THE TREATMENT OF INTANGIBLE RESOURCES AS CAPITAL

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The author describes the results of his current research designed to measure total investment, tangible and intangible, and the derived capital stocks for the U.S., 1929–1966. With respect to total investment, the estimates show a marked increase in its ratio to GNP. All of the increase occurs in the intangible component comprising R & D, education and training, health, and mobility. The increase was concentrated in the government sector, although households increased the proportion of disposable personal income devoted to total investment.

Consistent with the relative investment trends, the stock of intangible capital grew considerably faster than the tangible stock. The growth of total capital stocks was somewhat less than that of GNP, however, in both current and constant prices. Thus, the rate of return on total capital rose somewhat over the period. Average rates of return on human and nonhuman capital were closely similar.

In real terms, the growth of total capital stocks accounted for two-thirds of the growth in real GNP, 1929–1966. One-third of the growth is attributed to residual forces, chiefly economies of scale, changes in economic efficiency, changes in inherent quality of human and natural resources, changes in values and motivations, and changes in rates of utilization of capacity.

The growth of the ratio of real intangible stocks to real tangible stocks accounted for less than half of the increase in total factor productivity 1929–1966. This is significantly less than the contribution of intangibles as estimated by Denison, and the author adduces several reasons why his estimates may understate the contribution. Nevertheless, it seems that the net effect of the residual forces enumerated above must also have made a substantial contribution to the growth of tangible factor productivity and real GNP over the 37-year period.

INTRODUCTION

In this paper I shall describe my current research on total investment, capital, and economic growth, and summarize some of the preliminary findings. Despite the title of the paper we consider tangible as well as intangible investment and capital, but emphasize the latter, which has shown a marked relative increase in the United States, with important implications for the growth of tangible factor productivity and real product.

My work is based on the concept of capital as output- and income-producing capacity, and of net investment as outlays that increase productive capacity for the future. When these concepts are implemented broadly to include all significant forms of investment and capital, human and nonhuman, intangible and tangible, of all sectors, non-business as well as business, the resulting estimates can be very useful for increasing our understanding of economic growth. Growth can then be analyzed in terms of rates of change in capital stocks and associated inputs, of the various types, and the net effect of residual, non-capital forces that affect the rate of return on, or average productivity of, the total capital stock.

As Harry Johnson well stated it at a 1963 conference:

"The conception of economic growth as a process of accumulating capital, in all the manifold forms that the broad Fisherian concept of capital allows, is a potent simplification of the analytical problem of growth, and one which facilitates the discussion of growth policy by emphasizing the relative returns from alternative investments of currently available resources."[1]

In a paper presented at the same conference, the present author wrote:

"Economic growth is now seen largely to result from investments. This perhaps should be obvious when investment is defined as current outlays designed to enhance future income. But progress has been made in identifying and exploring the various types of investments made by the several economic sectors."[2]

A major impetus to work along these lines had been given by Professor Theodore W. Schultz, whose Presidential address before the American Economic Association in 1960 has been frequently cited:

"It has been widely observed that increases in national output have been large compared with the increases of land, man-hours, and physical reproducible capital. Investment in human capital is probably the major explanation for this difference."[3]

Schultz goes on to suggest that the ratio of income to *all* capital may have been roughly constant.[4]

A substantial body of useful work has accumulated during the past decade on various types of human (intangible) investment and capital, as well as on intangible investment in research and development activities designed largely to improve the quality or productive efficiency of tangible nonhuman capital goods. Yet, so far as I know, no one else in the United States, besides me, has tried to assemble or develop estimates of total investments of all types, and the associated stocks of capital, in order to test the Schultz hypothesis, or, more generally, to analyze the role of total capital formation, by type and sector, in economic growth, as distinct from the non-capital factors.

To state the analytical framework in its simplest form, an identity, income or product (Y) may be viewed as the product of the aggregate stock of capital (K_{AG}), and all the other "residual" forces which affect the productivity of aggregate capital (R, which can be calculated as the quotient of Y and K_{AG}, to satisfy the identity):

$$Y = R \cdot K_{AG}$$

When the income and stock variables are expressed in terms of current prices, R may be thought of as an average rate of return. When Y and K are in constant prices, it is more appropriate to think of R as an average productivity variable,

[1]Harry G. Johnson, "Comments," *The Residual Factor and Economic Growth* (Paris: OECD, 1964), p. 221.

[2]John W. Kendrick, "Comments," *Ibid.*, p. 109.

[3]Theodore W. Schultz, "Investment in Human Capital," reprinted in E. S. Phelps, *The Goal of Economic Growth* (New York: Norton and Co., 1969), p. 106,

[4]*Ibid.*, p. 109.

reflecting the residual forces such as economies of scale, changes in economic efficiency, and other non-capital variables that will be listed later.

