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4 New Books on the Measurement of Capital

Stanley Engerman and Sherwin Rosen

In this chapter we review two recent books: R. J. Gordon, *The Measurement of Durable Goods Prices* (forthcoming), and J. W. Kendrick, *The Formation and Stocks of Total Capital* (1976). The central problems discussed in both books concern conceptually better and more accurate measurement of the input and output of capital stock and the related issue of defining investment. Gordon's chief interest is the technical problem of measuring improvements in the productive capacity of capital goods and the problem of obtaining quality-adjusted investment goods price deflators to provide better measures of real investment and capital stock. His estimates show substantially larger growth of real capital than those generally available. Kendrick's book is wider in scope and presents estimates of a broad view of investment including measures of intangible as well as tangible human capital, which are then used to explain increased output and economic growth in the economy in a way familiar to readers of his earlier works on productivity trends. Kendrick's work represents the most complete test to date of a hypothesis, attributable to T. W. Schultz, that an inclusive measure of the growth of capital stock should be able to account for the entire growth of output. His estimates of total factor productivity growth based on this concept of capital are lower than previous estimates and lend some support to the hypothesis. But unmeasured factors still affect productivity growth. More controversial and uncertain owing to biases in both directions, is Kendrick's empirical result that the rate of return (both gross and net) on human capital exceeded the rate of return on nonhuman capital investment throughout most of the 1929–69 period.

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Our comments will be within the rules and conventions of the approaches taken by the authors; thus we shall not ascend to the ethereal heights of the various Cambridge controversies about the theory and measurement of capital.

Both topics have long histories in the theoretical and empirical literature on growth accounting. The proper adjustments for quality change in capital goods have been a major source of controversy for the past two decades of discussion on the sources of economic growth, although the classic article by Denison (1957) precedes this debate by a few years. The position taken by Gordon figured extensively in the debate between Jorgenson-Griliches and Denison,[1] and he both clarifies some of the theoretical issues and produces many detailed measurements and imputations of quality change across a broad spectrum of goods, commodity-by-commodity. The broader definitions of capital proposed by Kendrick have even a longer history. The measurement of tangible human capital, as identified by Kiker (1968), goes back to the pioneer national income accountant William Petty, whose estimates were first published in 1691. Discussion of the conception and estimation of various intangible human components has persisted ever since, and it is probably T. W. Schultz's work in the late 1950s that focused attention on the measurement of the stock of education. While many have appealed to the various components of human and nonhuman intangibles as plausible explanations for "the residual," Kendrick's book represents the most detailed empirical calculations and discussion to date of measuring the amounts and effects of these intangible investments.

Kendrick's central conception of capital rests on the value of resources that society has devoted out of past production to provide for future outputs. First, he broadens the Department of Commerce concept of capital to include stocks of consumer durables and government capital, as well as business tangible physical capital. Second, he calculates several components of tangible and intangible human capital, as well as the intangible value of knowledge specifically created by research and development. The components of human capital include rearing costs, education and training, health, migration, and search, which are usually treated in the official accounts as parts of consumption or as current business expenses. Moreover, some component elements involve imputations for opportunity costs and are ignored in official accounts, while expenditures on research and development either are treated as parts of government expenditure or written off as business expenses. Thus Kendrick's work includes two major types of calculations. First, he reallocates certain items of GNP from consumption to investment. These reallocations more than double the investment-income ratios in the official accounts. Second, he makes imputations for various consumption

and intangible investment items. These imputations increase measured investment, but they also increase measured GNP and have a lesser effect on investment-income ratios than the reallocations (see table 4.1).

Table 4.1 **Breakdown of Expenditure Categories, Kendrick's Adjustments and Official GNP, 1929 and 1948**

	1929 Reclassified			1948 Reclassified		
Category	Official GNP (1)	Official GNP (2)	Adjusted GNP (3)	Official GNP (1)	Official GNP (2)	Adjusted GNP (3)
Consumption	77.22	54.10	64.84	173.56	125.00	146.04
Investment	16.23	45.25	54.92	46.01	111.87	139.89
Tangible nonhuman	16.23	29.19	29.47	46.01	75.73	76.63
Tangible human		9.77	9.77		18.28	18.28
Intangible nonhuman and human		6.29	15.69		17.86	44.98
Government	8.50	2.60	6.43	31.55	14.25	35.30
Net exports	1.15	1.15	1.15	6.44	6.44	6.44
Total	103.10	103.10	127.34	257.56	257.56	327.67

Sources:
(1) U.S. Department of Commerce, *The National Income and Product Accounts of the United States, 1929–1965* (Washington, D.C., 1966), table 1.1.
(2) Kendrick (1976, tables 2-1 and 2-1a).
(3) Kendrick (1976, table 2-1).

In essence Kendrick's methods embody in their respective categories specific items that previously have been considered to generate productivity change and account for the residual. It should be noted, however, that his procedures for human capital are somewhat different from those used by Denison,[2] though their measures of physical capital basically are the same. Indeed, Kendrick's treatment of labor inputs differs from his own earlier treatment (Kendrick 1961, 1974; see table 4.2). Both Kendrick and Denison rely on the OBE concepts and measures for physical capital, which apparently capture only a small part, if any, of quality improvements. For human inputs Kendrick follows most of the literature by differentiating the scale of labor input in the form of "raw bodies" from "improved bodies" owing to additional education and training, better health, and so on. His measure of the education component of human capital is based upon costs of schooling, while Denison and most others have used cross-sectional income-education profiles to compute standardized labor input indexes. His treatment of raw bodies imputes investment values to cohorts of persons under fourteen years of age, based upon consumption values and other resources devoted to them. Increased consumption by children in a cohort implicitly

Table 4.2 **Selected Measures of "Labor Input," 1948 to 1966 Relative to 1929**

Measure	1948[a]	1966[b]
1. Population	120.0	160.6
2. Labor force	129.3	164.3
3. Kendrick		
Persons engaged	126.9	158.8
Man-hours	109.2	129.4
Labor input	119.6	151.1
4. Denison		
Employment-total	126.9	163.3
Employment-NRB	122.9	143.3
Hours-NRB	106.2	115.2
Education NRB	112.1	125.1
Total labor input-NRB	130.2	159.2
5. Kendrick		
Gross human tangible	145.8	246.3
Gross education and training	184.3	366.5
Total gross human capital stock	164.5	308.2
Net human tangible	129.9	240.0
Net education and training	172.2	337.5
Total net human capital stock	152.3	293.3
Total net human capital stock employed in private domestic business economy	168.1	287.1
Total net human capital stock utilized in private domestic economy	147.5	242.4

Sources: Rows 1 and 2: U.S. Department of Commerce, *Historical Statistics of the*
Row 3: Kendrick (1974), pp. 236, 237.
Row 3: Kendrick (1174), pp. 236, 237.
Row 4: Denison (1974), pp. 11, 32 (NRB is Nonresidential Business).
Row 5: Kendrick (1976), Appendix B (Constant Price Estimates).

[a]1929 = 100 for each row.

[b]The lower age cutoff for the labor force (row 2) changed from 1929 to the later years, but the extent of understatement is minor.

allows for quality change in the production of a labor force: the average raw body in the labor force in 1966 is considered to be about 50% larger than the average body in 1929.[3] Those "quality" changes in human investment output that are due to increased measured inputs in their production are incorporated in human capital formation. However, the embodiment of technical change in the physical capital index is imperfect owing to the nature of official investment goods price deflators. The same is true for intangible business capital and its deflator (based on salaries and foregone earnings of research personnel). Note that no allowance for "quality" change in addition to increased costs is imputed. For example, education is considered more productive only when it uses more costly inputs, and no additional output of the educational sector due to increased efficiency in the transmission of new knowledge is allowed.

The major conclusions following from Kendrick's adjustments are that society's provisions for the future have been considerably greater than indicated by the conventional investment-income ratios, and that, in the 1929–69 period, the share of output devoted to investment was increasing because of the growth of intangible investment in humans. Nevertheless, it is still true that the growth of output has exceeded the growth in even this broadly defined capital stock, so that the residual, while lowered, remains. Moreover, cyclical variations in total investment and in the augmented investment-income ratio are less than for the conventionally measured, since the short-run fluctuations in human capital investment are considerably less than in nonhuman goods.

The measurement of physical capital stock forms the basic issue in Gordon's book, which attempts to improve upon conventional physical investment goods price deflators and obtain better measures of real nonhuman investment. More generally, Gordon raises a question of major importance in all national income accounting: What is the definition of a commodity? Is the appropriate definitional unit some generic or specific physical good, or should it be some underlying set of performance characteristics among the class that yields utility or future services? To use Gordon's example, is the desired good a computer measured at cost, or is it the potential number of calculations performed? Is the relevant unit a car or, as is familiar from many studies, a combination of comfort, speed, braking time, and so forth? A similar example given by Griliches and quoted by Gordon is the appropriate definition of output in the birth control sector, where it has been found that the same contraceptive results can be achieved with smaller doses of pills, an improvement in productivity not adequately measured by cost-related indexes and a point that is easily generalized to have broader implications for Kendrick's measurement of the stock of health capital. Gordon's main point is that the transactional units of account—dollars worth of computers, cars, pills, and so on—are not appropriate for growth accounting because they embody arbitrary and changing packages of productive characteristics and that a more appropriate definition should be based on some invariant set of *performance characteristics*. Moreover, Gordon implements these methods by using several modern variants of familiar standardized comparisons of new and old equipment. First, implicit prices of the invariant characteristics of capital goods are imputed from market price data on the transactional units and the performance attributes embodied in them. Then the imputations are used to compute quality-adjusted price indexes that finally are used to deflate capital value expenditures and obtain the desired quality-adjusted real investment indexes.

In this Gordon is carrying on a running battle with several government statistical agencies, but it is often unclear whether the replies to his kind of critique are based on principle or practicality. Thus at times it

seems there is acceptance of the usefulness of the concept of quality-adjusted output; but there are also reservations about the practicalities of making adjustments that seem so complex as to be of little use in preparing national income statistics, and there is skepticism about the results to date, which often vary dramatically from study to study. Further, it is important to distinguish issues relating to measurement procedures from questions of the specific magnitude and direction of bias.[4] It does seem that under clearly specified conditions some quality changes are picked up by the conventional deflators. Thus, in cases where two related capital goods of different productive capacity are available in the market at the same time, relative costs are used to provide a quality-corrected linking. This procedure, however, apparently is performed in only a small number of cases, and there remain conceptual problems about the best time for such a linking. For example, if relative costs of production of new goods systematically decline, as is familiar from "learning curve" phenomena, the later the date when the linking is made, the smaller is the measured allowance for quality change. A second case in which quality changes are incorporated by conventional methods is when the improvement is embodied in a specific component that can be separately costed, such as seat belts. Gordon argues, however, that these varieties represent only a minor part of the total, and that conventional procedures therefore omit the bulk of quality improvements in capital goods. By extension, the same is true of consumption goods accounting as well. Given Gordon's analysis of the quality of consumer durable goods, it seems that Kendrick's imputed consumption from this stock is understated. More generally, any attempts to quality-adjust consumer nondurables and services no doubt would have a similar effect. Since the proper adjustment of consumption goods for quality change is not central to Gordon's work, we have not read his adjustments of the investment goods deflators as having any implications for possible differential biases in consumer and investment price indexes.

Gordon's major empirical result is that the rate of growth of the conventional investment price deflator has been too large by several percentage points: there has been a greater rate of quality change over time than is measured by the official accountants (see table 4.3). Consequently, measured growth in capital formation in the areas discussed—producer and consumer durables, autos, and construction—has been severely understated, and their real price increases have been overstated.

It should be noted that neither study provides estimates of broader definitions of GNP, such as the concept of Net Economic Welfare (NEW). Thus there are no direct imputations for the value of housewives' time, leisure, urban amenities and disamenities, changed working conditions, and other consumption aspects of work.[5] In part this reflects

Table 4.3 **Annual Percentage Rates of Change of Gordon's New Alternative Price Index and of Real Investment in Producers Durable Equipment Relative to Official NIA Measures, 1947–70**

	1947–57	1957–70	1947–70
Average deflator for all products			
Official NIA deflator	3.5	1.7	2.4
New alternative index	−0.2	−1.2	−0.7
New minus official	−3.7	−2.9	−3.1
Real investment in producers durable equipment			
Official NIA series	2.9	4.6	3.9
New alternative series	6.7	7.7	7.2
New minus official	3.8	3.1	3.3

Source: Robert J. Gordon, *The Measurement of Durable Goods Prices* (forthcoming).

an issue of principle: Kendrick justifies some omissions on the grounds that he is interested mainly in the production relationships in the economy. This point of view would be most appropriate if these unpriced commodities were "pure" consumption goods completely separable from the measured components. But this assumption about technology and the nature of inputs is too narrow, since such strong separability cannot be maintained. For example, Denison has noted that increased leisure affects worker productivity. But so do providing tickets to ball games, better personnel management, more frequent tea or coffee breaks, and air conditioning. Of course, some of these appear in the accounts as part of other components (air conditioning would be an investment), but corresponding consumption values generally are ignored. Indeed, a neglected major aspect of the entire genre of growth-accounting studies has been the analysis of changing quality of working conditions and the increased value of what is best labeled on-the-job consumption.[6]

Analytically the treatment would be similar to Gordon's measurement of quality change of physical capital, but using different aspects of work activities as the invariant characteristics. Strictly speaking, estimated potential income should be based upon the maximum pecuniary income each member of the population can earn (presumably evaluated at the base period average job quality), not on their actual job selections, which represent transactions in consumption aspects of work and therefore exclude increasingly important values of nonpecuniary income. While some of these issues lie beyond the scope of Kendrick's study, there remain others, concerning the value of housewives' time, and particularly time spent in child-rearing, that do not. Within the spirit of the imputations of foregone earnings for students, an allowance should be made for changing labor force participation of mothers as

well as time lost during pregnancy (and maternal death rates), surely among the more important investments made in the course of childbearing.[7] Indeed, could not some of the male-female differential in earnings be regarded as a long-term cost of childbearing? More generally, as market goods are substituted for nonmarket goods (the contemporary analogy to Pigou's example would be the wife who used to provide meals at home but who now works for a fast-food chain and brings home payment in kind), there is a spurious increase in measured output, although since measured input is also increased (spuriously) the net effect on measured productivity change is not transparent.

Gordon's substantive contribution to the growth productivity accounting literature involves the measurement of quality changes for a large number of commodities and industrial units. His conceptual framework is similar to that underlying the construction of hedonic price indexes, where market prices of commodities within each generic class of goods are related to their underlying product attributes by regression or similar methods.[8] The fundamental idea is to distinguish shifts in the observed price-attributes relationship from movements along it, the former being associated with pure price changes for all quality components and the latter associated with pure quality changes within the existing price structure. In the hedonic approach, the coefficients of the estimated price-characteristics regression function are interpreted as implicit prices of the various components of quality, from which quality-adjusted price and quantity indexes are computed by familiar methods.

As outsiders to the ongoing debate on the measurement of capital, it seems clear to us that Gordon appropriately has identified the conceptual issue as the proper definition of a commodity. Do we want a $2'' \times 6''$ radio or do we want x hours of playing time in the future? It is most meaningful to define the radios in terms of playing time, not by the arbitrary and varying packages used to provide it. As a formal matter, Gordon's method of quality adjustment makes most sense when quality change is "quantity augmenting" (the so-called repackaging case). In that case the services of capital enter the production function as the product of the quantity of capital and an elementary function of its quality, the latter represented by a vector of measurable characteristics—a measure of "efficiency units," as it were. (The obvious analogy to Kendrick's differentiation of human capital into "raw bodies" and improved bodies will not pass unnoticed.) This case represents a variety of perfect substitution between quantity and quality attributes. Then the transactional unit of account truly is arbitrary, and the estimated implicit prices of product attributes adequately serve as measures of marginal rates of substitution required for the construction of index num-

bers. On these terms Gordon's quality adjustments raise issues neither more nor less complex than are familiar from discussions of standard index number problems.

Gordon argues persuasively that the assumption of quantity augmentation and the methods implied by it are better than the official methods, to a first approximation. Yet one may wonder if the approximation is close to true when the efficiency units assumption cannot be maintained. No satisfactory capital aggregate has been shown to exist in such cases and the quantity-augmentation assumption is likely to break down in the presence of indivisibilities and multiple attributes that are not linearly combinable. While both black-and-white and color television sets provide entertainment services, in what sense is it meaningful to say that the latter represents x more units than the former? And granted that there exists between the two a marginal rate of substitution for each consumer unit, revealed preferences for one kind or the other show that most people live off the margin, that there are marginal rents, so that observed price-attribute differences measure the proper marginal rates of substitution for only a small fraction (those truly on the margin of indifference) of the population. This point is readily generalized to cases where a whole spectrum of goods of varying qualities and attributes exist side by side in the market (see Rosen 1974 for a detailed discussion of these points). For example, those who buy smaller, less expensive automobiles evidently do not value the additional attributes provided by larger and more expensive models as much as they value their additional cost. But Gordon's estimation of linear price-attributes surfaces automatically assigns the same implicit prices to everyone independent of their location in the sample space. Problems associated with differences in tastes are thereby simply ignored. Precisely analogous issues arise for capital goods used outright in market production, since machines of alternative specifications embody design characteristics tailored for specific purposes. For example, two motors of one-half horsepower are not obviously equivalent to one or some other number of one-horsepower motors. These are far from standard index number problems. Of course, this issue would be unimportant if price changes on all product varieties within each class of goods were sufficiently uniform that their relative prices were left intact. Then pure price changes virtually are defined by uniform shifts in the price-attributes function, and time dummy shift variables measure these changes quite adequately. However, Gordon's empirical results show that actual price movements are considerably more complex than that.

Related questions exist in cases where alternative varieties of a commodity embody multiple attributes. Gordon's principal example relates to new computers, costing the same as older models, but with twice as

much computational speed. His argument that they should be counted as twice as much capital instead of the same amount, as the official methods would do it, is well taken. Yet newer vintages of computers also embody greater core capacity, time-sharing and interactive capabilities, and so on. If it is a package of "computational services" that is to be priced out for productivity analysis, it seems more appropriate to compare the new models with the older ones plus the allied services (e.g., research assistants) that are also embodied ("capitalized," as it were) in the latest vintages but not in the older models. There is no great issue of principle here, but the point is that care must be exercised to guarantee that similar overall packages of total services are being compared. However, there are many practical difficulties of implementing this procedure, since the adjustments required to obtain comparable bundles must be made good for good and case by case. One could conceivably extend this kind of argument to the limit and link the displacement of horse-drawn vehicles by bicycles, trucks, autos, motorcycles, trains, and airplanes by using the production of "transportation services" as the general organizational principle; though not even such a strong advocate as Gordon has attempted to go that far.[9]

In addition, in empirically implementing Gordon's methods there are some genuinely difficult data problems that revolve around the definition of goods. Economic theory is disconcertingly fuzzy about some of its primitive constructs, and the definition of a good is one of them. While Gordon hardly can be faulted for gaps in economic theory, his analytic framework elevates them to a more prominent position than is necessary for many problems in economics. Once we have said that goods of varying qualities within the same generic class should be compared in terms of performance characteristics, there remains the hard work of obtaining adequate measures of these attributes. What performance indicators do we want, and how are multiple indicators of the various dimensions of services to be treated statistically? The fact is that most quality adjustments based on regression methods have had to make do with readily available data, which relate in unknown and imperfect ways to the ideal. Thus, for example, weight is used as a characteristic for hedonic studies of automobile prices. Surely weight is not a utility-bearing characteristic, and one might expect its implicit price to be sensitive to fuel prices. Though Gordon advances some interesting modifications of previous work here, it remains to be seen whether such things as weight, horsepower, and length can adequately proxy true performance characteristics and whether the relationship between measured and desired characteristics remains stable over time.

Gordon presents a large number of adjustments and assumptions for specific items. New hedonic price estimates are presented for some

goods, and earlier results of other investigators are used for other goods. For many goods the data are not adequate for thoroughgoing hedonic studies, and so comparisons of closely similar models several years apart (e.g., 1949 Buicks compared with 1970 Chevrolets) are used, on the grounds that these models represent comparable observations on implicit prices for both years, from which pure price shifts can be inferred. Also, for the preponderance of specific items, quality adjustments have been made by linking various vintages of models in Sears Roebuck catalogs, which give detailed information on price and specifications. It should be noted that these latter cases represent observations on durable equipment primarily used in the household sector, which often seem to be extrapolated to much larger scale industrial equipment. We do not feel qualified to discuss these details and so we note only that some of the specific adjustments already have been questioned by several government accountants and are likely to be debated for some time to come. Clearly, whatever principle is finally agreed upon, enormous work remains to fill in the details. Returning this to the respective agencies, we wish only to make a general remark on the implications of these adjustments for growth accounting.

There are two substantial differences of interpretation of measured productivity growth implied by cost-based versus quality-adjusted capital stock measures. First is the specific time period in which productivity change is measured. Second is the classification of technical change as embodied or disembodied.

1. Both methods do allow for measured productivity change, and it is simply not true that quality-adjusted measures define away technical advance, as some have claimed. However, the timing is different. Using quality-adjusted investment data raises GNP in the year the higher-quality goods are produced, increasing the measured residual at the time when the greater future productive capability is introduced into the economy. On the other hand, the conventional method shows a residual in those years in which the actual greater flow of services attributable to those capital goods occurs. Measured input in years subsequent to that in which the quality improvement is introduced is lower in the conventional method than if quality-adjusted indexes are used, but measured output in the year of production is higher in the quality-adjusted method than is shown by the conventional accounts. In actual practice, the problems are more complex, depending on accounting conventions, the precise nature of quality changes, and whether they occur in consumer or producer goods. But it seems that this contrast is the typical one for business investment. This difference in timing obviously is important to students of economic growth, since it yields substantially different interpretations of economic movements and the level of po-

tential output. For these reasons, and since they are based more securely on neoclassical production theory, quality-adjusted methods in principle appear to provide a more reasonable and meaningful set of estimates.

2. Related to this is the question of the extent to which productivity change is to be classified as embodied or disembodied. As shown by Jorgenson (1966), without detailed examination of technical advance for individual capital goods there can be no logically identifiable decomposition of embodied and disembodied technical change. What Gordon attempts to provide here is such a detailed, independent examination and analysis of the actual productive capabilities and characteristics of the capital goods. This is what makes identification of the embodied component possible and what makes such distinctions meaningful both empirically and theoretically. Much of the earlier debate on the correct measurement of capital concentrated too much on whether allowances for the changing nature of capital goods should be made before or after the residual was computed, an issue evidently not worth the heat it generated. In principle, quality-adjusted measures permit proper attribution of increased productive potential where they belong—to individual inputs. Curiously, adherents to the OBE concepts have never questioned similar adjustments in the case of increasing labor quality and have even computed standardized labor input measures based on education. We find this asymmetry puzzling. These distinctions are important for analyzing the sources of growth and for appropriate public policy, since they may point more clearly to some of the specific and ultimate causes of productivity growth.

Although Kendrick's measures of investment in business physical capital follow the official procedures, he is sympathetic to the quality-adjusted approach exemplified by Gordon's work. However, the most interesting, imaginative, and novel aspect of Kendrick's work relates to his treatment of investment in human capital and in intangible nonhuman capital. He gives detailed annual estimates of investment and capital stock for tangible and intangible nonhuman and human investment by sector. As stated above, he uses the conventional non-quality-adjusted measures of tangible nonhuman investment. Intangible nonhuman investment measurement is based upon research and development expenditures. Presumably the returns from these investments accrue from the production of new and better capital and consumer goods. To the extent that costs for research equal benefits it could be argued that this accounting adds a new sector whose output is quality change. In that case, Kendrick's accumulated nonhuman capital could be similar to that provided by quality-adjusted measures, albeit with substantial differences in timing as well as in the nature and form of embodiment. The complexities of interpretation depend also on the extent to which

changes due to R&D can be introduced only by embodiment in new capital goods, and on the nature of the price deflators applied to these goods. In this sense the accounting treatment of intangible nonhuman capital need not differ from that of tangible capital, since the output of the former sector is quality change. