding to the six characteristics of the labor force. We present these sixty-four partial indexes of labor input annually for the period 1948-1973 in Table 9. These indexes form the basis for our analysis of the effects of the changes in the postwar composition of aggregate hours worked.

Our next objective is to identify the contributions of the changing sex, age, education, employment class, occupation, and industry composition of total hours worked to aggregate economic growth. For this purpose, we first define an index of total labor quality that captures the effect of all changes in the composition of hours worked. This index is defined in terms of the aggregate hours worked and sixth-order partial indexes described in the preceding section. The rate of growth of the index of total labor quality is defined as the difference between the rate of growth of the sixth-order partial index of labor input and the rate of growth of aggregate hours worked. To analyze the effects of changes in the quality of hours worked, we can decompose the index of total labor quality into components corresponding to the contributions of changes in the composition of labor input.

Table 9

TRANSLOG INDEXES OF LABOR INPUT

YEAR	HOURS	S	C	A	E	O	I	SC
1948	.807	.844	.776	.816	.692	.757	.751	.805
1949	.779	.813	.748	.791	.670	.712	.725	.773
1950	.799	.834	.772	.820	.692	.739	.747	.798
1951	.832	.866	.807	.850	.720	.774	.793	.833
1952	.837	.870	.813	.860	.729	.787	.804	.838
1953	.845	.878	.822	.870	.739	.795	.814	.848
1954	.817	.847	.794	.843	.719	.768	.781	.816
1955	.841	.868	.820	.867	.742	.792	.807	.840
1956	.854	.880	.836	.886	.758	.810	.826	.855
1957	.846	.869	.829	.872	.756	.807	.822	.846
1958	.819	.839	.803	.845	.739	.785	.790	.817
1959	.842	.862	.829	.869	.763	.810	.817	.843
1960	.847	.872	.832	.879	.771	.819	.821	.855
1961	.842	.857	.828	.864	.776	.812	.818	.840
1962	.858	.873	.846	.881	.802	.832	.838	.859
1963	.866	.880	.856	.888	.808	.841	.850	.868
1964	.881	.893	.872	.900	.829	.860	.867	.883
1965	.908	.920	.901	.925	.859	.888	.898	.912
1966	.936	.946	.932	.951	.893	.928	.935	.941
1967	.944	.953	.941	.959	.906	.939	.947	.949
1968	.960	.966	.958	.973	.929	.959	.965	.964
1969	.984	.987	.983	.993	.957	.985	.990	.986
1970	.970	.977	.969	.993	.948	.971	.973	.976
1971	.971	.973	.970	.976	.963	.979	.971	.971
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.038	1.037	1.039	1.033	1.048	1.042	1.039	1.038
AVERAGE - ANNUAL RATE OF GROWTH	.0101	.0082	.0116	.0094	.0166	.0138	.0130	.0102

Table 9 (Continued)

TRANSLOG INDEXES OF LABOR INPUT

YEAR	SA	SE	SO	SI	CA	CE	CO	CI
1948	.650	.712	.753	.770	.778	.669	.714	.747
1949	.820	.688	.726	.740	.752	.647	.689	.719
1950	.850	.709	.751	.763	.785	.671	.714	.743
1951	.879	.737	.786	.808	.818	.701	.752	.789
1952	.889	.746	.798	.818	.830	.711	.765	.801
1953	.898	.757	.808	.828	.841	.722	.774	.810
1954	.869	.735	.781	.795	.815	.701	.747	.778
1955	.890	.756	.803	.819	.841	.726	.772	.804
1956	.900	.771	.821	.837	.856	.743	.790	.823
1957	.890	.768	.818	.832	.851	.743	.788	.819
1958	.860	.749	.794	.800	.825	.726	.766	.787
1959	.882	.773	.819	.826	.851	.751	.794	.814
1960	.900	.789	.837	.841	.863	.761	.805	.819
1961	.870	.785	.822	.827	.849	.766	.798	.815
1962	.893	.812	.843	.848	.868	.793	.821	.836
1963	.899	.817	.850	.859	.878	.801	.831	.848
1964	.910	.838	.869	.876	.892	.824	.852	.866
1965	.934	.868	.896	.906	.918	.855	.881	.898
1966	.960	.901	.934	.941	.947	.891	.923	.935
1967	.967	.913	.946	.953	.957	.905	.936	.948
1968	.980	.933	.965	.968	.972	.928	.957	.965
1969	.997	.960	.989	.991	.993	.957	.984	.990
1970	.999	.953	.978	.978	.992	.948	.969	.973
1971	.978	.965	.981	.972	.975	.962	.979	.971
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.032	1.048	1.039	1.038	1.033	1.048	1.043	1.039
*AVERAGE ANNUAL RATE OF GROWTH	.0078	.0154	.0129	.0119	.0114	.0180	.0152	.0132

Table 9 (Continued)

TRANSLOG INDEXES OF LABOR INPUT

YEAR	AE	AO	AI	FO	FI	OI	SCA	SCE
1948	.697	.744	.755	.648	.685	.736	.807	.685
1949	.678	.720	.728	.657	.660	.709	.777	.661
1950	.705	.753	.759	.682	.685	.736	.810	.684
1951	.732	.786	.803	.715	.726	.779	.843	.715
1952	.747	.808	.819	.728	.739	.793	.855	.725
1953	.759	.814	.830	.737	.749	.802	.866	.736
1954	.741	.789	.800	.714	.722	.769	.836	.714
1955	.764	.812	.826	.737	.746	.795	.860	.737
1956	.779	.829	.844	.755	.765	.811	.873	.753
1957	.778	.827	.840	.754	.764	.808	.866	.752
1958	.761	.804	.809	.734	.739	.780	.836	.733
1959	.786	.829	.836	.760	.765	.808	.861	.759
1960	.800	.843	.846	.770	.774	.819	.882	.777
1961	.798	.831	.837	.771	.776	.809	.859	.773
1962	.825	.851	.858	.798	.804	.833	.878	.802
1963	.831	.860	.869	.805	.811	.841	.887	.809
1964	.851	.877	.884	.829	.833	.860	.900	.832
1965	.879	.903	.913	.859	.865	.889	.926	.863
1966	.910	.938	.947	.900	.905	.933	.956	.899
1967	.923	.950	.959	.912	.919	.946	.965	.912
1968	.944	.969	.976	.935	.941	.966	.978	.932
1969	.969	.993	.998	.965	.968	.991	.997	.959
1970	.967	.987	.991	.952	.954	.972	.999	.953
1971	.971	.983	.976	.970	.964	.982	.977	.963
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.043	1.037	1.034	1.050	1.048	1.042	1.033	1.048
AVERAGE ANNUAL RATE OF GROWTH	.0161	.0133	.0126	.0173	.0170	.0139	.0099	.0170

Table 9 (Continued)

TRANSLOG INDEXES OF LABOR INPUT

YEAR	SCO	SCI	SAE	SAO	SAI	SEO	SFI	SOI
1948	.729	.763	.717	.761	.776	.694	.694	.749
1949	.703	.733	.695	.736	.748	.670	.668	.721
1950	.725	.757	.722	.767	.777	.693	.692	.746
1951	.764	.802	.749	.800	.821	.726	.731	.789
1952	.777	.812	.763	.817	.836	.739	.744	.802
1953	.787	.822	.776	.828	.848	.750	.756	.812
1954	.759	.790	.756	.803	.816	.726	.728	.779
1955	.783	.814	.777	.820	.839	.748	.752	.802
1956	.801	.832	.790	.839	.856	.766	.771	.820
1957	.799	.827	.788	.837	.851	.765	.770	.816
1958	.775	.794	.769	.813	.819	.744	.744	.787
1959	.803	.822	.792	.836	.845	.769	.771	.815
1960	.822	.837	.813	.859	.864	.787	.788	.831
1961	.808	.822	.804	.841	.845	.781	.782	.817
1962	.832	.845	.831	.861	.867	.809	.811	.841
1963	.840	.856	.837	.869	.878	.816	.818	.849
1964	.860	.873	.857	.885	.892	.838	.839	.867
1965	.889	.904	.884	.910	.920	.868	.871	.896
1966	.930	.940	.916	.944	.953	.907	.910	.937
1967	.943	.952	.929	.957	.966	.920	.924	.951
1968	.963	.966	.949	.975	.980	.942	.944	.970
1969	.987	.990	.973	.996	1.000	.969	.970	.993
1970	.976	.978	.972	.995	.997	.960	.958	.977
1971	.981	.972	.972	.985	.978	.972	.965	.983
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.041	1.038	1.043	1.035	1.033	1.047	1.047	1.040
AVERAGE ANNUAL RATE OF GROWTH	.0142	.0123	.0150	.0123	.0114	.0164	.0164	.0131

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Table 9 (Continued)

TRANSLOG INDEXES OF LABOR INPUT

YEAR	CAE	CAO	CAI	CLO	CLI	COI	AEO	AEI
1948	.665	.720	.748	.663	.680	.724	.685	.681
1949	.646	.696	.722	.640	.655	.697	.661	.659
1950	.676	.727	.752	.662	.680	.722	.691	.688
1951	.706	.764	.798	.699	.721	.767	.724	.728
1952	.722	.782	.814	.712	.734	.781	.742	.747
1953	.735	.792	.826	.722	.745	.790	.753	.759
1954	.717	.768	.796	.698	.718	.758	.732	.738
1955	.742	.792	.822	.723	.742	.782	.755	.759
1956	.759	.809	.839	.741	.761	.800	.773	.778
1957	.760	.808	.836	.740	.760	.796	.773	.777
1958	.744	.785	.804	.721	.734	.769	.753	.753
1959	.770	.814	.832	.749	.761	.798	.779	.780
1960	.786	.829	.845	.761	.771	.810	.793	.795
1961	.785	.818	.833	.762	.772	.801	.790	.792
1962	.814	.841	.855	.791	.801	.826	.817	.821
1963	.822	.851	.867	.799	.809	.835	.825	.829
1964	.844	.870	.883	.824	.831	.856	.847	.849
1965	.873	.896	.912	.855	.864	.885	.876	.880
1966	.907	.935	.947	.898	.904	.931	.912	.917
1967	.922	.947	.960	.911	.919	.944	.925	.932
1968	.943	.968	.976	.935	.941	.965	.947	.953
1969	.969	.992	.998	.965	.968	.990	.974	.978
1970	.968	.985	.991	.952	.954	.971	.967	.970
1971	.970	.984	.976	.970	.964	.982	.975	.971
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.044	1.038	1.034	1.051	1.049	1.043	1.045	1.044
AVERAGE ANNUAL RATE OF GROWTH	.0180	.0147	.0129	.0184	.0173	.0146	.0170	.0171

Table 9 (Continued)

TRANSLOG INDEXES OF LABOR INPUT

YEAR	ADI	EDI	SCAE	SCAI	SCAI	SCEI	SCEI	SCDI
1948	.738	.688	.681	.736	.767	.676	.687	.736
1949	.712	.663	.659	.711	.738	.652	.661	.709
1950	.744	.688	.684	.739	.768	.673	.685	.732
1951	.786	.729	.719	.777	.813	.709	.725	.776
1952	.804	.744	.735	.794	.829	.723	.738	.790
1953	.815	.754	.749	.806	.840	.734	.750	.800
1954	.784	.724	.729	.781	.809	.710	.723	.767
1955	.808	.749	.751	.803	.833	.733	.747	.790
1956	.824	.766	.767	.819	.850	.751	.765	.807
1957	.822	.765	.767	.818	.845	.751	.764	.804
1958	.794	.739	.748	.793	.812	.731	.738	.776
1959	.822	.768	.775	.820	.839	.758	.766	.804
1960	.836	.779	.797	.843	.860	.777	.785	.822
1961	.824	.771	.788	.826	.840	.771	.777	.808
1962	.847	.806	.818	.850	.863	.801	.807	.833
1963	.856	.813	.827	.859	.874	.809	.815	.842
1964	.874	.835	.848	.877	.889	.833	.837	.862
1965	.900	.866	.878	.903	.917	.864	.869	.891
1966	.941	.910	.913	.941	.952	.905	.908	.934
1967	.955	.924	.927	.955	.965	.919	.923	.949
1968	.975	.946	.948	.974	.980	.942	.945	.969
1969	.997	.973	.972	.995	1.000	.969	.969	.992
1970	.985	.957	.972	.993	.997	.959	.959	.976
1971	.985	.973	.971	.985	.978	.972	.965	.983
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.038	1.048	1.043	1.036	1.033	1.048	1.047	1.041
AVERAGE ANNUAL RATE OF GROWTH	.0136	.0169	.0170	.0137	.0119	.0175	.0169	.0138

Table 9 (Continued)

TRANSLOG INDEXES OF LABOR INPUT

YEAR	SALO	SALI	SAUI	SEUI	CAEO	CAEI	CAUI	CEUI
1948	.698	.693	.753	.699	.662	.672	.725	.678
1949	.674	.669	.726	.672	.641	.649	.700	.653
1950	.703	.697	.757	.696	.669	.679	.730	.677
1951	.735	.737	.798	.737	.705	.719	.774	.719
1952	.753	.755	.816	.752	.724	.739	.792	.734
1953	.766	.768	.827	.762	.736	.751	.803	.744
1954	.745	.743	.796	.733	.715	.727	.772	.715
1955	.766	.766	.818	.757	.740	.752	.796	.739
1956	.783	.784	.834	.774	.757	.770	.813	.757
1957	.783	.783	.831	.773	.757	.770	.810	.755
1958	.762	.758	.802	.747	.738	.745	.783	.730
1959	.786	.784	.829	.774	.767	.773	.812	.760
1960	.808	.804	.849	.791	.782	.787	.827	.772
1961	.798	.796	.832	.784	.780	.786	.816	.770
1962	.825	.825	.856	.813	.809	.816	.840	.801
1963	.833	.834	.864	.820	.818	.825	.851	.809
1964	.854	.854	.881	.842	.841	.846	.869	.832
1965	.883	.884	.907	.672	.871	.877	.897	.865
1966	.918	.921	.946	.915	.911	.916	.939	.909
1967	.932	.937	.961	.929	.924	.932	.954	.923
1968	.953	.956	.979	.950	.948	.953	.974	.946
1969	.978	.980	1.000	.976	.974	.978	.996	.973
1970	.975	.974	.991	.961	.967	.970	.984	.956
1971	.976	.972	.987	.974	.975	.970	.986	.974
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.043	1.043	1.036	1.046	1.046	1.044	1.039	1.049
AVERAGE ANNUAL RATE OF GROWTH	.0161	.0163	.0128	.0162	.0183	.0176	.0144	.0175

Table 9 (Concluded)

TRANSLOG INDEXES OF LABOR INPUT

YEAR	AEOI	SCAEO	SCAEI	SCAOI	SCEOI	SAEOI	CAEOI	SCAEOI
1948	.685	.677	.682	.739	.688	.697	.674	.685
1949	.662	.654	.658	.713	.662	.672	.650	.661
1950	.691	.680	.686	.742	.684	.701	.678	.687
1951	.733	.716	.727	.785	.727	.741	.721	.730
1952	.752	.735	.745	.803	.741	.760	.741	.749
1953	.768	.748	.759	.814	.752	.773	.753	.761
1954	.737	.727	.734	.783	.725	.746	.726	.734
1955	.761	.750	.758	.806	.747	.769	.750	.758
1956	.778	.766	.775	.821	.764	.786	.767	.774
1957	.777	.767	.775	.816	.762	.785	.766	.774
1958	.752	.746	.749	.790	.737	.759	.742	.748
1959	.791	.773	.776	.818	.766	.786	.772	.777
1960	.795	.795	.797	.839	.784	.806	.786	.797
1961	.791	.787	.789	.823	.777	.797	.783	.789
1962	.820	.817	.819	.848	.808	.826	.813	.819
1963	.828	.826	.829	.858	.815	.834	.823	.829
1964	.849	.848	.850	.875	.838	.855	.845	.850
1965	.878	.878	.881	.902	.869	.884	.875	.880
1966	.920	.916	.919	.943	.913	.923	.918	.921
1967	.934	.931	.936	.959	.928	.939	.933	.938
1968	.956	.953	.956	.978	.950	.960	.955	.959
1969	.980	.978	.980	.999	.975	.985	.980	.983
1970	.969	.974	.974	.990	.961	.974	.968	.974
1971	.978	.977	.972	.987	.975	.979	.978	.979
1972	1.000	1.000	1.000	1.000	1.060	1.000	1.000	1.000
1973	1.045	1.043	1.043	1.037	1.047	1.043	1.045	1.043
AVERAGE ANNUAL RATE OF GROWTH	.0169	.0173	.0170	.0135	.0168	.0161	.0176	.0168

The index of total labor quality must not be confused with the aggregate index of labor quality introduced in Section 2 above. The latter incorporates the effects of changes in the composition of labor input among all characteristics except industry. This is consistent with the requirements of our aggregate model of production and technical change. The index of total labor quality incorporates the effects of changes in the distribution of hours worked across all six labor characteristics. This index is the sum of the effects captured in the aggregate index of labor quality and the mutually exclusive term measuring the effect of reallocation among industries. Since our present objective is to identify all labor related source characteristics contributing to economic growth, the appropriate index is the total quality index. It is this index we decompose into its components.

The partial indexes of labor input derived in the last section and reported in Table 9 are instrumental in identifying the first- and higher-order contributions of the six characteristics of labor input. We can define the first-order contribution of each characteristic of labor input to the rate of growth of total labor quality as the difference between the rate of growth of the corresponding partial index of labor input and the rate of growth of aggregate hours worked. For example, the first-order contribution of sex to the rate of growth of labor quality, say Q_{Ls}, takes the form:

$$\Delta \ln Q_{Ls} = \Delta \ln L_s - \Delta \ln H .$$

This index reflects the effect of changes in the composition of aggregate hours worked by sex on the rate of growth of labor quality. There are six first-order contributions to the rate of growth of labor quality corresponding to the six characteristics of labor input.

We can define the second-order contribution of each pair of characteristics to the rate of growth of labor quality as the difference between the rate of growth of the corresponding partial index of labor input and the rate of growth of aggregate hours worked, less the sum of the two first-order contributions of these characteristics to the rate of growth of labor quality. For example, the second-order contribution of sex and age, say Q_{Lsa}, takes the form:

$$\Delta \ln Q_{Lsa} = \Delta \ln L_{sa} - \Delta \ln H - \Delta \ln Q_{Ls} - \Delta \ln Q_{La} ,$$

$$= \Delta \ln L_{sa} - \Delta \ln L_a - \Delta \ln L_s + \Delta \ln H .$$

This index reflects the effect of changes in the composition of aggregate hours worked by sex and age on the rate of growth of labor quality, exclusive of the effects already reflected in the first-order contributions of sex and age. There are fifteen second-order contributions to the rate of growth of labor quality. These second-order contributions together with the six first-order contributions are defined in Table 10. We can similarly define third-, fourth-, fifth-, and sixth-order contributions of characteristics of hours worked to the rate of

Table 10

CONTRIBUTIONS TO THE GROWTH OF LABOR QUALITY

FIRST-ORDER (SIX INDEXES):

$$\Delta \ln Q_{Ls} = \Delta \ln L_s - \Delta \ln H.$$

SECOND-ORDER (FIFTEEN INDEXES):

$$\Delta \ln Q_{Lsa} = \Delta \ln L_{sa} - \Delta \ln L_a - \Delta \ln L_s + \Delta \ln H.$$

THIRD-ORDER (TWENTY INDEXES):

$$\Delta \ln Q_{Lsae} = \Delta \ln L_{sae} - \Delta \ln L_{sa} - \Delta \ln L_{se} - \Delta \ln L_{ae}$$

$$+ \Delta \ln L_s + \Delta \ln L_a + \Delta \ln L_e - \Delta \ln H.$$

FOURTH-ORDER (FIFTEEN INDEXES):

$$\Delta \ln Q_{Lsaec} = \Delta \ln L_{saec} - \Delta \ln L_{sae} - \Delta \ln L_{sac} - \Delta \ln L_{sec}$$

$$- \Delta \ln L_{aec} + \Delta \ln L_{sa} + \Delta \ln L_{se} + \Delta \ln L_{sc}$$

$$+ \Delta \ln L_{ae} + \Delta \ln L_{ac} + \Delta \ln L_{ec} - \Delta \ln L_s$$

$$- \Delta \ln L_a - \Delta \ln L_e - \Delta \ln L_c + \Delta \ln H.$$

FIFTH-ORDER (SIX INDEXES):

$$\Delta \ln Q_{Lsaeco} = \Delta \ln L_{saeco} - \Delta \ln L_{saec} - \Delta \ln L_{saeo} - \Delta \ln L_{saco}$$

$$- \Delta \ln L_{seco} - \Delta \ln L_{aeco} + \Delta \ln L_{sae} + \Delta \ln L_{sac}$$

$$+ \Delta \ln L_{sao} + \Delta \ln L_{sec} + \Delta \ln L_{seo} + \Delta \ln L_{sco}$$

CONTRIBUTIONS TO THE GROWTH OF LABOR QUALITY

$$+ \Delta\ln L_{aec} + \Delta\ln L_{aeo} + \Delta\ln L_{aco} + \Delta\ln L_{eco}$$

$$- \Delta\ln L_{sa} - \Delta\ln L_{se} - \Delta\ln L_{sc} - \Delta\ln L_{so}$$

$$- \Delta\ln L_{ae} - \Delta\ln L_{ac} - \Delta\ln L_{ao} - \Delta\ln L_{ec}$$

$$- \Delta\ln L_{eo} - \Delta\ln L_{co} + \Delta\ln L_{s} + \Delta\ln L_{a}$$

$$+ \Delta\ln L_{e} + \Delta\ln L_{c} + \Delta\ln L_{o} - \Delta\ln H.$$

SIXTH-ORDER (ONE INDEX):

$$\Delta\ln Q_{Lsaecoi} = \Delta\ln L_{saecoi} - \Delta\ln L_{saeco} - \Delta\ln L_{saeci} - \Delta\ln L_{saeoi}$$

$$- \Delta\ln L_{sacoi} - \Delta\ln L_{secoi} - \Delta\ln L_{aecoi} + \Delta\ln L_{saec}$$

$$+ \Delta\ln L_{saeo} + \Delta\ln L_{saei} + \Delta\ln L_{saco} + \Delta\ln L_{saci}$$

$$+ \Delta\ln L_{saoi} + \Delta\ln L_{seco} + \Delta\ln L_{seci} + \Delta\ln L_{seoi}$$

$$+ \Delta\ln L_{scoi} + \Delta\ln L_{aeco} + \Delta\ln L_{aeci} + \Delta\ln L_{aeoi}$$

$$+ \Delta\ln L_{acoi} + \Delta\ln L_{ecoi} - \Delta\ln L_{sae} - \Delta\ln L_{sac}$$

$$- \Delta\ln L_{sao} - \Delta\ln L_{sai} - \Delta\ln L_{sec} - \Delta\ln L_{seo}$$

$$- \Delta\ln L_{sei} - \Delta\ln L_{sco} - \Delta\ln L_{sci} - \Delta\ln L_{soi}$$

$$- \Delta\ln L_{aec} - \Delta\ln L_{aeo} - \Delta\ln L_{aei} - \Delta\ln L_{aco}$$

Table 10 (Continued)

CONTRIBUTIONS TO THE GROWTH OF LABOR QUALITY

$$- \Delta \ln L_{aci} - \Delta \ln L_{aoi} - \Delta \ln L_{eco} - \Delta \ln L_{eci}$$

$$- \Delta \ln L_{eoi} - \Delta \ln L_{coi} + \Delta \ln L_{sa} + \Delta \ln L_{ae}$$

$$+ \Delta \ln L_{sc} + \Delta \ln L_{so} + \Delta \ln L_{si} + \Delta \ln L_{ae}$$

$$+ \Delta \ln L_{ac} + \Delta \ln L_{ao} + \Delta \ln L_{ai} + \Delta \ln L_{ec}$$

$$+ \Delta \ln L_{eo} + \Delta \ln L_{ei} + \Delta \ln L_{co} + \Delta \ln L_{ci}$$

$$+ \Delta \ln L_{oi} - \Delta \ln L_{s} - \Delta \ln L_{a} - \Delta \ln L_{e}$$

$$- \Delta \ln L_{c} - \Delta \ln L_{o} - \Delta \ln L_{i} + \Delta \ln H.$$

growth of the quality of labor input by extension of our definitions of first- and second-order contributions. There are twenty third-order indexes, fifteen fourth-order indexes, sic fifth-order indexes, and one sixth-order index. All are defined in Table 10.

By summing the contributions of all orders corresponding to a given set of characteristics of labor input we obtain the partial index of labor quality corresponding to those characteristics. For example our aggregate index of labor quality presented in column 4 of Table 7 is the partial index of labor quality corresponding to all characteristics of labor input except industry. We can represent this index in the form:

$$\Delta \ln Q_L = \Delta \ln Q_{Ls} + \Delta \ln Q_{La} + \Delta \ln Q_{Le} + \Delta \ln Q_{Lc}$$

$$+ \Delta \ln Q_{Lo} + \Delta \ln Q_{Lsa} + \Delta \ln Q_{Lse} + \Delta \ln Q_{Lsc}$$

$$+ \Delta \ln Q_{Lso} + \Delta \ln Q_{Lae} + \Delta \ln Q_{Lac} + \Delta \ln Q_{Lao}$$

$$+ \Delta \ln Q_{Lec} + \Delta \ln Q_{Leo} + \Delta \ln Q_{Lco} + \Delta \ln Q_{Lsae}$$

$$+ \Delta \ln Q_{Lsac} + \Delta \ln Q_{sao} + \Delta \ln Q_{Lsec} + \Delta \ln Q_{Lseo}$$

$$+ \Delta \ln Q_{Lsco} + \Delta \ln Q_{Laec} + \Delta \ln Q_{Laeo} + \Delta \ln Q_{Laco}$$

$$+ \Delta \ln Q_{Leco} + \Delta \ln Q_{Lsaec} + \Delta \ln Q_{Lsaeo} + \Delta \ln Q_{Lsaco}$$

$$+ \Delta \ln Q_{Lseco} + \Delta \ln Q_{Laeco} + \Delta \ln Q_{Lsaeco} .$$

This index is the sum of five first-order contributions, ten second-order contributions, ten third-order contributions, five fourth-order contributions, and one fifth-order contribution to the rate of growth of labor quality. This index incorporates the effects of changes in the composition of aggregate hours worked among all characteristics of labor input except industry.

We apply the formulas of Table 10 to the disaggregated labor data described above. The resulting quality indexes for each year in the period 1948-1973 are presented in the second through last columns in Table 11. The first column of this table reports the quality index representing the total contribution made by all sources. It is formed by summing over all first- and higher-order contributions corresponding to all six characteristics of labor input.

The analysis of variance provides an analogy useful in interpreting the first-and higher-order contributions of the characteristics of labor input to the rate of growth of labor quality. Each of the characteristics of hours worked corresponds to a factor in the analysis of variance. The decomposition of the rate of growth of labor quality by all six characteristics corresponds to a six-way layout in the analysis of variance. The first-order contribution of each of the six characteristics corresponds to the main effect of the factor in the analysis of variance. The second-order contribution of any two of the six characteristics

Table 11

DECOMPOSITION OF LABOR QUALITY

YEAR	LABOR QUALITY	S	C	A	E	O	I	SC
1948	.849	1.042	.958	1.008	.854	.910	.927	.995
1949	.848	1.039	.956	1.011	.857	.910	.924	.994
1950	.859	1.039	.962	1.021	.861	.921	.931	.994
1951	.876	1.036	.966	1.017	.861	.926	.949	.995
1952	.894	1.035	.967	1.023	.867	.936	.956	.995
1953	.900	1.035	.969	1.025	.871	.936	.958	.996
1954	.899	1.032	.967	1.028	.877	.936	.952	.995
1955	.901	1.029	.971	1.027	.879	.938	.956	.996
1956	.906	1.026	.974	1.025	.885	.944	.962	.996
1957	.914	1.024	.976	1.027	.890	.951	.968	.996
1958	.913	1.020	.977	1.028	.899	.954	.961	.996
1959	.922	1.020	.980	1.027	.902	.958	.966	.997
1960	.941	1.030	.982	1.037	.910	.967	.970	.997
1961	.936	1.016	.983	1.025	.921	.963	.970	.997
1962	.954	1.017	.985	1.025	.934	.969	.976	.997
1963	.956	1.015	.988	1.025	.932	.970	.980	.998
1964	.965	1.014	.990	1.022	.941	.976	.984	.998
1965	.968	1.012	.992	1.018	.946	.977	.988	.998
1966	.984	1.010	.995	1.016	.954	.991	.998	.999
1967	.993	1.008	.996	1.015	.959	.993	1.003	.999
1968	.999	1.006	.997	1.013	.967	.998	1.004	.999
1969	.998	1.003	.998	1.009	.972	1.001	1.005	.999
1970	1.003	1.007	.999	1.023	.976	1.000	1.002	.999
1971	1.008	1.001	.998	1.005	.992	1.008	.999	.999
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.005	.999	1.000	.995	1.009	1.003	1.001	1.000
AVERAGE ANNUAL RATE OF GROWTH	.0068	-.0017	.0017	-.0005	.0067	.0039	.0031	.0002

Table 11 (Continued)

DECOMPOSITION OF LABOR QUALITY

YEAR	SA	SE	SO	SI	CA	CE	CO	CI
1948	.998	.987	.979	.983	.994	1.009	1.010	1.030
1949	.998	.987	.981	.984	.994	1.009	1.011	1.039
1950	.997	.986	.978	.982	.995	1.008	1.003	1.033
1951	.997	.987	.979	.983	.996	1.008	1.005	1.030
1952	.997	.988	.980	.983	.997	1.007	1.005	1.029
1953	.997	.989	.982	.983	.997	1.007	1.004	1.027
1954	.997	.989	.984	.985	.998	1.007	1.005	1.029
1955	.997	.990	.985	.986	.998	1.006	1.003	1.025
1956	.996	.991	.987	.988	.998	1.006	1.001	1.022
1957	.996	.992	.989	.989	.999	1.005	.999	1.020
1958	.996	.992	.991	.991	.999	1.005	.999	1.019
1959	.995	.993	.990	.991	.999	1.004	1.000	1.016
1960	.994	.993	.991	.993	.999	1.004	.999	1.014
1961	.996	.994	.995	.994	.999	1.003	.999	1.013
1962	.996	.995	.996	.994	1.000	1.003	1.000	1.012
1963	.996	.996	.996	.995	1.000	1.003	.999	1.010
1964	.996	.996	.996	.996	1.000	1.002	1.000	1.008
1965	.997	.997	.996	.996	1.000	1.002	.999	1.007
1966	.998	.997	.996	.996	1.000	1.002	.999	1.004
1967	.999	.998	.999	.997	1.000	1.001	.999	1.003
1968	1.000	.998	.999	.997	1.001	1.001	1.000	1.002
1969	1.000	.999	1.000	.997	1.000	1.001	1.000	1.002
1970	.999	.998	.999	.998	1.001	1.001	.999	1.001
1971	1.000	.999	.999	.999	1.000	1.000	1.001	1.001
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.000	1.000	.998	.999	.999	.999	1.000	.999
AVERAGE ANNUAL RATE OF GROWTH	.0001	.0005	.0008	.0006	.0002	-.0004	-.0000	-.0015

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Table 11 (Continued)

DECOMPOSITION OF LABOR QUALITY

YEAR	AE	AO	AI	EO	EI	OI	SCA	SCE
1948	.999	1.001	.996	1.080	1.067	1.076	1.001	1.000
1949	.999	1.000	.996	1.075	1.064	1.077	1.001	1.000
1950	.997	.997	.994	1.070	1.064	1.069	1.000	1.000
1951	.999	.998	.995	1.072	1.062	1.060	1.001	1.000
1952	1.000	.998	.995	1.067	1.059	1.053	1.001	1.000
1953	1.001	.999	.996	1.064	1.057	1.053	1.001	1.000
1954	1.002	.999	.996	1.059	1.053	1.051	1.001	1.000
1955	1.002	.997	.995	1.058	1.052	1.048	1.000	1.000
1956	1.002	.997	.996	1.055	1.048	1.040	1.000	1.000
1957	1.002	.997	.995	1.048	1.044	1.033	1.000	1.000
1958	1.002	.996	.995	1.041	1.040	1.033	1.000	1.000
1959	1.002	.996	.996	1.039	1.038	1.032	1.000	1.000
1960	.999	.991	.993	1.032	1.035	1.029	.999	1.000
1961	1.003	.998	.997	1.030	1.030	1.027	1.000	1.000
1962	1.002	.997	.997	1.026	1.027	1.024	1.000	1.000
1963	1.003	.997	.997	1.027	1.024	1.020	1.000	1.000
1964	1.004	.997	.998	1.023	1.020	1.016	1.000	1.000
1965	1.004	.998	.998	1.022	1.017	1.012	1.000	1.000
1966	1.003	.995	.997	1.016	1.014	1.007	1.000	1.000
1967	1.003	.996	.997	1.012	1.011	1.005	1.000	1.000
1968	1.002	.997	.998	1.008	1.008	1.003	1.000	1.000
1969	1.003	.998	.998	1.006	1.005	.999	1.000	1.000
1970	.997	.995	.995	1.004	1.004	.998	1.000	1.000
1971	1.001	.998	.999	.998	1.001	1.002	1.000	1.000
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.000	1.001	1.000	.998	.999	.999	.999	1.000
AVERAGE ANNUAL RATE OF GROWTH	.0001	-.0000	.0001	-.0032	-.0026	-.0030	-.0001	-.0000

Table 11 (Continued)

DECOMPOSITION OF LABOR QUALITY

YEAR	SCO	SCI	SAE	SAU	SAI	SEO	SEI	SOI
1948	1.005	1.000	1.001	1.003	1.005	1.012	1.001	1.014
1949	1.005	1.001	1.001	1.003	1.005	1.012	1.001	1.013
1950	1.005	1.003	1.001	1.004	1.005	1.013	1.001	1.015
1951	1.004	1.001	1.001	1.004	1.005	1.012	1.001	1.014
1952	1.004	1.001	1.000	1.003	1.004	1.012	1.001	1.014
1953	1.004	1.001	1.000	1.003	1.004	1.011	1.001	1.012
1954	1.004	1.002	1.000	1.003	1.004	1.011	1.002	1.011
1955	1.004	1.001	1.000	1.003	1.004	1.010	1.002	1.010
1956	1.003	1.001	1.000	1.003	1.003	1.010	1.002	1.009
1957	1.003	1.001	1.000	1.002	1.003	1.009	1.002	1.008
1958	1.003	1.001	.999	1.002	1.003	1.009	1.002	1.006
1959	1.002	1.000	.999	1.002	1.003	1.008	1.002	1.006
1960	1.001	1.000	.999	1.003	1.003	1.007	1.000	1.000
1961	1.002	1.000	.999	1.002	1.002	1.006	1.001	1.003
1962	1.001	1.000	.999	1.002	1.002	1.005	1.000	1.002
1963	1.001	1.000	.999	1.002	1.002	1.005	1.001	1.002
1964	1.001	.999	.999	1.002	1.002	1.004	1.001	1.001
1965	1.000	.999	.999	1.001	1.001	1.004	1.001	1.002
1966	1.000	.999	.999	1.000	1.001	1.003	1.001	1.001
1967	1.000	.999	.999	.999	1.000	1.002	1.000	1.000
1968	1.000	.999	.999	.999	1.000	1.002	1.001	1.001
1969	1.000	.999	.999	.999	1.000	1.001	1.001	1.001
1970	1.000	1.000	.999	1.001	1.000	1.002	1.000	.999
1971	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	.999	1.000	1.000	1.000	1.000	.999	.999	1.001
AVERAGE ANNUAL RATE OF GROWTH	-.0002	-.0000	-.0001	-.0001	-.0002	-.0005	-.0001	-.0005

Table 11 (Continued)

DECOMPOSITION OF LABOR QUALITY

YEAR	CAE	CAO	CAI	CEO	CEI	COI	AEO	AEI
1948	.993	1.004	1.002	.996	.988	.978	.995	.991
1949	.993	1.004	1.002	.996	.988	.977	.995	.990
1950	.993	1.004	1.001	.997	.989	.983	.996	.991
1951	.993	1.003	1.001	.997	.989	.984	.996	.991
1952	.994	1.003	1.001	.998	.990	.984	.996	.991
1953	.994	1.002	1.000	.998	.990	.984	.996	.990
1954	.994	1.002	1.000	.998	.990	.983	.996	.991
1955	.995	1.002	1.000	.999	.991	.985	.997	.991
1956	.995	1.001	.999	.999	.992	.988	.998	.992
1957	.995	1.001	.999	.999	.992	.990	.998	.992
1958	.995	1.001	.999	1.000	.992	.990	.999	.993
1959	.996	1.001	.999	1.000	.993	.990	.999	.993
1960	.996	1.001	.999	1.000	.994	.992	1.000	.994
1961	.996	1.001	.999	1.001	.994	.993	.997	.993
1962	.997	1.001	.999	1.001	.995	.993	.998	.994
1963	.997	1.000	.999	1.001	.995	.994	.998	.995
1964	.998	1.000	.998	1.001	.996	.995	.997	.995
1965	.998	1.000	.999	1.001	.996	.996	.998	.996
1966	.998	1.000	.999	1.000	.997	.997	.999	.997
1967	.998	1.000	.999	1.000	.997	.997	.999	.998
1968	.999	1.000	.999	1.000	.998	.998	.999	.998
1969	.999	1.000	.999	1.000	.998	.998	.998	.999
1970	.999	.999	.999	1.000	.999	1.000	1.001	.999
1971	.999	.999	.999	1.000	.999	.999	.999	.999
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.000	1.000	1.000	.999	1.000	.999	.999	1.000
AVERAGE ANNUAL RATE OF GROWTH	.0003	-.0002	-.0001	.0001	.0005	.0009	.0002	.0004

Table 11 (Continued

DECOMPOSITION OF LABOR QUALITY

YEAR	AOI	EOI	SCAE	SCAO	SCAI	SCEO	SCEI	SCOI
1948	.997	.948	.998	.998	.998	.999	.979	.998
1949	.997	.951	.998	.998	.999	.999	.982	.997
1950	.998	.951	.998	.998	.999	.999	.985	.996
1951	.998	.953	.998	.998	.999	.999	.973	.997
1952	.997	.956	.998	.998	.999	.999	.976	.997
1953	.996	.958	.999	.998	.999	.999	.976	.998
1954	.996	.961	.998	.998	.999	.999	.983	.997
1955	.997	.963	.998	.999	.999	.999	.980	.998
1956	.997	.966	.998	.999	.999	.999	.980	.998
1957	.998	.970	.998	.999	.999	.999	.983	.998
1958	.997	.974	.998	.999	.999	.999	.993	.998
1959	.997	.975	.998	.999	1.000	.999	.990	.998
1960	.999	.978	.999	.999	1.000	.999	.996	.999
1961	.996	.981	.999	.999	1.000	.999	.994	.999
1962	.997	.983	.999	.999	1.000	.999	.994	.999
1963	.997	.984	.999	.999	1.000	.999	.990	.999
1964	.997	.987	.999	.999	1.000	.999	.992	.999
1965	.998	.989	.999	.999	1.000	.999	.989	.999
1966	.999	.991	.999	.999	1.000	.999	.992	1.000
1967	1.000	.993	.999	.999	1.000	.999	.993	1.000
1968	1.000	.995	.999	.999	1.000	.999	.997	1.000
1969	1.000	.997	1.000	.999	.999	1.000	.998	1.000
1970	1.001	.998	.999	1.000	1.000	1.000	.999	1.000
1971	.999	1.000	1.000	.999	1.000	1.000	1.008	1.000
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.000	.999	1.000	1.000	1.000	1.000	1.001	1.000
AVERAGE ANNUAL RATE OF GROWTH	.0001	.0021	.0001	.0001	.0000	.0000	.0009	.0001

Table 11 (Continued)

DECOMPOSITION OF LABOR QUALITY

YEAR	SAEO	SAEI	SAII	SEOI	CAEO	CAEI	CAII	CEOI
1948	.997	.999	.995	.997	1.004	1.003	.997	1.007
1949	.997	.999	.995	.997	1.004	1.003	.998	1.007
1950	.998	.999	.995	.996	1.003	1.003	.998	1.007
1951	.997	.999	.995	.996	1.003	1.003	.998	1.006
1952	.998	.999	.996	.996	1.003	1.003	.998	1.006
1953	.998	.999	.996	.996	1.003	1.003	.999	1.005
1954	.998	.999	.996	.996	1.003	1.003	.999	1.005
1955	.998	1.000	.997	.996	1.003	1.002	.999	1.004
1956	.998	1.000	.997	.996	1.002	1.002	1.000	1.004
1957	.998	.999	.997	.996	1.002	1.002	1.000	1.004
1958	.998	.999	.998	.996	1.002	1.002	1.000	1.003
1959	.999	1.000	.998	.996	1.002	1.002	1.000	1.003
1960	.999	1.000	.998	.998	1.001	1.002	1.000	1.002
1961	.999	1.000	.999	.997	1.001	1.001	1.000	1.002
1962	.999	1.000	.999	.998	1.001	1.001	1.000	1.002
1963	.999	1.000	.999	.997	1.000	1.001	1.000	1.002
1964	.999	1.000	.999	.997	1.000	1.001	1.000	1.001
1965	.999	1.000	.999	.997	1.000	1.001	1.000	1.001
1966	.999	1.000	.999	.998	1.000	1.000	1.000	1.001
1967	1.000	1.000	.999	.998	1.000	1.000	1.000	1.001
1968	.999	.999	.999	.998	1.000	1.000	1.000	1.000
1969	1.000	.999	.999	.998	1.000	1.000	1.000	1.000
1970	.999	1.000	.999	.999	1.000	1.000	1.000	1.000
1971	.999	.999	.999	1.000	1.000	1.000	1.000	1.000
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.000	1.000	1.000	1.000	1.000	.999	1.000	1.000
AVERAGE ANNUAL RATE OF GROWTH	.0001	.0000	.0002	.0001	-.0002	-.0001	.0001	-.0003

Table 11 (Concluded)

DECOMPOSITION OF LABOR QUALITY

YEAR	AEQI	SCAEQ	SCAEI	SCAQI	SCEQI	SAEQI	CAFQI	SCAEQI
1948	1.008	1.001	1.001	1.001	.999	1.051	.997	.999
1949	1.008	1.001	1.001	1.001	.999	1.048	.997	.999
1950	1.008	1.001	1.001	1.001	.999	1.057	.997	.999
1951	1.008	1.001	1.000	1.001	.999	1.076	.997	.999
1952	1.008	1.001	1.000	1.000	.999	1.087	.997	.999
1953	1.008	1.001	1.000	1.000	.999	1.086	.997	.999
1954	1.008	1.001	1.000	1.001	1.000	1.074	.997	.999
1955	1.007	1.001	1.000	1.000	1.000	1.073	.997	.999
1956	1.006	1.001	1.000	1.000	1.000	1.073	.997	.999
1957	1.006	1.001	1.000	1.000	1.000	1.072	.998	.999
1958	1.005	1.001	1.000	1.000	1.000	1.062	.998	.999
1959	1.005	1.001	1.000	1.000	1.000	1.067	.998	.999
1960	1.004	1.001	1.000	.999	.999	1.071	.998	.999
1961	1.004	1.001	1.000	1.000	.999	1.054	.998	.999
1962	1.004	1.001	1.000	1.000	.999	1.049	.998	.999
1963	1.003	1.000	1.000	1.000	1.000	1.053	.999	.999
1964	1.003	1.000	1.000	1.000	1.000	1.048	.999	.999
1965	1.002	1.000	1.000	1.000	1.000	1.041	.999	.999
1966	1.001	1.000	1.000	.999	.999	1.049	.999	1.000
1967	1.000	1.000	1.000	1.000	.999	1.051	.999	1.000
1968	1.000	1.000	1.000	1.000	.999	1.048	.999	.999
1969	1.000	1.000	1.000	1.000	.999	1.041	.999	1.000
1970	1.000	1.000	1.000	1.000	1.000	1.034	.999	1.000
1971	1.000	1.000	1.000	1.000	1.000	1.029	1.000	1.000
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	.999	1.000	1.000	1.000	1.000	.990	1.000	1.000
AVERAGE ANNUAL RATE OF GROWTH	-.0003	-.0001	-.0000	-.0001	.0000	-.0024	.0001	.0000

corresponds to the interaction effect of the two factors in the analysis of variance. The third-, fourth-, fifth-, and sixth-order contributions to the rate of growth of labor quality correspond to higher-order interactions in the analysis of variance.

The indexes reported in Tables 9 and 11 imply that the shifting demographic, occupational, and industrial composition of the labor force historically has been a very significant source of postwar economic growth. The sixth-order partial index of labor input given in the last column of Table 9 increases at an average annual rate of 1.68 percent for the period 1948-1973. This represents the sum of the growth rates of aggregate hours worked and the index of total quality change. Forty-one percent of this growth was due to quality change; the quality index given in the first column of Table 11 increases at .69 percent per year. Hours worked account for the remaining fifty-nine percent, growing at an average annual rate equal to .99 percent. However, if the postwar period is

partitioned at 1960, we observe that the importance of quality change has declined in both absolute and relative terms. On average, the total quality index increased .86 percent per year over the 1948-1960 period and .51 percent per year between 1960 and 1973. At the same time, the importance of compositional change declined substantially relative to increases in hours worked. Between 1948 and 1960, hours worked increased at an average .40 percent annual rate; quality change accounted for nearly sixty-eight percent of the growth in the partial index of labor input. After 1960, the economy experienced a surge in hours worked. The unweighted hours index grows at an average rate equal to 1.56 percent; labor quality is responsible for approximately twenty-five percent of the growth in the sixth-order partial index of labor input. An analysis of the most recent sub-period, 1969-1973, suggests that this decline in the absolute and relative importance of quality change continued. While unadjusted hours worked increased at a 1.34 percent rate during 1969-1973, labor input grew at a 1.48 percent annual rate. The difference is the rate of growth in the labor quality index. It increases at an average annual rate equal to .14 percent, accounting for less than ten percent of input growth.

The sources of the postwar change in aggregate labor input can be determined from the quality indexes reported in Table 11. Comparing the main effects, only sex and education have smooth persistent trends over the 1948-1973 period. The former, reflecting the high rate of

entry of women into low paying jobs, has a negative effect averaging -.17 percent per year; the latter, caused by the increasing proportion of highly educated laborers, is positive, increasing at an average annual rate equal to .67 percent. The main effects of employment class, occupation, and industry are all positive -- .17 percent, .39 percent, and .31 percent per year, respectively -- but peak in the middle of the nineteen-sixties. The postwar shift of laborers to high-paying occupations and industries slows down considerably by the end of the 1960-1966 period. Consequently, these characteristics have little effect on total quality change after 1966. Between 1966-1973, the main effects of class, occupation, and industry are .07 percent, .18 percent, and .04 percent, respectively. The main effect of age reverses itself after 1960. The effect is positive through 1960, averaging .24 percent per year; after 1960, the effect turns negative, declining at an average annual rate equal to -.32 percent. This reversal reflects the entry into the employed labor force of a large number of young laborers who were born immediately following World War II. Their low wages and low imputed productivity account for the negative effect of age on labor quality.

Although the second and higher order interactive effects are small, their aggregate effect is quantitatively important. The annual average rate of growth of the sum of the interactive effects equals -.64 percent over the full 1948-1973 period. Had these effects not been considered, the quality index would have been found to increase at a 1.32 percent annual rate. This compares to .68 percent when all main and interaction effects are considered. In brief, failing to consider interaction effects

nearly doubles the calculated contribution of changing labor quality as a source of economic growth. Relative to the 1.68 percent average annual rate of growth in labor's total contribution to economic growth, neglecting interaction effects would upward bias the calculated contribution by thirty-eight percent. To identify the sources of economic growth, the interaction effections among demographic, occupational, and industrial characteristics must be explicitly incorporated in the analysis.

While second and higher order effects are quantitatively significant, their inclusion does not qualitatively affect the interpretation of the source characteristics of economic growth. The sex and age factors are still the dominant causes of the decline in the growth of the quality index. The interaction effects of age and sex with each other and other factors are generally positive and consequently reduce the aggregate negative effect of -.22 percent that would be inferred by simply summing the main effects of sex and age, -.17 percent and -.05 percent, respectively. The positive interaction between sex and occupation for example suggests that women are increasingly entering high-paying occupation groups. Yet, even when all interaction effects are taken into account, the conclusion remains that the changing sex-age composition of the aggregate employed labor force has had a negative impact on labor input per hour worked. The combined sex-age contribution to the total quality index is -.18 percent per year over 1948-1973. When the full period is partitioned into the sub-periods 1948-1960, 1960-1973, and 1969-1973, the sex-age effect is .44 percent, -.76 percent, and -1.18 percent, respectively. The increasing entry of women and young workers into low-paying jobs increases hours worked proportionately more than it increases labor input.

4. Investment in Education

Our final objective is to present measures of investment in education for the United States for the period 1948-1973. For this purpose we construct a new data base for measuring lifetime labor incomes for all individuals in the U.S. population. Our data base includes demographic accounts in each year for the population of each sex, cross-classified by individual year of age and individual year of highest educational attainment. Our demographic accounts include data on the number of individuals enrolled in formal schooling and data on births, deaths, and migration. These demographic accounts are based on annual population data from the U.S. Bureau of the Census. We incorporate more detailed data from the decennial censuses of population to obtain estimates of the population cross-classified by sex, age, and education.

To measure lifetime labor incomes for all individuals in the U.S. population we begin with the data base on labor time devoted to market activities described in Section 3 above. We derive estimates of hours worked and labor compensation for each sex by sixty-one age groups and eighteen education groups or a total of 2196 groups for each year. We impute wage rates for nonmarket activities from wage rates for employed individuals. We allocate the total time available for all individuals in the population among work, schooling, household production and leisure, and maintenance. We exclude maintenance through the satisfaction of physiological needs from our accounts for lifetime labor incomes. We assign the value of time spent in household production and leisure to consumption and time spent in schooling to investment.

Our final step in measuring lifetime labor incomes for all individuals in the U.S. population is to project incomes for future years and to discount incomes for all future years back to the present, weighting income by the probability of survival. We combine estimates of lifetime labor incomes by sex, age, and education with demographic accounts for the numbers of individuals to obtain estimates of investment in education. We present these estimates in current and constant prices for the period 1948-1973 for all individuals in the U.S. population. We compare our estimates of the value of leisure and nonmarket activities with those of Nordhaus and Tobin (1972) and our estimats of investment in education with those of Kendrick (1976).

Our estimates of investment in education are based on a system of demographic accounts. Human capital is accumulated through births, immigration, and investment in education and decumulated through deaths, emigration, and aging. Our demographic accounts distinguish among individuals by sex, individual year of age, and individual year of highest educational attainment. Individuals must also be classified by school enrollment status and by employment status in order to encompass both market and nonmarket activities that generate labor income.

Our accounts include annual estimates of mid-year propulation by sex and age for individuals under 75 years of age. We employ population data from the U.S. Bureau of the Census. Using data from the Censuses of Population for 1940, 1950, 1960, and 1970, we have distributed the population of each sex by individual years of age and individual years of educational attainment for each year in the period 1947-

1973. Our procedure results in estimates of school enrollment by sex and age for each year. Unfortunately, lack of information on deaths and migration, cross-classified by sex, age, and education, has made it impossible for us to reconcile enrollment data with estimates of transitions from one grade to the next.

In this section we present the demographic information in our data base in summary form. Table 12 presents population under 75 years of age and population under 75 years of age and population under one year of age, classified by sex. We can observe an increase in population of 44 percent over the period. Sex ratios, defined by the number of males per hundred females, are frequently used in demographic analysis. The usual pattern of sex ratios, exceeding one hundred at the time of birth and monotonically decreasing with age as a consequence of lower female mortality, is consistent with the data in Table 12. The sex ratio for the population as a whole has declined from near parity at 100.0 at the beginning of the period to 97.2 at the end of the period.

Table 13 presents our estimates of students between 5 to 34 years of age, classified by sex. Enrollments in the period have practically doubled. Enrollment ratios have increased from 40 percent at the beginning of the period to 54 percent at the end of the 1960's. We observe a sex differential in the enrollment ratios of four percentage points in favor of males throughout the period. Sex ratios for the population of school age, 5 to 34 years, at the beginning of the period were very close to parity at 100.1. For students, sex ratios are ten percent above parity due to male selectivity. As a consequence of a

Table 12

Total Population 0 to 74 Years of Age by Sex,
United States, 1947-73 (Thousands)

	Total			Less Than One Year		
	Total	Male	Female	Total	Male	Female
1947	140,713	70,386	70.327	3,452	1,767	1,685
1948	143,063	71,505	71,558	3,169	1,622	1,547
1949	145,460	72,641	72,819	3,169	1,619	1,550
1950	147,742	73,733	74,009	3,146	1,602	1,544
1951	150,150	74,887	75,263	3,297	1,697	1,621
1952	152,639	76,074	76,565	3,411	1,737	1,674
1953	155,103	77,250	77,853	3,526	1,794	1,732
1954	157,778	78,553	79,225	3,648	1,855	1,793
1955	160,466	79,849	80,617	3,755	1,913	1,842
1956	163,251	81,195	82,056	3,835	1,951	1,884
1957	166,122	82,582	83,540	4,009	2,041	1,968
1958	168,845	83,887	84,958	4,048	2,060	1,988
1959	171,576	85,202	86,374	4,072	2,069	2,003
1960	175,051	86,911	88,140	4,094	2,080	2,014
1961	177,872	88,261	89,611	4,173	2,121	2,052
1962	180,559	89,538	91,021	4,084	2,077	2,007
1963	183,075	90,724	92,351	4,013	2,042	1,971
1964	185,518	91,875	93,643	3,947	2,012	1,935
1965	187,741	92,916	94,825	3,770	1,917	1,853
1966	189,798	93,875	95,923	3,553	1,812	1,743
1967	191,722	94,754	96,968	3,450	1,757	1,693
1968	193,525	95,572	97,953	3,366	1,718	1,648
1969	195,299	96,388	98,911	3,412	1,742	1,670
1970	197,276	97,322	99,954	3,503	1,788	1,715
1971	199,237	98,274	100,963	3,579	1,832	1,747
1972	200,857	99,048	101,809	3,261	1,671	1,590
1973	202,288	99,731	102,557	3,081	1,574	1,507

Table 13

Noninstitutional Population and School Enrollment
5 to 34 Years of Age by Sex, United States, 1947-73 (Thousands)

Year	Total			Male			Female		
	Population	Enrollment	Percent	Population	Enrollment	Percent	Population	Enrollment	Percent
1947	68,616	27,725	40.41	34,318	14,683	42.79	34,298	13,042	38.03
1948	69,443	28,129	40.51	34,731	14,901	42.91	34,712	13,227	38.11
1949	70,066	28,773	41.07	35,022	15,236	43.51	35,044	13,536	38.63
1950	70,629	29,494	41.76	35,304	15,609	44.22	35,325	13,884	39.31
1951	71,075	30,141	42.41	35,540	15,902	44.75	35,535	14,238	40.07
1952	72,541	30,884	42.57	36,289	16,243	44.76	36,252	14,640	40.39
1953	73,682	32,156	43.64	36,890	16,861	45.71	36,792	15,294	41.57
1954	74,893	33,574	44.83	37,528	17,559	46.79	37,365	16,014	42.86
1955	75,999	34,903	45.93	38,104	18,210	47.79	37,895	16,692	44.05
1956	77,217	36,231	46.92	38,737	18,868	48.71	38,480	17,363	45.12
1957	78,474	37,603	47.92	39,395	19,555	49.64	39,079	18,047	46.18
1958	79,844	39,000	48.85	40,108	20,258	50.51	39,736	18,741	47.17
1959	81,273	40,418	49.73	40,851	20,975	51.35	40,422	19,442	48.10
1960	83,233	42,033	50.50	41,866	21,807	52.09	41,367	20,226	48.89
1961	84,961	43.502	51.20	42,763	22,576	52.80	42.198	20,925	49.59
1962	86,839	44,985	51.80	43,744	23,357	53.39	43,095	21,628	50.19
1963	88,756	46,516	52.41	44,724	24,159	54.02	44,032	22,357	50.77
1964	90,700	48,037	52.96	45,717	24,963	54.60	44,983	23,073	51.29
1965	99,666	49,348	53.25	46,726	25,681	54.96	45,940	23,666	51.52
1966	94,792	50,582	53.36	47,814	26,358	55.13	46,978	24,223	51.56
1967	96,850	51,798	53.48	48,853	27,025	55.32	47,997	24,772	51.61
1968	98,853	52,963	53.58	49,861	27,669	55.49	48,992	25,293	51.63
1969	100,891	53,971	53.54	50,849	28,244	55.55	49,952	25,727	51.50
1970	102,525	54,853	53.50	51,728	28,763	55.60	50,797	26,090	51.36
1971	104,006	55,196	53.07	52,465	28,965	55.21	51,541	26,231	50.89
1972	105,330	55,261	52.47	53,127	29,027	54.64	52,203	26,234	50.25
1973	106,493	55,107	51.75	53,718	28,978	53.95	52,775	26,129	49.51

rapid increase in female enrollment, sex ratios have declined. The greatest decrease -- from 211.2 in 1947 to 153.1 in 1973 -- occurred in higher education.

In Table 14 we present the distribution of students by sex and educational level. Enrollment in higher education has increased by 244.4 percent in the period as a whole. The number of female students enrolled in higher education has increased by the greatest proportion, 423.6 percent for the period as a whole. As a consequence of a more rapid rate of growth in enrollment in higher education, the share of higher education in total enrollment has increased from 8.3 percent in 1947 to 14.5 percent in 1973. Enrollment in secondary education has also increased more rapidly than total enrollment. The share of secondary enrollment has increased by three percentage points from 24.6 percent in 1947 to 27.6 percent in 1973. The lowest rate of growth in enrollment by educational level took place at the elementary level. As a consequence, the elementary share in enrollment declined by more than nine percentage points from 67.1 percent in 1947 to 58.0 percent in 1973.

Table 15 presents our estimates of the employment status of the economically active population, defined as the number of individuals 14 years of age and over, by sex. We observe an increase of 46.8 percent in the number of workers from 1947 to 1973; this increase was slightly higher than the increase of 42.1 percent in the economically active population. The number of male workers has increased by only 26.0 percent. This constrasts with the 39 percent increase in the economically active male population. Employment rates, based on number of workers divided

Table 14

School Enrollment by Sex and Educational Attainment, United States, 1947-73

(Thousands)

Year	Total	Male			Female		
		Elem.	Second.	College	Elem.	Second.	College
1947	27726	9638	3476	1570	8962	3336	743
1948	28129	9864	3434	1604	9194	3287	746
1949	28773	10199	3406	1632	9528	3256	752
1950	29495	10581	3379	1650	9884	3244	756
1951	30141	10854	3444	1604	10157	3322	759
1952	30884	11143	3535	1565	10448	3425	768
1953	32156	11681	3634	1546	10976	3529	789
1954	33574	12272	3744	1543	11551	3646	817
1955	34903	12783	3878	1549	12052	3788	852
1956	36231	13234	4056	1578	12490	3974	899
1957	37603	13620	4313	1622	12857	4240	950
1958	39000	14006	4573	1680	13244	4490	1008
1959	40418	14441	4775	1760	13690	4673	1080
1960	42034	14981	4942	1884	14234	4815	1178
1961	43502	15295	5235	2046	14501	5117	1307
1962	44986	15545	5597	2215	14731	5469	1429
1963	46516	15829	5952	2378	15010	5807	1540
1964	48037	16134	6281	2548	15309	6110	1654
1965	49348	16398	6456	2828	15564	6238	1865
1966	50582	16624	6591	3144	15784	6356	2083
1967	51798	16820	6749	3456	15972	6510	2291
1968	52964	16956	6942	3772	16099	6698	2497
1969	53972	17014	7141	4090	16150	6881	2695
1970	54854	17001	7325	4437	16124	7052	2914
1971	55196	16918	7487	4561	16033	7209	2989
1972	55262	16700	7635	4693	15818	7347	3069
1973	55108	16411	7748	4819	15531	7451	3147

Table 15

Employment Status of the Population 14 Years of Age and Over by Sex, United States, 1947-73 (Thousands)

Year	Male			Female			Total		
	Economically Active Population	Employment	Percentage Employment Rate	Economically Active Population	Employment	Percentage Employment Rate	Economically Active Population	Employment	Percentage Employment Rate
1947	52810	43341	82.07	53376	17408	32.61	106187	60749	57.21
1948	53224	43660	82.03	53933	17681	32.78	107158	61341	57.24
1949	53682	42152	78.52	54539	17660	32.38	108222	59812	55.27
1950	54047	43261	80.04	55041	18074	32.84	109089	61336	56.23
1951	54440	44487	81.72	55567	19459	35.02	110008	63946	58.13
1952	54874	44758	81.56	56142	19935	35.51	111017	64693	58.27
1953	55280	45634	82.55	56682	20031	35.34	111963	65665	58.65
1954	55776	44272	79.37	57272	19919	34.78	113049	64191	56.78
1955	56291	44920	70.80	57909	20960	36.20	114201	54880	57.69
1956	56918	45642	80.19	58643	21843	37.25	115562	67486	58.40
1957	57688	45538	78.94	59519	22154	37.22	117208	67692	57.75
1958	58311	44051	75.54	60264	22061	36.61	118576	66113	55.76
1959	58925	45150	76.62	60984	22683	37.20	119910	67834	56.57
1960	59808	45278	75.70	61933	23256	37.55	121742	68535	56.30
1961	60938	45030	73.90	63194	23601	37.35	124133	68631	55.29
1962	61892	45811	74.02	64299	24113	37.50	126192	69924	55.41
1963	62791	46022	73.29	65364	24611	37.65	128156	70633	55.11
1964	63682	46810	73.51	66425	25323	38.12	130108	72133	55.44
1965	64633	48035	74.32	67531	26425	39.13	132165	74460	56.34
1966	65630	49454	75.35	68674	28062	40.86	134305	77516	57.72
1967	66656	50010	75.03	69872	28922	41.39	136529	78933	57.81
1968	67707	50852	75.11	71098	30012	42.21	138806	80865	58.26
1969	68772	51711	75.19	72314	31319	43.31	141087	83031	58.85
1970	69911	51613	73.83	73579	31433	42.72	143491	83046	57.88
1971	71113	51540	72.48	74839	31799	42.49	145953	83340	57.10
1972	72310	52670	72.84	76106	33105	43.50	148417	85776	57.79
1973	73508	54613	74.30	77349	34564	44.69	150858	89178	59.11

by the economically active population, have no clear trend at the aggregate level. When the sexes are viewed separately, however, clear trends emerge. Over the period 1947 to 1973 there has been a gradual decline in male employment rates and a marked increase in female employment rates of eight percentage points. As a consequence of the increase on female employment rates, the sex ratio for employed workers has declined from 249.0 in 1947 to 158.0 in 1973.

Table 16 gives the rate of growth of total population, school enrollment, school age population, employment, and economically active population by educational attainment and sex. Growth rates are given for the period 1948-1973 and for subperiods corresponding to individual business cycles during the postwar period. Rates of growth of female school enrollment were systematically higher than the corresponding rates of growth of male school enrollment. Female employment also grew more rapidly than male employment. The table provides a contrast between the behavior of the school age population and school enrollment. Similarly, the table provides a contrast between the behavior of the economically active population and that of employment. Much less variation is found in rates of growth of the school age population than in school enrollment and less variation is found in rates of growth of the economically active population than in employment.

Table 16

Total Population, School Enrollment, School Age Population, Employment, and Economically Active Population by Sex and Level of Educational Attainment -- Rates of Growth, 1948-1973.

	1948 1973	1948 1953	1953 1957	1957 1960	1960 1966	1966 1969	1969 1973
Elementary							
Male							
Population	.07	1.01	1.09	.73	-.38	-1.55	-.68
Enrollment	2.06	3.44	3.91	3.23	1.75	.78	-.90
School Age	.93	1.33	1.89	1.73	1.08	.15	-.77
Employment	-3.33	-0.85	-3.25	-3.19	-4.06	-3.69	-5.23
Econ. Active	-1.30	-1.14	-.92	-1.65	-1.78	-2.71	.19
Female							
Population	.18	1.15	1.22	.87	-.26	-1.46	-.65
Enrollment	2.12	3.61	4.03	3.45	1.74	.77	-.97
School Age	1.02	1.37	1.96	1.89	1.21	.37	-.78
Employment	-1.50	0.78	0.12	-0.72	-2.30	-1.89	-5.07
Econ. Active	-1.12	-1.00	-.80	-1.56	-1.51	-2.43	.33
Secondary							
Male							
Population	2.44	2.10	2.30	2.84	2.89	2.55	1.99
Enrollment	3.31	1.14	4.38	4.64	4.92	2.70	2.06
School Age	2.10	.62	1.06	2.23	3.06	2.84	2.92
Employment	1.98	1.75	1.70	0.34	3.47	1.93	1.56
Econ. Active	2.45	2.10	2.30	2.83	2.89	2.55	1.99
Female							
Population	2.50	2.38	2.44	2.78	2.85	2.60	1.92
Enrollment	3.53	1.43	4.69	4.32	4.74	2.68	2.01
School Age	1.86	.91	.95	1.71	2.46	2.42	2.78
Employment	3.49	3.32	3.61	1.09	4.94	4.33	2.56
Econ. Active	2.51	2.39	2.44	2.78	2.86	2.61	1.93
College							
Male							
Population	3.72	3.31	3.24	3.71	4.36	5.19	2.09
Enrollment	4.50	-.73	1.20	5.12	8.91	9.17	4.19
School Age	4.00	2.63	2.35	3.10	5.07	7.10	4.13
Employment	4.04	3.48	2.69	4.06	4.08	5.15	5.18
Econ. Active	3.72	3.31	3.24	3.71	4.36	5.19	2.09
Female							
Population	3.39	2.52	2.58	3.30	4.26	5.21	2.71
Enrollment	5.93	1.12	4.77	7.42	9.97	8.97	3.95
School Age	3.88	1.26	1.57	3.05	5.76	7.99	4.52
Employment	4.70	3.21	3.09	6.89	3.85	6.27	6.63
Econ. Active	3.39	2.52	2.58	3.30	4.26	5.21	2.71

In Section 3 we have described a data base that includes the number of employed persons for the United States on an annual basis, cross-classified by sex, employment class, age, education, occupation and industry. We have aggregated over employment class, occupation, and industry, and distributed the work force of each sex by individual years of age from 14 to 74 and by individual years of educational attainment from one to 18. The data base described in Section 3 also includes data on hours worked and labor compensation on the same basis as data on employed persons. We have derived annual estimates of hours worked and labor compensation required for measuring incomes from market labor activities by summing over employment class, occupation, and industry, as before. We obtain average hourly labor compensation for individuals classified by the two sexes, sixty-one age groups, and eight education groups for a total of 2196 groups by dividing market labor compensation by hours worked for each group.

Labor input in constant prices is based on data on annual hours worked and labor compensation per hour, cross-classified by sex, age and education. To construct an index of labor input, we assume that labor input can be expressed as a translog function of its 2196 components. The corresponding index of labor input is a translog quantity index of individual labor inputs where weights are given by average shares of each component in the value of labor outlay. Table 17 presents our estimates of the value of market labor activities in current prices, cross-classified by sex and educational attainment, for the U.S. economy from 1947 to 1973. Table 18 presents the corresponding estimates in constant prices of 1972.

Table 17

Value of Market Labor Activities by Sex and Educational Attainment, 1947-1973
(Billions of Current Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	169.3	51.2	58.8	29.6	7.8	15.8	6.0
1948	178.1	53.5	61.9	31.4	8.3	16.6	6.5
1949	177.5	52.1	61.0	32.2	8.4	16.9	6.9
1950	191.0	55.4	64.8	35.6	8.9	18.2	8.2
1951	215.5	61.1	74.5	40.3	10.1	20.9	8.6
1952	230.2	62.2	80.5	44.9	10.3	22.8	9.5
1953	246.1	64.1	87.4	49.6	10.7	24.3	10.0
1954	245.9	61.2	87.7	51.2	10.3	25.0	10.5
1955	263.5	62.8	95.1	55.4	11.2	27.4	11.6
1956	284.9	65.6	103.9	60.4	11.9	30.5	12.5
1957	299.2	65.6	110.1	65.2	12.1	32.7	13.6
1958	301.4	62.1	110.5	68.4	12.0	33.9	14.6
1959	324.7	64.6	120.6	74.5	12.8	36.4	15.7
1960	339.9	66.5	126.5	80.0	12.1	33.4	17.2
1961	348.8	61.0	128.1	88.3	12.5	39.4	19.5
1962	370.3	59.4	138.5	96.8	12.0	42.2	21.3
1963	387.4	60.8	146.9	99.9	12.6	45.8	21.5
1964	413.6	60.1	159.4	108.1	12.7	49.8	23.5
1965	443.1	62.3	172.4	115.3	12.9	54.8	25.3
1966	484.7	64.0	188.9	128.8	13.4	61.0	28.6
1967	518.6	64.8	198.8	143.6	14.0	66.0	31.6
1968	569.4	66.5	219.0	159.3	14.5	73.7	36.4
1969	626.7	69.0	239.5	178.5	15.1	84.2	40.5
1970	668.1	73.6	251.5	195.8	15.7	85.8	45.8
1971	714.8	68.6	267.8	215.3	15.0	95.6	52.6
1972	783.1	69.7	291.4	239.7	15.1	108.0	59.2
1973	866.1	70.6	321.4	269.9	15.4	120.0	68.8

Table 18

Value of Market Labor Activities by Sex and Educational Attainment, 1947-1973
(Billions of Constant Dollars)

1947	556.9	163.9	195.8	102.5	24.1	49.4	21.3
1948	561.1	162.6	197.1	104.9	24.5	50.0	22.0
1949	543.3	154.7	188.7	103.5	24.3	49.5	22.6
1950	564.5	161.6	193.0	109.3	24.2	51.1	25.4
1951	586.3	161.6	204.3	113.8	26.2	55.7	24.8
1952	598.8	157.8	211.2	120.4	25.3	58.1	25.9
1953	609.4	154.9	218.0	125.8	25.0	59.5	26.1
1954	594.6	145.4	213.3	126.1	23.8	59.7	26.2
1955	610.8	144.1	221.4	129.0	25.1	63.5	27.6
1956	621.4	140.6	227.0	133.1	25.4	66.9	28.4
1957	619.7	133.3	227.9	136.2	24.7	68.4	29.2
1958	605.1	122.9	221.5	138.3	23.9	68.7	29.9
1959	623.9	122.3	230.8	143.9	24.6	71.4	30.9
1960	641.0	126.0	237.8	157.0	22.4	64.6	33.1
1961	636.2	110.2	232.7	161.0	22.7	72.7	36.8
1962	657.0	104.4	244.5	171.4	21.3	76.0	39.4
1963	663.2	102.8	249.6	172.0	21.6	79.0	38.3
1964	677.9	97.4	259.1	177.9	20.8	82.7	39.9
1965	699.4	96.3	268.9	184.7	20.4	87.3	41.9
1966	721.7	94.3	278.8	192.3	19.5	92.2	44.5
1967	732.6	90.5	279.3	203.0	19.5	94.2	46.1
1968	746.9	86.3	285.1	209.9	18.5	97.6	49.4
1969	765.2	82.9	290.6	219.0	17.9	103.7	51.1
1970	765.6	84.1	288.8	224.3	17.7	98.0	52.8
1971	763.1	72.8	285.7	230.0	15.7	102.6	56.4
1972	783.1	69.7	291.4	239.7	15.1	108.0	59.2
1973	815.2	65.2	302.4	256.5	14.3	112.2	64.6

The value of market labor compensation in current prices has increased by 411.6 percent over the postwar period. The proportional increases were greatest for college trained workers -- 811.8 percent for males and 1046.7 percent for females. By contrast compensation for workers with only elementary education has increased by 37.9 percent for males and 97.4 percent for females. Compensation for workers with secondary education has increased by 446.6 percent for males and 659.5 percent for females. For all levels of educational attainment the proportional increase for females has exceeded that for males. The corresponding patterns for market labor compensation in constant prices are very similar. Labor compensation in constant prices represents a quantity index of labor input. The quantity of labor input for the economy as a whole has increased by 46.4 percent over the postwar period. The quantity of labor input for workers with only elementary education has fallen 60.2 percent for males and 40.7 percent for females. By contrast the quantity of labor input for college trained workers has increased by 150.2 percent for males and 203.3 percent for females. The corresponding increases for workers with secondary education were 54.4 percent for males and 127.1 percent for females.

We next analyze the sources of growth in labor input in more detail. For each of the 2196 components of the labor force incorporated into our data base, labor input is the product of the the number of persons employed and annual hours worked per person. We present estimates of the number of persons employed, cross-classified by sex and educational attainment, in Table 19. We present the corresponding estimates of annual hours worked per person, also cross-classified by sex and educational

Table 19

Employment by Sex and Educational Attainment, 1947-73
(Thousands)

		Male			Female		
Year	Total	Elementary	Secondary	College	Elementary	Secondary	College
1947	60749	19747	17728	5866	5769	9039	2601
1948	61342	19687	17935	6038	5878	9124	2679
1949	59812	18901	17254	5998	5858	9044	2759
1950	61336	19534	17432	6295	5777	9217	3081
1951	63946	19556	18442	6489	6298	10147	3015
1952	64694	19046	18889	6823	6169	10620	3147
1953	65666	18866	19583	7186	6114	10773	3146
1954	64192	17824	19223	7225	5868	10857	3195
1955	65881	17549	19956	7415	6157	11460	3344
1956	67486	17248	20667	7728	6289	12115	3440
1957	67692	16564	20969	8005	6145	12448	3561
1958	66113	15394	20470	8187	5949	12475	3637
1959	67834	15248	21353	8550	6032	12940	3711
1960	68535	15048	21187	9044	6013	12865	4379
1961	68632	13784	21624	9623	5764	13384	4454
1962	69924	13054	22531	10226	5479	13913	4722
1963	70633	12774	23047	10201	5519	14483	4609
1964	72133	12164	24056	10590	5356	15179	4789
1965	74460	12014	25062	10960	5273	16074	5078
1966	77516	11791	26106	11558	5235	17311	5517
1967	78933	11393	26262	12356	5234	17833	5855
1968	80865	10955	27005	12893	5096	18545	6372
1969	83031	10554	27665	13493	4946	19714	6659
1970	83046	10583	27113	13917	4846	19364	7224
1971	83340	9443	27484	14613	4443	19831	7526
1972	85776	9071	28148	15452	4252	20914	7939
1973	89178	9560	29448	16605	4038	21844	8683

attainment, in Table 20. Finally, we define the quality of hours worked as the ratio of the translog index of labor input from Table 18 to the number of hours worked by the corresponding component of the work force. Labor input then becomes the product of the number of persons employed, annual hours worked per person, and the quality of hours worked. We present indexes of labor quality by sex and educational attainment in Table 21. Employment declines for both male and female workers with elementary education, increases substantially for workers with secondary education, and increases very rapidly for college trained workers. By contrast hours worked per person decline for workers of both sexes at all three levels of educational attainment. Changes in the quality of hours worked within each category are relatively small.

Finally, we analyze changes in the structure of labor input for the U.S. economy over the period 1947-1973. For this purpose we present growth rates of the value of market labor activities in current and constant prices. The quantity of labor input per worker, and the price of labor input for the period as a whole and for six subperiods in Table 22. The annual growth rates for market labor compensation in current and constant prices for the postwar period as a whole reflect the trends we have already analyzed in Tables 17 and 18. For both males and females the price of labor input increases most rapidly for college trained workers, next most rapidly for workers with secondary education, and least rapidly for workers with elementary education. The patterns are positively correlated with the growth of labor input within these categories -- higher rates of price increase are associated with higher rates of growth of labor input.

Table 20

Annual Hours per Person by Sex and Educational Attainment, 1947-73

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	2055	2134	2143	2193	1825	1814	1895
1948	2048	2125	2135	2184	1823	1813	1892
1949	2026	2103	2113	2161	1809	1799	1873
1950	2028	2106	2117	2157	1812	1801	1859
1951	2027	2111	2119	2168	1805	1792	1862
1952	2016	2106	2112	2159	1788	1777	1842
1953	2005	2086	2091	2130	1794	1790	1845
1954	1983	2065	2068	2108	1777	1773	1823
1955	1988	2072	2071	2113	1788	1784	1830
1956	1973	2057	2052	2097	1781	1779	1822
1957	1947	2026	2026	2071	1760	1764	1808
1958	1932	2001	2010	2055	1751	1760	1804
1959	1938	2005	2014	2062	1768	1766	1812
1960	1928	2063	2076	2158	1610	1595	1681
1961	1915	1995	1999	2044	1722	1734	1770
1962	1915	1993	2005	2050	1705	1728	1771
1963	1913	1995	2009	2049	1703	1723	1766
1964	1905	1980	1999	2043	1692	1719	1765
1965	1904	1985	2001	2045	1681	1718	1752
1966	1884	1977	1990	2035	1639	1684	1730
1967	1868	1962	1971	2022	1618	1673	1715
1968	1854	1949	1957	2006	1603	1662	1705
1969	1849	1949	1953	2004	1603	1659	1699
1970	1824	1953	1947	2019	1585	1574	1633
1971	1819	1915	1927	1974	1567	1623	1666
1972	1820	1907	1932	1981	1559	1625	1665
1973	1817	1898	1930	1982	1505	1621	1663

Table 21

Quality of Labor Input by Sex and Educational Attainment, 1947-73
(1972 = 1.000)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	0.894	.964	.962	1.017	1.005	.948	.965
1948	0.895	.964	.961	1.016	1.005	.952	.971
1949	0.898	.965	.966	1.020	1.007	.958	.979
1950	0.909	.974	.976	1.029	1.015	.968	.989
1951	0.906	.971	.976	1.033	1.012	.963	.985
1952	0.919	.976	.988	1.044	1.009	.969	.998
1953	0.926	.977	.994	1.050	1.004	.971	1.003
1954	0.934	.980	1.001	1.058	1.004	.976	1.006
1955	0.933	.983	1.000	1.052	1.003	.978	1.009
1956	0.933	.983	.999	1.049	.998	.977	1.010
1957	0.939	.986	1.001	1.049	1.004	.980	1.013
1958	0.946	.989	1.005	1.050	1.007	.984	1.017
1959	0.948	.992	1.002	1.043	1.013	.984	1.026
1960	0.969	1.007	1.009	1.027	1.013	.991	1.006
1961	0.967	.994	1.005	1.045	1.005	.986	1.044
1962	0.980	.995	1.010	1.045	1.002	.995	1.052
1963	0.980	1.000	1.007	1.051	1.010	.996	1.050
1964	0.985	1.003	1.006	1.050	1.009	.997	1.055
1965	0.985	1.002	1.000	1.052	1.011	.995	1.053
1966	0.986	1.004	1.001	1.045	1.000	.995	1.042
1967	0.991	1.005	1.007	1.038	1.014	.993	1.025
1968	0.994	1.002	1.007	1.037	.997	.997	1.017
1969	0.994	1.000	1.004	1.035	.991	.998	1.009
1970	1.008	1.009	1.021	1.020	1.014	1.012	.999
1971	1.004	.999	1.007	1.018	.993	1.003	1.004
1972	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1973	1.003	.996	.993	.995	1.005	.998	.999

Table 22

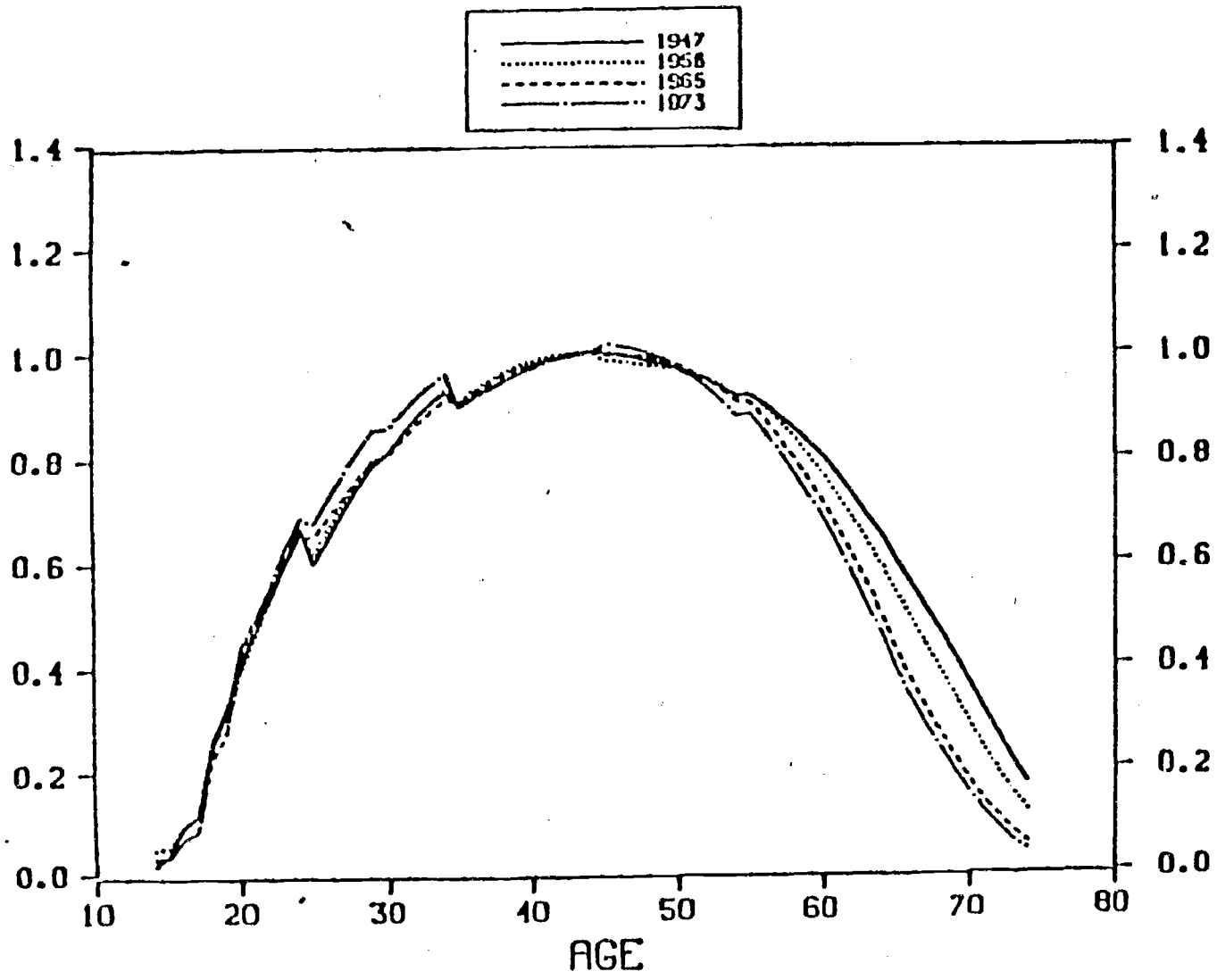
Value of Market Labor Activities by Educational Attainment and Sex, Rates of Growth, 1948-1973

	1948 1973	1948 1953	1953 1957	1957 1960	1960 1966	1966 1969	1969 1973
ELEM							
MALE							
VALUE (CURRENT)	1.12	3.69	.60	.43	-.63	2.54	.57
VALUE (CONSTANT)	-3.59	-.96	-3.68	-1.87	-4.71	-4.20	-5.83
PER CAP.(CONSTANT)	-.32	-.11	-.50	1.32	-.76	-.59	-.77
PRICE INDEX	4.88	4.69	4.44	2.35	4.28	7.03	6.80
FEMALE							
VALUE (CURRENT)	2.47	5.15	3.02	.21	1.61	4.14	.42
VALUE (CONSTANT)	-2.14	.44	-.36	-3.15	-2.29	-2.90	-5.50
PER CAP.(CONSTANT)	-.66	-.35	-.49	-2.44	-.00	-1.04	-.58
PRICE INDEX	4.72	4.68	3.40	3.46	3.99	7.25	6.27
SECOND							
MALE							
VALUE (CURRENT)	6.81	7.16	5.92	4.76	6.90	9.24	7.62
VALUE (CONSTANT)	1.73	2.04	1.11	1.42	2.69	1.39	1.00
PER CAP.(CONSTANT)	-.27	.26	-.60	1.07	-.82	-.55	-.56
PRICE INDEX	5.00	5.02	4.76	3.29	4.11	6.76	6.56
FEMALE							
VALUE (CURRENT)	8.24	7.94	7.68	.77	10.55	11.33	9.27
VALUE (CONSTANT)	3.29	3.52	3.56	-1.86	6.10	4.01	1.99
PER CAP.(CONSTANT)	-.26	.14	-.12	-2.94	.97	-.40	-.59
PRICE INDEX	4.80	4.27	3.97	2.68	4.20	7.04	7.14
COLLEG							
MALE							
VALUE (CURRENT)	8.98	9.54	7.08	8.84	7.37	11.48	10.90
VALUE (CONSTANT)	3.64	3.70	2.00	4.85	3.44	4.42	4.03
PER CAP.(CONSTANT)	-.47	.15	-.72	.67	-.70	-.83	-1.23
PRICE INDEX	5.15	5.63	4.98	3.81	3.80	6.76	6.60
FEMALE							
VALUE (CURRENT)	9.93	9.15	8.01	8.23	8.81	12.25	14.18
VALUE (CONSTANT)	4.40	3.42	2.89	4.30	5.04	4.72	6.01
PER CAP.(CONSTANT)	-.40	.15	-.25	-2.65	1.08	-1.65	-.79
PRICE INDEX	5.30	5.54	4.98	3.77	3.58	7.20	7.70

In Figure 1 we present age-earnings profiles for different periods to illustrate the character of the data base employed in the estimation of labor input in constant prices. These profiles also indicate potential applications of our data on labor input in other areas of research. We have derived average per capita earnings from market labor activities by single years of age, aggregating labor compensation over sex and education and dividing by population. We have then normalized all age-earnings profiles to age 44 where labor compensation per person is highest. Figure 1 presents age-earnings per capita for selected years — 1947, 1956, 1965, 1973. The profiles are very similar from ages 14 through 55, but after age 55 we note a decrease in participation in the labor market by these age groups.

Figure 1

Relative Earnings by Age
Selected Years, United States, 1947-73



We have now completed the presentation of the utilization of human resources in the labor market. Our next objective is to evaluate the time spent on nonmarket activities, considering both consumption and investment activities. The importance of the valuation of nonmarket activities is widely recognized. Nordhaus and Tobin (1972) have incorporated nonmarket activities into their measure of economic welfare. Kendrick (1976) and Eisner (1978) have extended the national income and product accounts by imputing value to time spent outside the labor market.[14] Unfortunately, there is no clear agreement on what types of activities should be included or on methods appropriate for valuation of nonmarket activities.

To account for nonmarket labor activities in a complete accounting system, we consider only contributions to final product and deduct all uses of time that are instrumental to the production of goods. Six types of nonmarket activities are commonly distinguished in studies of time allocation -- production of goods and services within the household unit, volunteer work outside the household unit, commuting to work, formal education, leisure, and the satisfaction of physiological needs such as eating and sleeping.[15] We classify time spent satisfying physiological needs as maintenance and exclude this time from our measure of time spent in nonmarket activities. We assume that the time available for all market and nonmarket activities has been constant over time and is equal to fourteen hours per day for all individuals.

We allocate the annual time available for all individuals in the population among work, schooling, household production and leisure, and maintenance. Our system of demographic accounts includes the enrollment status for individuals of each sex between five and 34 years of age. We estimate the time spent in formal schooling for all individuals by assigning 1300 hours per year to each person enrolled in school.[16] We allocate time spent in schooling to investment. Similarly, our demographic accounts include employment status for individuals of each sex between 14 and 74 years of age. Hours worked for all employed individuals, classified by sex, age, and education, are included in our data base for market labor activities. We allocate time that is not spent working or in formal schooling directly to consumption. For all individuals this time is equal to the difference between fourteen hours per day and time spent working or in school.

The final step in the measurement of lifetime labor incomes is to impute the value of labor compensation for nonmarket activities.[17] For this purpose we first obtain average hourly labor compensation for all employed persons, cross-classified by sex, age, and education, from our data base for market labor activities. Second, we estimate marginal tax rates for all employed persons, again cross-classified by sex, age, and education.[18] We multiply compensation per hour by one minus the marginal tax rate to obtain imputed hourly labor compensation for nonmarket activities other than formal schooling. Since individuals under fourteen years of age do not participate in the labor force, their

imputed hourly labor compensation is set equal to zero. Individuals over seventy-four years of age are also assigned zero as their hourly labor compensation.

We multiply compensation per hour by one minus the marginal tax rate to obtain the value of compensation per hour for nonmarket activities. Hours used in nonmarket activities are obtained by subtracting hours spent on the market and hours spent in formal education from the total time available. Table 23 presents our estimates of the value of leisure and nonmarket labor activities other than formal education in current prices, cross-classified by sex and educational attainment, for the U.S. economy from 1947 to 1973. Table 24 presents the corresponding estimates in constant prices of 1972.

The value of nonmarket activities in current prices has increased by 421.2 percent over the postwar period by comparison with the 411.6 percent increase in the value of market labor activities. Similarly, the value of nonmarket activities in constant prices, a quantity index of labor time devoted to these activities in constant prices, has increased by 50.9 percent by comparison with an increase in the quantity of market labor activities of 46.4 percent. Proportional increases in the value of nonmarket labor activities in both current and constant prices were largest for workers with college education, next largest for those with secondary education, and smallest for those with elementary education. This pattern coincides with that for increases in the value of market labor activities. By contrast proportional increases for the value of nonmarket labor activities were largest for male workers, the reverse of the pattern for market labor activities,

Table 23

Value of Nonmarket Labor Activities by Sex and Educational Attainment
(Billions of Current Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	371.8	82.5	73.7	33.2	69.8	85.5	27.1
1948	405.7	88.3	82.2	38.5	73.2	93.4	30.0
1949	429.5	91.5	89.3	42.8	73.8	99.5	32.6
1950	446.2	90.7	93.6	45.9	76.1	105.0	34.8
1951	467.7	95.5	99.6	49.1	76.0	110.3	37.1
1952	489.1	97.2	104.7	52.3	78.2	116.3	39.4
1953	518.9	101.3	113.0	57.3	81.1	124.1	42.1
1954	555.2	105.8	124.0	63.8	81.9	133.5	46.3
1955	580.2	108.7	131.9	69.0	81.9	139.6	49.1
1956	621.2	114.7	143.9	75.4	84.3	150.1	52.7
1957	666.5	121.3	157.2	83.0	86.8	161.0	57.3
1958	704.1	124.7	169.3	90.1	87.2	170.8	61.9
1959	733.9	127.8	179.9	96.4	85.3	178.8	65.8
1960	762.2	124.6	185.6	101.1	90.8	189.7	70.5
1961	809.4	130.2	200.3	113.3	89.3	201.6	74.7
1962	844.2	131.3	211.2	121.0	89.8	211.7	79.1
1963	886.6	132.3	223.5	128.8	90.5	226.4	85.1
1964	956.4	136.9	243.4	142.9	95.7	243.6	93.9
1965	1016.6	139.2	261.9	153.5	98.3	262.9	100.8
1966	1096.3	144.4	281.1	171.4	104.3	283.0	111.9
1967	1171.2	147.8	303.2	187.1	102.9	306.1	124.0
1968	1269.7	151.0	331.0	207.1	112.1	332.5	136.0
1969	1379.5	155.7	360.3	230.1	119.1	362.3	152.1
1970	1540.8	160.1	403.7	266.6	120.8	410.3	179.2
1971	1711.0	181.5	453.2	297.4	135.7	447.3	195.9
1972	1819.2	189.5	485.3	315.6	136.5	481.3	211.0
1973	1960.0	211.3	518.2	336.2	149.4	518.3	226.8

Table 24

Value of Nonmarket Labor Activities by Sex and Educational Attainment
(Billions of Constant Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	1224.1	281.4	261.1	126.2	208.9	254.2	92.4
1948	1243.8	278.0	269.3	131.8	206.3	262.2	96.1
1949	1264.1	274.9	277.5	137.5	203.8	270.4	99.9
1950	1282.1	271.3	285.1	143.2	200.9	278.0	105.5
1951	1298.3	268.9	291.9	148.0	198.4	285.5	105.7
1952	1314.8	266.3	298.7	153.0	195.8	292.9	108.1
1953	1330.4	263.2	305.5	158.0	193.0	300.1	110.6
1954	1347.7	260.3	312.8	163.6	190.2	307.5	113.4
1955	1365.1	257.2	320.0	169.4	187.4	314.8	116.3
1956	1384.0	254.2	327.7	175.5	184.6	322.5	119.5
1957	1404.1	251.4	335.6	181.8	182.1	330.3	122.9
1958	1422.4	247.3	343.6	188.2	178.7	338.2	126.4
1959	1441.2	242.9	352.1	195.0	174.7	346.4	130.2
1960	1467.2	239.2	362.6	203.0	171.2	356.4	134.9
1961	1494.5	237.4	371.9	210.6	169.6	365.6	139.4
1962	1519.9	232.9	381.9	218.9	166.1	375.5	144.6
1963	1543.7	227.3	391.7	227.4	162.1	385.4	150.0
1964	1568.5	221.4	401.6	236.3	158.0	395.6	155.7
1965	1597.4	215.9	412.8	245.7	154.2	407.0	161.8
1966	1628.7	210.3	424.1	256.5	150.3	418.4	169.1
1967	1660.6	204.4	435.0	268.0	146.3	429.8	177.0
1968	1693.6	198.2	446.2	280.1	142.2	441.5	185.4
1969	1727.3	191.6	457.7	292.8	137.6	453.3	194.2
1970	1763.4	184.5	470.1	306.6	132.6	465.7	203.8
1971	1791.2	187.3	477.6	310.9	134.7	473.6	207.2
1972	1819.2	189.5	485.3	315.6	136.5	481.3	211.0
1973	1847.6	191.7	493.3	320.5	138.3	489.2	214.7

where proportional increases were largest for female workers.

Finally, we analyze changes in the structure of nonmarket labor activities for the U.S. economy over the period 1948-1973. For this purpose we present growth rates of the value of nonmarket labor activities in current and constant prices, the quantity of nonmarket activity per worker, and the price of labor utilized in nonmarket activities for the period as a whole and for six subperiods in Table 25. As in the analysis of the structure of market labor activities, the annual growth rates for nonmarket labor compensation in current and constant prices for the postwar period as a whole reflect the trends we have analyzed in Tables 23 and 24. For both males and females the price of labor utilized in nonmarket activities increased most rapidly for college trained workers, next most rapidly for workers with elementary education and least rapidly for workers with secondary education. For the price of labor utilized in market labor activities the increases were greatest for college trained workers and least for workers with elementary education.

Table 26 presents a comparison between our results and those obtained by Nordhaus and Tobin (1972) for four years in which comparable estimates are available. For this purpose we have taken the base for all price indexes employed in our estimates of the value of nonmarket labor activity to be 1958. Nordhaus and Tobin's estimates are six to fifteen percent above our estimates in current dollars, and twelve to thirteen percent above our estimates in constant dollars. Since their estimates are derived using wage rates before taxes, we would expect an upward bias.

Table 25

Value of Nonmarket Labor Activities by
Educational Attainment and Sex, Rates of Growth, 1948-1973

	1948 1973	1948 1953	1953 1957	1957 1960	1960 1966	1966 1969	1969 1973
ELEM							
MALE							
VALUE (CURRENT)	3.55	2.77	4.60	.92	2.49	2.53	7.94
VALUE (CONSTANT)	-1.48	-1.09	-1.14	-1.65	-2.12	-3.06	.01
PER CAP.(CONSTANT)	-1.55	-2.08	-2.20	-2.36	-1.75	-1.53	.70
PRICE INDEX	5.10	3.91	5.80	2.61	4.71	5.76	7.92
FEMALE							
VALUE (CURRENT)	2.89	2.06	1.71	1.50	2.35	4.50	5.83
VALUE (CONSTANT)	-1.59	-1.32	-1.44	-2.05	-2.15	-2.89	.11
PER CAP.(CONSTANT)	-1.77	-2.45	-2.62	-2.89	-1.89	-1.46	.78
PRICE INDEX	4.55	3.42	3.19	3.62	4.60	7.61	5.71
SECOND							
MALE							
VALUE (CURRENT)	7.64	6.58	8.59	5.69	7.17	8.62	9.51
VALUE (CONSTANT)	2.45	2.55	2.38	2.62	2.64	2.58	1.89
PER CAP.(CONSTANT)	.01	.45	.07	-.21	-.24	.03	-.10
PRICE INDEX	5.07	3.93	6.07	2.99	4.41	5.90	7.48
FEMALE							
VALUE (CURRENT)	7.09	5.94	6.73	5.62	6.90	8.58	9.36
VALUE (CONSTANT)	2.53	2.74	2.42	2.57	2.71	2.71	1.92
PER CAP.(CONSTANT)	.02	.35	-.02	-.21	-.14	.10	-.01
PRICE INDEX	4.46	3.02	4.21	2.97	4.08	5.71	7.30
COLLEG							
MALE							
VALUE (CURRENT)	9.05	8.28	9.70	6.80	9.20	10.31	9.94
VALUE (CONSTANT)	3.62	3.70	3.57	3.74	3.98	4.51	2.29
PER CAP.(CONSTANT)	-.10	.38	.31	.03	-.37	-.65	-.39
PRICE INDEX	5.25	4.42	5.92	2.95	5.02	5.56	7.49
FEMALE							
VALUE (CURRENT)	8.42	6.99	8.01	7.17	8.00	10.75	10.51
VALUE (CONSTANT)	3.27	2.84	2.66	3.15	3.85	4.72	2.54
PER CAP.(CONSTANT)	-.12	.32	.08	-.14	-.40	-.46	-.17
PRICE INDEX	4.99	4.03	5.22	3.89	4.00	5.76	7.77

Table 26

Value of Nonmarket Labor Activities
Selected Years, 1947-1973 (Billions of Dollars)

	Current			Constant (1958)		
Year	J-P	Nordhaus-Tobin	Ratio	J-P	Nordhaus-Tobin	Ratio
1947	371.8	393.6	.945	607.9	682.4	.891
1954	555.2	637.0	.871	667.6	755.1	.884
1958	704.1	794.6	.886	704.1	794.6	.886
1965	1016.01	1096.9	.926	790.3	886.7	.891

The measurement of human capital is a very active area of research. Investment in formal education has been measured by Schultz (1961), Machlup (1962), Kendrick (1976) and many others.[19] To estimate lifetime labor incomes for all individuals in the U.S. population we distinguish among three stages in the life cycle. In the first stage individuals may participate in formal schooling, but not in the labor market. In the second stage individuals may enroll in school and also work. In the third stage individuals may participate in the labor market, but not in formal schooling. For individuals in the third stage of the life cycle total labor compensation is the sum of compensation for market labor activities after taxes and imputed compensation for nonmarket labor activities. For individuals in the second stage of the life cycle total labor compensation also includes imputed labor compensation for schooling. For individuals in the first stage of the life cycle labor compensation includes only the imputed value of time spent in schooling.

For an individual in the third stage of the life cycle, we assume that expected incomes in future time periods are equal to the incomes of individuals of the same sex and education, but with the age that the individual will have in the future time period, adjusted for increases in real income. We assume that real incomes rise over time at the rate of Harrod-neutral technical change, which we estimate at two percent per year. We weight income for each future year by the probability of survival, given the initial age of the individual. We obtain these

probabilities by sex from publications of the National Center for Health Statistics. Where necessary, these survival functions, giving probability of survival by age and sex, are interpolated by means of standard demographic technique. Finally, we discount expected future incomes at a real rate of return of four percent per year to obtain the lifetime labor income of an individual of a given sex, age, and education.

For an individual at the second stage of the life cycle, combining formal schooling with the possibility of participation in the labor market, we impute the value of time spent in schooling through its impact on lifetime labor income. For an individual of a given sex and age who is completing the highest level of schooling, grade eighteen, lifetime labor income is the discounted value of expected future labor incomes for a person of that sex and age and eighteen years of schooling. The imputed labor compensation for the time spent in formal schooling is equal to the difference between the lifetime labor incomes of an individual with eighteen years of education and an individual with the same sex and age and one less year of education, less tuition and fees for that grade of schooling. Total labor compensation is equal to the value of time spent in formal schooling plus labor compensation for market and nonmarket activities other than formal schooling.

For an individual completing grade seventeen, lifetime labor income is equal to the lifetime labor income of an individual of the same sex and education, but one year older, plus expected labor compensation for one year, discounted back to the present and multiplied by the probability of survival for one year. Expected labor compensation is equal to the

probability of enrollment in grade eighteen, multiplied by market and nonmarket labor compensation for a person enrolled in that grade, and one minus the probability of enrollment, multiplied by market and nonlabor compensation for a person with seventeen years of education, not enrolled in school. As before, the imputed labor compensation for the time spent in formal schooling is equal to the difference between the lifetime incomes of an individual with seventeen years of education and an individual with the same sex and age and one less year of education, less tuition and fees. Using the same approach to defining lifetime labor incomes for individuals completing earlier grades, lifetime incomes and imputed labor compensation for the time spent in formal schooling can be determined for individuals completing sixteen years of education, fifteen years of education and so on.

For an individual in the first stage of the life cycle, where participation in the labor market is ruled out, the value of labor compensation is limited to the imputed value of schooling. Lifetime incomes for individuals at this stage of the life cycle can be determined for individuals completing one year of education, two years of education, and so on, working back from higher levels of education as outlined above. For individuals too young to be enrolled in school, imputed labor compensation is zero, but lifetime labor incomes are well defined. The value of a newborn entrant into the population is equal to the lifetime labor income of the individual at age zero.

To estimate investment in human capital through education we employ data on lifetime labor incomes, cross-classified by single year of age and single grade of highest educational attainment. We use the increments in lifetime labor incomes and the number of individuals enrolled in school to estimate the value of investment in education. In Table 27 we present our estimates of the investment in formal education in current dollars. The most striking feature of our estimates is the high values we obtain. In 1947 investment through formal education is 2.7 times the value of market labor input. The rate of growth of the value of investment in education, 10.8 percent per year, is considerably higher than the rate of growth of the value of labor input, 6.5 percent per year. Investment is highest for elementary education, second highest for secondary education, and lowest for higher education. Considering the shares of each level of education in total investment, we observe a decrease in the shares of secondary and higher education. Considering shares in investment by sex, we see that the male share has decreased throughout the postwar period.

Table 28 presents our estimates of investment in formal education in constant dollars. We observe the same striking features: Investment in education is very large by comparison with market labor input, amounting to 5.13 times labor input in 1973; the rate of growth is higher than the rate of growth in labor input -- 3.0 percent per year for investment in education versus 1.5 percent per year for labor input. Investment is highest for elementary education, next to highest for secondary education, and lowest

Table 27

Investment In Formal Education by Sex and Educational Attainment, 1947-73
(Billions of Current Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	450.4	220.8	66.4	14.5	115.3	27.2	6.3
1948	498.7	246.1	73.4	16.9	125.0	29.7	7.7
1949	554.6	273.5	78.3	18.7	143.2	32.5	8.5
1950	600.9	302.1	82.0	20.6	152.4	34.4	9.6
1951	660.0	322.5	88.2	22.5	175.1	40.5	11.1
1952	721.5	351.2	95.9	24.2	192.0	45.8	12.4
1953	814.1	398.2	106.7	26.1	218.2	51.6	13.3
1954	961.2	465.4	122.3	28.6	266.4	62.6	15.8
1955	1098.7	530.1	138.4	31.4	307.5	73.3	18.0
1956	1214.6	584.5	152.5	33.7	342.7	81.5	19.7
1957	1384.9	656.9	173.9	37.0	397.0	97.3	22.8
1958	1549.1	717.3	197.4	39.6	451.4	117.4	26.1
1959	1721.6	780.9	221.7	42.6	508.5	138.2	29.6
1960	1900.0	880.2	251.7	47.0	533.7	152.6	34.8
1961	2159.5	1002.1	287.4	50.7	615.4	168.5	35.4
1962	2362.7	1090.4	329.7	57.9	654.5	190.0	40.2
1963	2535.0	1141.6	365.5	63.9	703.6	215.4	45.1
1964	2887.0	1282.1	430.4	73.4	788.7	258.7	53.6
1965	3059.1	1347.2	467.6	79.2	826.2	280.9	58.2
1966	3434.1	1520.1	536.4	91.7	899.7	315.1	71.1
1967	3830.7	1676.7	602.6	108.6	998.4	358.8	85.6
1968	4087.1	1762.9	643.8	118.7	1071.3	394.2	96.2
1969	4099.8	1920.2	727.0	135.3	1171.9	440.7	104.6
1970	5576.1	2344.0	931.3	169.8	1436.7	562.6	131.7
1971	6081.2	2543.8	1026.2	186.9	1549.4	627.2	147.6
1972	6263.1	2542.9	1057.7	201.7	1618.7	677.7	164.4
1973	6520.1	2599.4	1125.5	224.3	1671.3	723.7	175.9

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Table 28

Investment in Formal Education by Sex and Educational Attainment, 1947-73
(Billions of Constant Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	2870.4	1241.9	425.5	71.8	786.3	295.8	49.2
1948	2927.1	1275.7	424.2	74.7	809.2	292.8	50.5
1949	3013.6	1328.1	422.8	77.2	844.2	289.7	51.9
1950	3108.8	1390.5	417.2	79.7	881.7	286.8	52.9
1951	3195.5	1433.7	424.5	80.4	912.2	291.8	52.9
1952	3285.4	1476.5	433.8	81.0	942.7	298.5	52.9
1953	3438.1	1551.6	447.4	81.6	996.3	308.2	53.1
1954	3613.6	1639.7	463.6	83.0	1054.4	318.6	54.3
1955	3776.7	1719.4	479.3	84.6	1108.4	329.2	55.8
1956	3941.4	1795.6	499.7	86.2	1159.4	343.0	57.5
1957	4109.8	1867.6	526.0	88.3	1207.4	360.7	59.8
1958	4284.1	1931.4	563.6	90.9	1248.8	387.0	62.4
1959	4462.3	1994.9	603.5	93.7	1293.2	411.8	65.3
1960	4664.6	2078.7	637.3	97.9	1350.8	430.5	69.4
1961	4847.5	2161.6	659.6	102.9	1406.0	442.2	74.9
1962	5029.5	2223.6	702.0	109.7	1438.7	472.6	82.8
1963	5213.2	2269.9	759.6	116.8	1468.2	509.4	89.2
1964	5397.6	2323.2	813.1	122.9	1501.6	542.5	94.3
1965	5572.6	2377.0	861.6	129.0	1535.2	570.7	99.1
1966	5725.6	2429.2	893.8	140.3	1566.3	582.8	113.3
1967	5862.1	2477.6	914.3	155.0	1594.4	594.0	126.8
1968	5992.2	2518.7	942.5	166.8	1617.0	610.3	137.0
1969	6110.7	2549.4	976.6	117.5	1631.8	629.7	145.7
1970	6215.5	2569.4	1012.8	189.5	1638.6	649.2	156.0
1971	6255.8	2566.3	1035.3	195.6	1635.4	663.3	160.1
1972	6263.1	2542.9	1057.7	201.7	1618.7	677.7	164.4
1973	6244.9	2505.2	1079.4	207.7	1593.3	690.4	168.8

for higher education. While investment in current prices increases throughout the postwar period, investment in constant prices peaks in 1972 and begins to decline. Investment in constant prices for elementary education peaks for both males and females in 1970. Investment in constant prices for secondary and higher education increases throughout the postwar period for both sexes.

In Table 29 we present the investment in formal education per student in current dollars. We present the corresponding estimates in constant prices of 1972 in Table 30. The estimates of investment per student are very high, considerably in excess of per capita earnings. Second, the highest levels of investment per student correspond to elementary education. Third, investment per student at the college level is higher for females than for males. Fourth, while the value of investment per student in constant prices rises for males and females with elementary and secondary education, this value peaks for college trained males in 1955 and for college trained females in 1950. These results are very different from the usual findings on investment in education. In interpreting our estimates it is important to recall that we include the value of leisure and nonmarket activities in lifetime labor incomes, producing very large values for investment in education and reducing the difference between males and females. We measure expected lifetime labor income of a person with one additional year of education from lifetime labor incomes of persons with all higher educational attainment levels by means of the nested procedure described above.

Table 29

Investment per Student by Sex and Educational Attainment, Market and Nonmarket Labor Activities, 1947-73
(Thousands of Current Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	16.2	22.9	19.1	9.2	12.8	8.1	8.4
1948	17.7	22.9	21.3	10.5	13.5	9.0	10.2
1949	19.2	26.8	22.9	11.4	15.0	9.9	11.3
1950	20.3	28.5	24.2	12.4	15.4	10.5	12.6
1951	21.8	29.7	25.6	14.0	17.2	12.1	14.6
1952	23.3	31.5	27.1	15.4	18.3	13.3	16.1
1953	23.3	34.0	29.3	16.9	19.8	14.6	16.8
1954	28.6	37.9	32.6	18.5	23.0	17.1	19.2
1955	31.4	41.4	35.6	20.2	25.5	19.3	21.1
1956	33.5	44.1	37.6	21.3	27.4	20.5	21.8
1957	36.8	48.2	40.3	22.7	30.8	22.9	23.9
1958	39.7	51.2	43.1	23.5	34.0	26.1	25.8
1959	42.5	54.0	46.4	24.2	37.7	29.5	27.4
1960	45.2	58.7	50.9	24.9	37.4	31.6	29.5
1961	49.6	65.5	54.9	24.7	42.4	32.9	27.0
1962	52.5	70.1	58.9	26.1	44.4	34.7	28.1
1963	54.4	72.1	61.3	26.8	46.8	37.0	29.3
1964	60.0	79.4	68.5	28.8	51.5	42.3	32.3
1965	61.9	82.1	72.4	28.0	53.0	45.0	31.1
1966	67.8	91.4	81.3	29.1	56.9	49.5	34.1
1967	73.9	99.6	89.2	31.4	62.5	55.1	37.3
1968	77.1	103.9	92.7	31.4	66.5	58.8	38.5
1969	83.3	112.8	101.8	33.0	72.5	64.0	38.8
1970	101.6	137.8	127.1	38.2	89.1	79.7	45.1
1971	110.1	150.3	137.0	40.9	96.6	86.9	49.3
1972	113.3	152.2	138.5	42.9	102.3	92.2	53.5
1973	118.3	158.3	145.2	46.5	107.6	97.1	55.9

Table 30

Investment per Student by Sex and Educational Attainment, Market and Nonmarket Labor Activities, 1947-73
(Thousands of Constant Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	103.5	128.9	122.4	45.8	87.7	88.7	66.2
1948	104.1	129.3	123.5	46.6	88.0	89.1	67.7
1949	104.7	130.2	124.1	47.3	88.6	89.0	68.9
1950	105.4	131.4	123.5	48.3	89.2	88.4	70.0
1951	106.0	132.1	123.2	50.1	89.8	87.8	69.7
1952	106.4	132.5	122.7	51.7	90.2	87.2	68.8
1953	106.9	132.8	123.1	52.8	90.8	87.3	67.3
1954	107.6	133.6	123.8	53.8	91.3	87.4	66.4
1955	108.2	134.5	123.6	54.6	92.0	86.9	65.4
1956	108.8	135.7	123.2	54.6	92.8	86.3	63.9
1957	109.3	137.1	122.0	54.4	93.9	85.1	62.9
1958	109.8	137.9	123.3	54.1	94.3	86.2	61.9
1959	110.4	138.1	126.4	53.2	94.5	88.1	60.5
1960	111.0	138.7	129.0	51.9	94.9	89.4	58.9
1961	111.4	141.3	126.1	50.3	97.0	86.4	57.3
1962	111.8	143.0	125.4	49.5	97.7	86.4	57.9
1963	112.1	143.4	127.6	49.1	97.8	87.7	58.0
1964	112.4	144.0	129.4	48.2	98.1	88.8	57.0
1965	112.9	145.0	133.5	45.6	98.6	91.5	53.2
1966	113.2	146.1	135.6	44.6	99.2	91.7	54.4
1967	113.2	147.3	135.5	44.8	99.8	91.2	55.3
1968	113.1	148.5	135.8	44.2	100.4	91.1	54.8
1969	113.2	149.8	136.8	43.4	101.0	91.5	54.1
1970	113.3	151.1	138.3	42.7	101.6	92.1	53.5
1971	113.3	151.7	138.3	42.9	102.0	92.0	53.6
1972	113.3	152.3	138.5	43.0	102.3	92.2	53.6
1973	113.3	152.7	139.3	43.1	102.6	92.7	53.6

Table 31 presents rates of growth of investment value in formal education by period. For each of the three educational levels and the two sexes, four sets of values are presented. The first corresponds to the value measured in current prices; the second corresponds to values measured in constant prices of 1972; the third corresponds to values per student in constant dollars; and the fourth corresponds to the price deflator of investment in formal education. Considering the current dollar values we observe that average annual rates of growth for females over the period 1948-73 exceed the average annual rates of growth for males for elementary, secondary, and higher education. In this period the highest rate of growth for males occurs for secondary education, while the highest rate of growth for males occurs for secondary education, while the highest rate of growth for females occurs for higher education. Growth rates for the six subperiods presented in Table 31 are similar but not identical to those for the period as a whole.

Considering the constant dollar values presented in Table 20 we find that average annual growth rates for the period as a whole are very similar for males and females at the elementary level, are higher for males at the secondary level, and are higher for females in higher education. For subperiods we can observe a displacement of the maximum rate of growth by educational level that reflects the displacement of the "baby-boom" group through the educational sector. For the 1953 to 1957 period the highest rate of growth corresponds to elementary education; for the 1957 to 1960 period the highest rate of growth corresponds to secondary education; for the last two subperiods, the highest rate of growth corresponds to higher education.

Table 31

Investment in Formal Education by Sex and Educational Attainment
1948-1973, Rates of Growth

	1948 1973	1948 1953	1953 1957	1957 1960	1960 1966	1966 1969	1969 1973
ELEMENTARY							
MALE							
VALUE (CURRENT)	9.89	10.10	13.33	10.25	9.53	8.10	7.87
VALUE (CONSTANT)	2.74	3.99	4.74	3.63	2.63	1.62	-.44
PER CAP. (CONSTANT)	.67	.53	.80	.39	.87	.84	.47
PRICE INDEX	6.96	5.88	8.20	6.38	6.72	6.37	8.34
FEMALE							
VALUE (CURRENT)	10.93	11.79	16.14	10.36	9.09	9.21	9.28
VALUE (CONSTANT)	2.75	4.25	4.92	3.81	2.50	1.38	-.60
PER CAP. (CONSTANT)	.62	.62	.85	.35	.75	.60	.38
PRICE INDEX	7.96	7.24	10.69	6.31	6.44	7.73	9.93
SECONDARY							
MALE							
VALUE (CURRENT)	11.54	7.77	12.99	13.13	13.44	10.67	11.55
VALUE (CONSTANT)	3.81	1.07	4.13	6.61	5.80	3.00	2.54
PER CAP. (CONSTANT)	.48	-.07	-.23	1.88	.84	.28	.47
PRICE INDEX	7.45	6.63	8.51	6.11	7.22	7.45	8.79
FEMALE							
VALUE (CURRENT)	13.63	11.67	17.22	16.15	12.85	11.83	13.20
VALUE (CONSTANT)	3.49	1.03	4.01	6.07	5.18	2.61	2.33
PER CAP. (CONSTANT)	.16	-.40	-.65	1.68	.42	-.07	.32
PRICE INDEX	9.80	10.54	12.70	9.50	7.30	8.98	10.62
COLLEGE							
MALE							
VALUE (CURRENT)	10.89	9.10	9.06	8.35	11.76	13.86	13.46
VALUE (CONSTANT)	4.17	1.79	1.97	3.51	6.19	8.15	4.01
PER CAP. (CONSTANT)	-.31	2.54	.76	-1.54	-2.50	-.93	-.17
PRICE INDEX	6.45	7.18	6.95	4.68	5.25	5.28	9.09
FEMALE							
VALUE (CURRENT)	13.36	11.73	14.35	15.13	12.68	13.72	13.87
VALUE (CONSTANT)	4.94	.99	3.02	5.12	8.50	8.75	3.75
PER CAP. (CONSTANT)	-.93	-.13	-1.68	-2.14	-1.33	-.20	-.19
PRICE INDEX	8.02	10.64	11.00	9.52	3.85	4.57	9.76

To eliminate the effect of the size of a given age cohort we present investment in education in constant prices per student in Table 31. For the postwar period as a whole the growth of investment per student at the elementary level is positive for both males and females and similar in magnitude. Growth of investment per student at the secondary level is positive for both sexes, but the average annual growth rate for males exceeds that for females. Investment per student in constant prices in higher education is negative for the postwar period as a whole and is more negative for females than for males. Rapid gains in enrollment rather than increases in investment per student account for the increase in investment in constant prices for both sexes over the postwar period.

To bring out the implications of our methodology for measuring lifetime labor incomes, we have estimated investment in formal education by conventional methods. For this purpose we have restricted the returns to market labor earnings and considered only the earnings of persons with one additional year of schooling. We have used the same rate of return and rate of increase in wages as in estimates that include the value of nonmarket labor activities. In Table 32 we present the resulting estimates of investment in education in current dollars. We can observe that using more conventional methodology the value of investment in education is reduced dramatically, that the greatest reduction occurs at the elementary level, and that returns to investment in education for females are reduced more than the returns to investment for males.

Table 32

Investment per Student by Sex and Educational Attainment, Market Labor Activities Only, 1947-1973
(Thousands of Current Dollars)

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	2.9	3.9	4.9	9.1	.4	2.0	2.3
1948	3.1	4.4	4.8	9.3	.5	2.1	2.6
1949	3.1	4.4	4.9	9.6	.5	2.2	2.9
1950	3.5	5.1	5.0	10.3	.4	2.3	3.3
1951	3.7	5.4	5.3	11.2	.5	2.5	3.7
1952	3.8	5.7	5.6	12.0	.5	2.5	4.1
1953	4.0	6.0	5.8	12.7	.5	2.6	4.1
1954	4.2	6.3	6.1	13.2	.5	2.7	4.4
1955	4.5	6.9	6.5	14.2	.6	2.9	4.9
1956	4.8	7.4	6.8	14.8	.6	3.1	5.1
1957	5.0	7.7	7.0	15.3	.7	3.2	5.4
1958	5.1	7.8	7.2	15.4	.7	3.3	5.7
1959	5.4	8.3	8.0	15.9	.7	3.6	6.3
1960	5.5	8.2	8.8	16.6	.7	3.0	5.8
1961	5.1	7.0	8.1	16.8	.5	3.6	9.1
1962	5.3	7.0	8.6	17.8	.5	3.7	9.4
1963	5.6	7.4	9.0	18.2	.6	3.9	9.7
1964	6.1	7.8	9.9	19.5	.8	4.2	10.6
1965	6.3	7.8	10.5	19.0	.9	4.6	10.7
1966	6.9	8.2	11.0	20.0	1.8	5.1	9.5
1967	7.0	8.1	11.5	21.9	.9	5.1	10.4
1968	7.6	8.5	12.1	22.4	1.4	5.8	11.3
1969	7.5	7.4	12.8	23.7	.7	6.8	11.8
1970	9.1	9.7	13.3	28.7	1.3	7.2	12.7
1971	9.8	9.1	16.5	30.4	1.5	8.3	14.3
1972	10.4	10.5	16.9	29.4	1.4	8.8	15.1
1973	11.0	9.9	18.3	31.1	1.9	9.9	15.8

Table 33 presents a comparison in constant dollars of the results of our two different methods for estimating investment in education. The share of market returns is given by the percentage of the value obtained using market returns in the value obtained using the nested procedure with both market and nonmarket returns. We observe that the estimate using the more restricted definition of labor incomes is only eight to nine percent of the estimate derived using the more comprehensive definition. The lowest percentage in the table corresponds to females enrolled in elementary school; the estimate of investment in education using the restricted definition of labor incomes is a little more than one percent of investment using the comprehensive definition. The highest percentage corresponds to males enrolled in college with the restricted definition of returns ranging from 64 to 69 percent of the comprehensive definition.

There are no other estimates of investment in education on the basis of lifetime labor incomes to compare with our results. However, we can compare our estimates with estimates based on cost of education. In Table 34 we present a comparison of our estimates with those of Kendrick (1976).[20] Kendrick's estimates of the value of investment are only 4 to 5 percent of our estimates. As indicated in Table 33, the traditional method of imputing investment in education from lifetime earnings results in estimates between 8 and 9 percent of our estimates, implying that the traditional method of imputing lifetime earnings leads to estimates that are twice as large as those based on costs of education. Our overall conclusion is that the most important innovation we have made is to incorporate both market and nonmarket activities into our measures of lifetime labor income.

Table 33

Percentage of Investment Based on Market Labor Activities to Total Educational Investment, 1947-1973

Year	Total	Male			Female		
		Elementary	Secondary	College	Elementary	Secondary	College
1947	9.2	8.3	13.0	65.4	1.5	10.1	32.7
1948	9.1	8.2	12.9	65.2	1.5	10.0	32.7
1949	8.9	8.1	12.8	65.0	1.4	9.9	32.6
1950	8.8	8.0	12.7	64.8	1.4	9.9	32.5
1951	8.7	7.9	12.8	64.5	1.4	9.9	32.2
1952	8.6	7.8	12.9	64.3	1.3	9.9	32.1
1953	8.5	7.8	12.9	64.2	1.3	9.9	31.8
1954	8.3	7.7	12.9	64.0	1.3	9.9	31.3
1955	8.3	7.6	12.9	63.9	1.3	9.9	30.8
1956	8.2	7.6	12.9	64.0	1.3	9.9	30.5
1957	8.1	7.5	12.9	64.2	1.3	9.8	30.1
1958	8.1	7.5	13.0	64.4	1.3	9.8	29.8
1959	8.2	7.5	13.0	64.7	1.3	9.9	29.6
1960	8.2	7.4	12.9	65.1	1.4	10.0	29.3
1961	8.1	7.3	12.8	65.5	1.4	9.9	28.8
1962	8.2	7.3	12.7	65.9	1.4	9.6	28.1
1963	8.3	7.2	12.7	66.4	1.4	9.6	28.1
1964	8.5	7.2	12.9	67.1	1.4	10.0	28.6
1965	8.5	7.2	12.7	67.6	1.4	9.8	28.9
1966	8.5	7.1	12.4	67.6	1.4	9.7	27.4
1967	8.6	7.1	12.4	67.4	1.4	9.7	27.0
1968	8.8	7.0	12.4	68.3	1.4	9.7	27.7
1969	8.9	7.0	12.3	68.8	1.4	9.7	28.1
1970	9.1	7.0	12.3	68.9	1.4	9.6	28.2
1971	9.1	7.0	12.2	68.7	1.4	9.7	28.2
1972	9.3	6.9	12.2	68.5	1.5	9.6	28.2
1973	9.4	6.9	12.2	68.4	1.5	9.6	28.2

Table 34

Investment in Education Based on Costs and on Lifetime Labor Incomes, 1947-1969

Year	Billions of Current Dollars			Billions of 1958 Dollars		
	J-P Income Based	Kendrick Cost Based	Ratio	J-P Income Based	Kendrick Cost Based	Ratio
1947	450.4	28.0	16.07	1037.9	43.4	23.90
1948	498.7	30.7	16.20	1058.4	44.5	23.80
1949	554.6	30.4	18.22	1089.8	43.0	25.34
1950	600.9	33.6	17.88	1124.1	45.9	24.46
1951	660.0	38.8	17.00	1155.1	49.9	23.12
1952	721.5	42.5	16.95	1188.0	52.2	22.75
1953	814.1	45.9	17.72	1243.2	54.6	22.76
1954	961.2	44.9	21.39	1306.7	52.4	24.94
1955	1098.7	50.8	21.59	1365.6	57.4	23.76
1956	1214.6	56.2	21.60	1425.2	60.5	23.54
1957	1384.9	61.3	22.57	1486.1	63.2	23.49
1958	1549.1	63.7	24.30	1549.1	63.7	24.30
1959	1721.6	71.4	24.10	1613.5	68.8	23.43
1960	1900.0	75.2	25.24	1686.7	70.6	23.88
1961	2159.5	79.8	27.03	1752.8	73.2	23.92
1962	2362.7	88.2	26.76	1818.6	78.7	23.08
1963	2535.0	95.8	26.44	1885.1	83.2	22.66
1964	2887.0	106.1	27.19	1951.7	89.1	21.90
1965	3059.1	118.4	28.84	2015.0	96.4	20.89
1966	3434.1	137.4	24.99	2070.7	107.6	19.24
1967	3830.7	148.6	25.76	2119.7	112.0	18.92
1968	4087.1	170.4	23.99	2166.7	121.8	17.78
1969	4499.8	192.3	23.39	2209.6	129.9	17.00

Footnotes

1. An aggregate production function was introduced by Cobb and Douglas (1928). References to aggregate production studies based on this approach are given in a survey paper by Douglas (1948). References to more recent studies of production at the aggregate level are given by Kennedy and Thirlwall (1971) and Nadiri (1970). More recent references are given by Takayama (1974).

2. Alternative approaches to generating data and analyzing the sources of U.S. economic growth at the aggregate level are discussed by Christensen and Jorgenson (1969, 1970, 1973a, 1973b), Denison (1962, 1967, 1969, 1972, 1974), Jorgenson and Griliches (1967, 1972a, 1972b), and Kendrick (1961, 1973).

3. The breakdown of capital input by class of asset and legal form of organization was originated by Christensen and Jorgenson (1969, 1970, 1973a, 1973b). Changes in the structure of capital input for the United States have been discussed by Griliches and Jorgenson (1966) and by Jorgenson and Griliches (1967, 1972a, 1972b). Gollop and Jorgenson (1980) have presented the first results based on this approach at the sectoral level.

4. The breakdown of labor input by demographic characteristics was originated by Griliches (1960) and by Denison (1962, 1967, 1974). Changes in the structure of labor input for the United States have been discussed by Jorgenson and Griliches (1967, 1972a, 1972b). Gollop and Jorgenson (1980) have presented the first results based on this approach at the sectoral level.

5. Welfare measures of aggregate economic activity for the United States have been presented by Sametz (1968) and by Nordhaus and Tobin (1972). Proposals for measuring welfare have been reviewed by Campbell and Peskin (1979), the United Nations (1977), and Beckerman (1978). Detailed references to the literature are given by Campbell and Peskin (1979). We present a comparison between our estimates of the value of time spent in nonmarket activities and those of Nordhaus and Tobin in Table 26 below.

6. Previous attempts to employ lifetime incomes as a basis for measuring human capital have been limited to earnings for men based on market labor activities. Estimates of this type have been presented by Weisbrod (1961), Miller (1965), Miller and Hornseth (1967), the U.S. Bureau of the Census (1968, 1974), and Graham and Webb (1979).

7. Demographic accounting is discussed in detail by Stone (1971) and the United Nations (1975).

8. The translog index of technical change was introduced by Christensen and Jorgenson (1970). It was first derived from the translog production function by Diewert (1977) and by Jorgenson and Lau (1977). The translog production function was introduced by Christensen, Jorgenson, and Lau (1971, 1973).

9. The role of an aggregate production account in a complete accounting system for the U.S. economy is discussed by Christensen and Jorgenson (1969, 1970, 1973a, 1973b).

10. The translog index numbers were introduced by Fisher (1922) and have been discussed by Tornquist (1936), Theil (1965) and Kloek (1966). They were first derived from the translog production function by Diewert (1976).

11. The decomposition of growth in labor input between growth in hours worked and growth in labor quality is discussed in greater detail in Section 3 below.

12. Detailed discussions of quality indexes and applications to disaggregated labor data can be found in the doctoral dissertations by Barger (1971) and Chinloy (1974). Chinloy (1980) presents an application to U.S. aggregate data. Extremely valuable assistance in programming the computations was provided by Peter Derksen.

13. The initial design of our approach to the measurement of labor input, the collection of data, and much of the required estimation were carried out in collaboration with Peter Chinloy. The results of his measurement and analysis of labor input for the U.S. economy at the aggregate level are reported in his doctoral dissertation. See Chinloy (1974).

14. Campbell and Peskin (1979) have summarized accounting systems developed by Kendrick (1976, 1979), Ruggles and Ruggles (1970, 1973), and Eisner (1978, 1980). Kendrick's accounting system is also discussed by Engerman and Rosen (1980). We present a comparison between our estimates of investment in education and human wealth and those of Kendrick in Section 4 below.

15. An economic theory of time allocation is presented by Becker (1965). Detailed references to more recent literature on time allocation are given by Murphy (1980). Results of a comprehensive and recent empirical study for the United States are presented by Juster, Courant, Duncan, Robinson, and Stafford (1978). Kendrick (1979) summarizes the results of an unpublished paper by Wehle, comparing seventeen studies of time allocation for the United States, covering the period 1924-1976.

16. A review of estimates of time spent in formal schooling is given by Parsons (1974).

17. Nineteen empirical studies of the valuation of nonmarket labor activities for the United States are surveyed by Murphy (1980). Kendrick (1979) provides recent estimates covering the period 1929-1973.

18. Houthakker (1959) has allocated income taxes to individuals on the basis of demographic characteristics. We control the total taxes paid on labor incomes to estimates for the U.S. economy as a whole based on the methods of Frane and Klein (1953).

19. A complete account for the educational sector is needed to estimate rates of return to educational investment. Estimates of investment in education have been presented by Schultz (1961). Rates of return are given by Becker (1964). Kendrick (1976) provides estimates covering the period 1929-1969. Detailed references to recent literature are provided by Campbell and Peskin (1979).

20. Kendrick's estimates of human capital have been compared with estimates based on lifetime labor incomes for males between the ages of 14 and 74 for the United States, excluding the value of nonmarket activities, for the year 1969 by Graham and Webb (1979).

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