If it is desired to highlight the separate contributions of tangible capital (K_{TN})—human and nonhuman, without allowance for quality change—and the embodied intangible capital (K_{IN}) as well as the net effect of residual factors, the identity may be further elaborated:

$$Y = K_{TN} \cdot \left(1 + \frac{K_{IN}}{K_{TN}}\right) \cdot R$$

Or, if one wishes to confine the statistical explanation to total tangible factor productivity, this may be done in terms of the growth of real aggregate capital (including intangible) relative to real tangible capital and the residual forces. Note, however, that in the following formulation factor inputs are implicitly assumed to move proportionately to the corresponding real stocks, so that changes in rates of utilization of stocks show up in R. Alternatively, of course, the stocks could be adjusted for changes in utlization rates.

$$Y/K_{TN} = K_{AG}/K_{TN} \cdot R$$

A limitation of this type of formulation is the implicit assumption that the contribution of each type of capital to output is proportionate to its value; i.e., that the productivities, or rates of return, of all types are equal. We shall discuss this limitation further during the summary of findings. It would be possible, of course, to attempt to determine the elasticities of output with respect to each of the types of capital services through econometric production function analyses. We have begun to work on such analyses, but are not yet ready to report on the results.

Before turning to a description of the estimates, it may be useful to contrast our approach with the alternative approach pioneered by Denison.[5] Denison, Jorgenson, and others have attempted to estimate directly the contribution of increased average education per worker to the economic growth rate by means of estimating income differentials due to educational differentials. Denison estimated the contribution of the advance in knowledge to economic growth as a residual after accounting for the contributions of all the other factors in his schema. The contributions of some of the forms of intangible capital formation have not been estimated by others, or only inadequately (as in the use of a residual method, which is affected by net errors and omissions). Actually, the approaches can be complementary in that independent estimates of rates of return could be useful to us in developing weights for the different types of capital; whereas elasticities obtained from use of our capital estimates in production function analyses can help others estimate the contributions of types of capital formation not now included in their formulations. Also, the alternative approaches can be used as cross-checks on each other. In a final section of this paper we shall roughly compare our estimates of the contribution of intangible capital accumulation to the U.S. growth rate with those of Denison.

[5]Edward F. Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us* (N.Y.: Committee for Economic Development, 1962).

It must be noted at the outset that the net capital stocks are estimated in terms of their costs, revalued to current and constant prices, rather than as the discounted present value of future income streams. Not only is this the more expedient method, but also it avoids circularity when income is related to capital in calculating rates of return or productivities. We have estimated depreciable stocks both net and gross of accumulated depreciation. Since the capital stock estimates have been derived from the investment estimates, we shall first describe the latter.

Intangible Investments

As shown in subsequent tables, the chief types of intangible investment we identify are expenditures by all sectors for research and development (R & D), education and training, health, and mobility. Each of these types of outlays is designed primarily to improve the quality and enhance the productivity of human or of nonhuman capital, and is "embodied" in human beings, or in nonhuman capital goods in the case of applied R & D. We briefly note some of the chief features of our estimates of each of the intangible investments.

(1) *Research and development outlays* result in the production of new knowledge and its commerical application in the development of new or improved consumer and producers' goods, processes, and methods of production. The resulting technological advances are a major source of economic growth, reducing unit real costs and thus increasing productivity, as well as expanding the variety and improving the quality of consumer goods.

While basic research, about 10 percent of total R & D, is not directed towards practical applications, it progressively enlarges the pool of scientific knowledge which is continually drawn upon (and contributed to) by those engaged in applied research, invention, and engineering development. It seems fair to count basic research as well as development activities as investment, with the cost of the "useless" research being borne by that which has an economic pay-off (just as dry-holes and other unsuccessful mineral explorations are charged to the cost of the discoveries).

Measured R & D includes only the formal activities of the several sectors. Some informal activity, such as that of the lone-wolf inventor, is not included. As informal inventive activity has become relatively less important with the spread of the industrial laboratory, the estimates tend to have some upward bias as a measure of total R & D. This is accentuated by a tendency for more complete reporting of such costs, as R & D became a more prestigious activity. In real terms, however, this upward bias is offset by the upward bias of the price deflators, which are based on input prices due to the difficulty of defining and measuring R & D outputs.

Data on R & D outlays in the U.S. are available back to 1920. The estimates prepared by the National Science Foundation since 1953 are of reasonably good quality.

(2) *Education and training.* The dissemination of knowledge and know-how through education and training has long been recognized as an important form

of intangible investment. It clearly increases the income-producing capacity of its recipients, as demonstrated by the rate-of-return studies of Schultz, Becker, Mincer, and others.[6] In addition, general education is an important source of psychic income in future periods. Current psychic income from the educational process is judged to be small relative to the investment aspect of building capital for the enhancement of future monetary and psychic income, so we include total outlays for education and training as investment.

Learning results not only from formal schooling and other more or less structured education and training, but people also learn from experience, by "doing," and from leisure-time reflection. This type of unstructured learning, which does not involve specific costs, generally eludes the investigator and is not included in our investment estimates.

Outlays for "formal" education in public and private schools and other institutions are included in the U.S. national income accounts. But the largest cost of education is the foregone earnings of students of working age. These we estimated by applying to the numbers of students, by demographic groupings, the average earnings of the corresponding employed groups with the same attained levels of education.

In addition to formal education, we also include appropriate portions of expenditures for libraries and museums, educational radio and TV programs, church schools, educational sections of newspapers and periodicals, and non-school teaching aids.

Training outlays comprise not only the costs of formal training programs, but also informal on-the-job training. The latter includes the time of supervisors, and the expense of sub-standard production during the "breaking-in" period. Unfortunately, the data on training costs are fragmentary, and the estimates are subject to larger margins of error than those for the other types of intangible investment.

(3) *Medical and health outlays,* like educational expenditures, enhance both monetary and psychic income over future periods. Returns associated with reductions in mortality, disability, and debility and the consequent increases in longevity, working-time, and vitality have been quantified in part, and appear to be substantial. Yet it can be argued that a significant part of medical, health and safety outlays are of a "maintenance" nature, or of little or no value at all. In the absence of reliable guidelines as to the proportion of these outlays which represent investment, we have taken one-half. Other investigators may wish to vary the proportions.

Factors other than medical and direct health outlays may affect levels of health, of course, such as the adequacy of food and shelter. Improvements in these factors have probably not been of major health significance in the United States in recent decades, however, and we do not count as investment any portion of those expenditures which have only an indirect and problematical effect on health. It should be noted, however, that we do include safety expenditures, and public health programs that include costs of environmental improvements.

[6]See *Journal of Political Economy,* Supplement: "Human Capital," October, 1962.

As in the case of education, most of the medical and health expenditures in the United States are included in the gross national product, under personal consumption expenditures and government purchases.

(4) *Mobility costs* are incurred in order to shift human resources in response to dynamic economic changes. Individual and national income and productivity are increased as resources are transferred from industrial and/or geographical areas of declining relative demand to those of increasing relative demand for outputs and inputs.

We distinguish three types of human mobility costs. The first is for job search and hiring, which involves expenditures by individuals, enterprises, and government. The second category is moving expenses of workers who migrate to seek or assume new jobs. Finally, we include the private and public costs of frictional unemployment as a social cost of economic progress. A certain volume of unemployment (which we take at 3 percent of the U.S. civilian labor force) is necessary to accommodate dynamic economic changes, particularly technological advances, which raise productivity.

Tangible Investments

These may be described under two headings, the conventional tangible non-human investment, and tangible human investment which comprises the costs of rearing children to working age, excluding the intangible human investments listed above.

(1) Tangible nonhuman investment consists of expenditures for new construction, durable goods, inventory accumulation, and natural resource development, by all sectors. In the U.S. national income accounts, only gross private domestic investment by businesses and institutions is identified as such. We include also the parallel outlays by households and governments. Most of non-business investments can be drawn from the GNP estimates, except for net inventory changes which must be independently estimated.

(2) Tangible human investment consists of the portion of personal consumption expenditures required to rear children to working age. Estimates of average annual costs per child were based on surveys of family consumption patterns, by age-sex groupings, and applied to the annual numbers in each group. Age 14 was chosen as the upper limit for the rearing period, since, at the time the estimates were made, the official U.S. labor force estimates included persons 14 years of age and over. Since then the boundary was moved to 16 years. The exact boundary does not make much difference to our total human investment estimates, however, since we include the opportunity costs of students of working age as part of investment in education, and rearing costs are close to average earnings in the 14 to 16 years age bracket.

Some economists have questioned the desirability in a free society of counting rearing costs as investment. But it is clearly necessary for our approach, in which we seek to estimate the total cost of all resources which provide inputs into the production process. Not only is it necessary since we deal with total human capital stocks instead of "labor input" as such, but the rearing cost estimates facilitate analysis of the investment and saving functions. To some extent, the costs of rearing children reduce the consumption of parents, thus increasing total saving and investment through an "abstinence effect"; to some extent tangible human investment competes with other forms of investment.

Stocks of Intangible Capital

Tangible factor productivity is related to the stocks of intangible capital, rather than to intangible investment. In this section we describe briefly how we used the investment estimates to derive stock estimates. The stocks are first estimated on a gross basis in real terms, then reflated to current prices. Methods for estimating depreciation and net stocks will be described below.

For education, general training, and health, we estimate the average annual real expenditures per head by single age-brackets up to age 95, cumulate for each cohort, multiply by the number of persons in each age-bracket each year, and summate across age-brackets. This means we had to push the investment estimates back 95 years prior to the first year, 1929, for which the stock estimates begin. This method has the advantage over the perpetual inventory approach to estimating nonhuman capital in that the population estimates enable us precisely to reflect the annual retirements of human capital from each year's stock. A further step was necessary to estimate the productivity of employed human capital of the above types. To do this, we applied ratios of employment to population to the total stock estimates, by age groupings. Sector proportions of persons engaged were then applied to the productive stock to obtain a sector break-down.

For specific training, and the job-search, hiring, and frictional unemployment portions of mobility costs, we estimated the average periods of employment on one job and held the relevant investments of each year in the real gross stock for these periods. For migration costs we used the average lifetime of the investment.

In the case of basic research, we cumulated real costs without allowance for retirements on the grounds that advances in knowledge are cumulative, each year's advances contributing to subsequent advances. The estimates of stock resulting from applied research and development required the following pieces of information, obtained from a sample survey we conducted: (a) the portion of annual AR & D representing completed projects; (b) the mean time-lag between completion of AR & D and incorporation in new products or processes; (c) the average lives of products and processes; and (d) a distribution of retirements around the average lives. With this information we could obtain estimates of the real stock of knowledge and know-how resulting from AR & D (at cost) by means of the perpetual inventory method.

For consistency with the preferred net tangible stock estimates, we depreciated real intangible investment using the double-declining balance method. Accumulated depreciation was subtracted from gross capital stocks to obtain net capital stocks—all in constant prices. The real gross and net capital stock estimates, by type, were reflated to current prices using the same price indexes that were used to deflate current dollar investments, by type. The annual depreciation charges, in constant and current prices, were subtracted from the corresponding gross investment series to obtain net investment estimates.

Tangible Capital Stocks

The estimates of tangible reproducible (nonhuman) capital were prepared using the familiar perpetual inventory method. The business stock estimates were those published by the Office of Business Economics, using the Winfrey S-3 retirement pattern, Bulletin F minus 15 percent, and double-declining balance depreciation. We made the non-business depreciable stock estimates on a comparable basis, extrapolating our investment estimates back by those assembled by Raymond Goldsmith.[7] We also relied heavily on Goldsmith for estimates of land, non-business inventory stocks, and net foreign assets in earlier years. Business inventory estimates were provided by O.B.E.

To estimate the stock of tangible human capital we cumulated the average rearing costs per child up to age 14, and multiplied the average cumulative cost by the number of persons in each cohort up to age 95+. Retirements are thus automatically accounted for. The employed stocks, by sector, were obtained as described for intangible human capital. Depreciation was calculated consistently by the declining-balance formula.

Some Preliminary Findings

In this section we compare total investment and capital, gross and net, with GNP and NNP. For these comparisons we have adjusted the official national product estimates of O.B.E. for consistency with the investment and stock estimates. That is, we have added certain investments charged by business to current expense; imputed investment estimates, such as the opportunity cost of students; and the imputed rental values of non-business capital stocks. The adjusted GNP increased from a 1.20 ratio to official GNP in 1929 to about 1.25 in 1966. The adjusted NNP estimates were obtained by deducting capital consumption allowances on total capital stocks in current replacement prices from adjusted GNP. In the following discussion the national product estimates to which we refer are the adjusted series.[8]

Investment

Between 1929 and 1966 total gross investment in the United States increased from 44 to 51 percent of GNP (See table 1.) This significant increase is in sharp contrast to the relative stability of the gross investment ratio to GNP in the official estimates, in which investment is confined largely to business sector tangible investment (including all new residential construction) plus net foreign investment.

Our gross tangible investment estimates are likewise a relatively constant proportion of GNP, near 30 percent in both 1929 and 1966. Tangible human investment (rearing costs) declined somewhat, while tangible nonhuman investment rose a bit, reflecting increases in the non-business components.

[7]See Raymond W. Goldsmith, *The National Wealth of the United States in the Postwar Period* (Princeton University Press for the National Bureau of Economic Research, 1962).

[8]For further discussion of our modifications of the U.S. income accounts, see John W. Kendrick, "Restructuring the National Economic Accounts for Investment and Growth Analysis," *Statistisk Tidskrift*, Stockholm, 1966:5.

TABLE 1

U.S. ECONOMY

TOTAL GROSS INVESTMENT, BY TYPE, IN CURRENT AND 1958 PRICES IN RELATION TO ADJUSTED NATIONAL PRODUCT, SELECTED YEARS

(billions of dollars, and percentages)

	Current dollars			Constant (1958) dollars		
	1929	1948	1966	1929	1948	1966
	(billions of dollars)					
Adjusted GNP	127.3	327.7	982.6	252.4	420.5	853.7
Total investment	55.7	141.8	499.7	119.0	185.6	436.1
	(percentages of GNP)					
Total investment	43.7	43.3	50.9	47.2	44.1	51.1
Net foreign investment	0.6	0.6	0.2	0.6	0.6	0.3
Gross domestic investment	43.1	42.7	50.6	46.6	43.6	50.8
Tangible	30.8	29.0	30.5	32.2	28.0	32.6
Human	7.7	5.6	5.6	6.8	5.1	5.8
Nonhuman	23.1	23.4	24.9	25.4	22.9	26.8
Intangible	12.3	13.7	20.2	14.4	15.6	18.2
Research and Development	0.2	0.7	2.3	0.3	0.9	2.1
Human	12.1	13.0	17.9	14.1	14.7	16.1
Education and Training	8.6	9.4	13.9	10.1	10.6	12.5
Health	1.5	1.6	2.2	1.6	1.8	2.0
Mobility	2.0	2.0	1.8	2.4	2.3	1.6

The increase in the total investment ratio was thus entirely due to a large relative increase in gross intangible investments, from 12.3 percent in 1929 to 20.2 percent in 1966. Most of the relative increase occurred after 1949. The largest proportionate increase came in the R & D category; next, education and training; then, medical and health; while mobility remained a fairly constant fraction of GNP.

Not only is total saving-investment a rising function of GNP in contrast to the relatively stable function using the narrower, conventional definitions, but the fraction of GNP saved and invested is far higher. By 1966, as noted, more than half of GNP was being devoted to forward-looking outlays. Only a wealthy economy could afford this; and it appears that as the U.S. economy has increased per capita income and wealth, the share of income saved and invested has likewise increased.

The ratios of total net investment ratios to NNP are, of course, lower than the gross ratios, since capital consumption allowances are a higher proportion of gross investment than of GNP. Total net investment increased from 22.4 to 32.0 percent of NNP between 1929 and 1966, a somewhat greater relative increase that was true of the gross ratios; the net-to-gross investment ratio rose from less than 0.40 to about 0.45. The proportionate increase was relatively greater in the case of intangible net investment, which more than doubled in relation to NNP, rising from 6.6 percent in 1929 to 14.2 percent in 1966.

The relative increases in both the gross and net investment ratios were less in constant prices than in current prices. This reflects the fact that the price deflators for total investment rose more than the price deflators for national product. In real terms (1958 prices) the ratio of total gross investment to GNP rose from 47.2 percent in 1929 to 51.1 percent in 1966; while the net ratios increased from 24.8 to 31.8 percent. In both cases, the ratios in 1948 were a bit below those in 1929, so that all of the relative increase appears to have occurred in the post-World War II period. In the deflated estimates, as in the current dollar estimates, most of the relative increase came in the intangible investment component. This suggests, of course, that the stocks of intangible capital grew significantly faster than the tangible capital stocks, as we shall verify in the next section.

Finally, as shown in Table 2, all of the relative increase in gross investment occurred in the portion financed by the general government sector. This was the result both of a sharp (two-fold) increase in the share of total gross income

TABLE 2

GROSS DISPOSABLE INCOME AND TOTAL INVESTMENT, U.S. ECONOMY BY MAJOR SECTOR

(percentage of adjusted GNP)

Sector	1929	1948	1966
	Total gross investment		
Households and private nonprofit institutions	26.1	24.8	26.5
Private business	12.4	12.6	12.9
General governments	4.6	5.3	11.2
Foreign (net)	0.6	0.6	0.2
Total gross investment	43.7	43.3	50.9
	Gross disposable income		
Households and institutions	79.2	70.0	67.3
Private business	10.0	10.1	11.3
General governments	10.5	18.5	21.1
Foreign	0.3	1.4	0.3
Total	100.0	100.0	100.0

accruing to governments as tax rates increased, and an increase in the proportion of the disposable income of governments devoted to total investment. Although the share of gross income accruing to the personal sector dropped, this was offset by increases in the proportions of disposable personal income saved and invested. There was a mild increase in the share of gross income accruing to the business sector between 1929 and 1966, partially offset by a modest decrease in the ratio of total investment to disposable income.

It is clear that much new work will be needed to explain the new saving and investment functions that emerge for the economy and its sectors when the definitions of these variables are broadened in the ways we propose.

TABLE 3

U.S. Domestic Economy
Relation of Capital Stocks, by Type, to National Product, Current Prices, Gross and Net

(billions of current dollars, and ratios)

	Gross stocks/GNP			Net stocks/NNP		
	1929	1948	1966	1929	1948	1966
			(Billions of dollars)			
Total capital stocks	1,186.2	2,974.6	8,468.6	782.8	1,801.4	5,345.9
Adjusted national product	127.3	327.7	982.6	92.3	236.4	710.0
			(Ratios to product)			
Total capital stocks	9.32	9.08	8.62	8.48	7.62	7.53
Tangible	7.15	6.63	5.46	6.44	5.40	4.69
Human	2.28	1.94	1.45	2.21	1.68	1.33
Nonhuman	4.87	4.69	4.01	4.23	3.72	3.36
Intangible	2.16	2.45	3.16	2.04	2.22	2.84
Research and Development	0.02	0.06	0.22	0.02	0.06	0.20
Human	2.14	2.39	2.94	2.02	2.16	2.64
Education and Training	1.77	2.06	2.53	1.78	1.94	2.35
Health	0.25	0.25	0.34	0.20	0.18	0.25
Mobility	0.12	0.08	0.08	0.05	0.04	0.04

Capital Stocks in Current Prices

In current prices the total gross capital stock in the U.S. domestic economy grew only moderately less rapidly than GNP. As shown in Table 3, the capital/product ratio fell from 9.4 in 1929 to 8.6 in 1966. Tangible capital fell in relation to total capital stock, particularly the tangible human component. Within the tangible nonhuman stock, land and inventories declined relatively, structures maintained a relatively stable proportion, while equipment showed a significant relative increase.

The gross stock of all intangible capital rose as a ratio to GNP from 2.2 in 1929 to 3.2 in 1966, and its share of the total stock rose from 24 to 41 percent. The largest proportionate increase came in the stock of knowledge resulting from R & D. The intangible stocks resulting from education, training and health outlays increased by almost half in relation to GNP, while the mobility stocks declined relatively in line with the relative decline in tangible human capital.

On a net basis, the decline in the total capital/product ratio was more marked—from 8.5 in 1929 to 7.5 in 1966. Apparently, accumulated depreciation rose somewhat more in relation to total gross capital stocks than depreciation allowances rose in relation to GNP. The several components showed much the same relative movements in net as in gross stocks.

Rates of return on total capital are obtained by dividing current dollar income by the current dollar stocks. The percentage rates are not the exact reciprocals of the capital-product ratios, however, since indirect taxes less subsidies (and statistical discrepancy) are subtracted from the product estimates to obtain factor incomes, gross and net of capital consumption allowances. Also, we confine the estimates of rates of return to the private domestic business economy, since net rentals of the tangible nonhuman capital stocks in the non-business sectors had been obtained by imputation. Further, we have included only that part of human capital which was embodied in persons engaged in productive activity. On the compensation side, since fixed capital compensation is computed after allowance for maintenance expense, to be symmetrical we have estimated the cost of maintaining the population at minimum standards, and deducted this from labor compensation. Income taxes are not deducted. We compute rates of return on human and nonhuman capital separately, and in combination, both gross and net of capital consumption allowances relative to gross and net stocks, respectively.

TABLE 4

U.S. PRIVATE DOMESTIC BUSINESS ECONOMY
RATES OF RETURN ON PRODUCTIVE CAPITAL, GROSS AND NET, TOTAL, HUMAN AND NONHUMAN: SELECTED YEARS
(percentages)

	Gross Return (excluding maintenance) on Gross Capital Stocks		
Year	Total	Human	Nonhuman
1929	9.4	9.7	9.2
1940	9.7	11.0	8.7
1948	11.4	10.7	12.0
1957	11.4	12.7	10.1
1966	12.3	13.2	11.5
	Net Return (excluding maintenance and depreciation) on Net Capital Stocks		
	Total	Human	Nonhuman
1929	8.7	6.9	10.0
1940	10.1	10.1	10.2
1948	12.2	10.1	14.2
1957	11.6	13.4	9.9
1966	12.9	14.5	11.4

There are several interesting aspects of the rate of return estimates, shown for 5 selected years of relatively high business activity in Table 4. First, the rates of return for both human and nonhuman capital are of the same order of magnitude. On the net basis, they both average 11.0 percent. On the gross basis, the average rate of return on human capital is almost 11.5 percent, somewhat higher than the 10.3 percent on nonhuman capital. In view of the experimental nature of our total human capital estimates, the similarity of the rates of return is reassuring. It may even be termed surprising, given the various non-economic considerations that influence investments in the quantity and quality of the human productive agent. It does lend support to our use of the stock estimates to indicate the relative importance to production of the tangibles and intangibles.

The rates of return on total gross and net stocks trended up during the period, as shown in the table, mirroring the declining capital/product ratio. The rates of return on total nonhuman capital reached a peak in 1948, reflecting the relative shortage of nonhuman capital in the early post-war period due to low investment during the depression of the 1930's, and restrictions on civilian capital formation during World War II. The rates of return were lower in 1966 than in 1948, particularly on a net basis.

Rates of return on human capital were no higher in 1948 than in 1940, but then resumed an upward trend. It is important to observe, however, that on a gross-gross basis (before deduction for maintenance) the rate of return on employed human capital declined slightly—from 22.1 percent in 1929 to 20.5 percent in 1966. If we had adjusted maintenance estimates to reflect rising standards and planes of living, rates of return on human and aggregate capital stocks would have risen less, and on a gross basis would probably have remained relatively stable in years of high-level business activity.

Total Capital Coefficients

In real terms, the ratios of real total stocks of capital, both gross and net, to real GNP and NNP declined more than they did in current prices. As shown in Table 5, the gross ratios for the private domestic business economy fell from 5.2 in 1929 to 3.5 in 1966. The net ratios fell from 4.8 to 3.0 over the same period. Or, to state it conversely, the productivity of the total resources employed in the business economy appears to have increased by approximately

TABLE 5

U.S. PRIVATE DOMESTIC BUSINESS ECONOMY
RELATION OF CAPITAL STOCKS, BY TYPE, TO NATIONAL PRODUCT
CONSTANT PRICES, GROSS AND NET
(billions of 1958 dollars, and ratios)

	Gross stocks/gross product			Net stocks/net product		
	1929	1948	1966	1929	1948	1966
			(Billions of 1958 dollars)			
Total capital stocks	1,324.0	1,728.6	2,977.0	847.3	1,081.9	1,858.1
National product	252.4	420.5	853.7	177.2	297.6	612.7
			(Ratios to product)			
Total capital stocks	5.25	4.11	3.49	4.78	3.64	3.03
Tangible	3.98	2.69	2.06	3.58	2.31	1.74
Human	0.71	0.68	0.49	0.60	0.52	0.37
Nonhuman	3.27	2.01	1.57	2.98	1.79	1.37
Intangible	1.27	1.43	1.43	1.20	1.32	1.29
Research and Development	0.03	0.08	0.19	0.03	0.07	0.18
Human	1.24	1.35	1.24	1.17	1.25	1.11
Education and Training	1.01	1.15	1.07	1.03	1.12	0.99
Health	0.11	0.12	0.12	0.09	0.09	0.09
Mobility	0.12	0.08	0.05	0.05	0.04	0.03

50 percent over the 37-year period on a gross basis, and 57 percent on a net basis, accounting for about one-third of the overall economic growth rates.

The greater decline in the total capital coefficient in real terms than in current prices reflects a greater increase in the implicit deflator for capital than in that for product. To some extent, this may be due to an upward bias in the price deflators for investment and capital, which affects the capital estimates more than the investment estimates. Most of the price deflators for intangible investment are essentially input price indexes, and do not reflect possible increases in productivity in education, medical activities, and so on. The same is true, to a lesser extent, of the price deflators for structures and equipment.

Despite this possible bias in the relative movements of the real stock and product estimates, it seems probable that there has been a significant secular increase in real product in relation to real total capital stocks, as we have defined them. To this extent the Schultz hypothesis would have to be qualified. The rising productivity of total capital is the net result of all of the forces affecting economic growth other than the growth of the real stock of total capital as defined, plus the growth of capital not included in our measures (such as knowledge acquired through "learning by doing"), and the net effect of errors in the capital and product estimates.

Edward Denison's paper provides a comprehensive check-list of forces affecting economic growth. Of those not associated with changes in capital stocks, human and nonhuman, tangible and intangible, I would place the others under the following chief headings: (1) changes in rates of utilization of resources, which is very important over the business cycle, and so some extent from one cycle-average or cycle-peak to the next; (2) economies of scale; (3) changes in economic efficiency, defined as changes in the degree to which the allocation of resources departs from an optimum allocation, due to imperfect knowledge and foresight, barriers to mobility, and so on; (4) changes in the inherent quality of natural and human resources and inputs; and (5) changes in values, motivations, attitudes and other elements which affect the content of the manhour or other units by which labor input is measured.

I have not attempted to quantify the effect of the residual forces individually, and I doubt if it is possible to do so satisfactorily for all of them.

Components of Growth

In Table 6 we show the major components of economic growth in the United States, 1929–1966, as developed in the equations given in the introductory section of this paper. In addition to the link relatives for 1966 (1929 = 100), we show the average annual percentage rates of change for the components, which are within ± 0.1 additive to the growth rate for GNP. We deal here with the gross variables—the net variables yield much the same results.

From the table we see that the 3.3 percent annual growth rate of real GNP over the 37-year period can be explained in terms of percentage rates of growth of 1.5 in real tangible stocks, 0.7 in the ratio of total real stocks (including intangibles) to real tangible stocks, and 1.1 in the residual elements. Narrowing the dependent variable to total tangible factor productivity, which increased

TABLE 6

MAJOR COMPONENTS OF U.S. ECONOMIC GROWTH, 1929–1966

Variable[a]	1966 (Index no., 1929 = 100)	Average annual percentage rate of change
(1) Real GNP $(2) \times (3) \times (4) = (6) \times (4) = (2) \times (5)$	338	3.3
(2) Real tangible capital	175	1.5
(3) Ratio of real total capital to real tangible capital $(6) \div (2)$	128	0.7
(4) Residual factors (ratio of real GNP to real total capital) $(1) \div (6)$	152	1.1
Addendum:		
(5) Real tangible factor productivity $(1) \div (2) = (3) \times (4)$	193	1.8
(6) Real total capital $(0.32(7) + 0.68(2))$	224	2.2
(7) Real intangible capital	382	3.7

[a]The capital variables are all gross of depreciation.

Note: The identities, shown in multiplicative form, refer to the index numbers; with respect to the percentage rates of change, they are roughly additive.

at a 1.8 percent annual rate over the period, the statistical explanation is narrowed to the 0.7 percent increase in the stock ratio, and 1.1 percent increase in the residual elements.

Next we shall express the component rates of change as percentages of the overall growth rate, and compare with the component shares estimated by Denison, rearranged to correspond to our categories. Although Denison's study relates to real national income for the period 1929–1957, the comparison suffices to bring out certain broad divergencies which warrant discussion. Our growth of real tangible human and nonhuman capital accounts for 46 percent of the growth rate, while the growth of employment and real tangible nonhuman capital accounts for 49 percent of Denison's growth rate—an unimportant difference. But Denison's components associated with intangible capital formation—education and the advance in knowledge—account for 43 percent of his growth rate, while the relative growth of intangible capital accounts for only 21 percent of ours. Consequently, the residual forces account for a much higher proportion of our growth rate—33 percent, compared with 8 percent for his. It should be noted that we have shifted the −7 percent net effect of declining average hours worked per year as estimated by Denison from input to the residual, where it is combined with 11 percent due to scale economies and 4 percent due largely to the net effect of factors which affect economic (allocative) efficiency.

I suspect that Denison's judgment concerning the relative importance of the contribution to growth of intangible capital (and he does not include directly the health and mobility factors) is closer to the mark than are my computations. There are several possible reasons why my estimates may understate the contribution of intangible capital. In the first place, the estimates may be too low. I have already mentioned the omission of the knowledge acquired through informal R & D, and learning-by-doing. Further, my estimates of the stock of knowledge and know-how resulting from formal R & D may be low. I count the annual stock available for use in the production process, but it recently occurred to me that I am neglecting the accumulated R & D embodied in the stock of tangible nonhuman capital goods used in current production. This could raise the R & D stock severalfold, and I plan later to attempt estimates of embodied AR & D.

Second, the productivity and average rate of return on intangible capital may be higher than on tangible capital. If so, this could make a significant difference in the calculated relative contributions to growth. For example, if one assumes that intangible and tangible capital were of equal importance in 1929 (instead of intangible being one-third the importance of tangible, as indicated by the real stock estimates), real intangible relative to real tangible stock grew by 117 percent between 1929 and 1966. This is an average annual percentage rate of 2.1—more than enough to account for all of the increase in tangible factor productivity. This calculation overstates the case, no doubt, but it illustrates the importance of the weighting scheme.

Third, the relative growth of real intangible capital stocks may be understated in our estimates, due to the probability of a greater upward bias in the price deflator for intangibles than in that for tangibles.

Finally, I am not sure that the growth of intangible stock in relation to the tangible stock tells the whole story. That is, even if the two types of stock grew at the same rate, or even if both were constant, productivity would probably continue to rise. The annual R & D that replaces previous technical knowledge with new knowledge and inventions would increase the productivity of new capital goods in which it was embodied, even if these merely replace older goods. Likewise, it would enhance the productivity of the knowledge and know-how embodied in humans, even if the per capita stocks in terms of real costs did not rise. The question is how this new–old replacement effect can be quantified.

Concluding Comments

I am convinced that the development of estimates of total investment and capital stocks, intangible as well as tangible, opens up fruitful new approaches to the study of economic growth. I hope this has been demonstrated by the present paper, although it may have raised as many questions as it answered. But if the questions are as important as I believe, the ensuing discussion and investigations should contribute to our understanding of economic growth.

I have already indicated some of the future research that is needed. The concepts and estimates of total investment and capital need to be refined and improved, although I believe that the estimates I have developed for the U.S.

economy, by sector, 1929–1969, which will be published eventually, can immediately lead to useful new research. In particular, they will provide the basis for analyses of total saving and investment functions, by sector, and for new formulations and analyses of production functions, particularly for the enterprise sector of the economy. If we can answer the questions raised in the preceding section, the estimates can contribute to an expansion of our knowledge of the sources of economic growth.

Finally, it is to be hoped that parallel total investment and capital estimates will be developed for other countries. The resulting comparative growth analyses should help to reveal the roles of differing and changing value-systems and institutions which are, after all, fundamental to the more proximate determinants of economic progress.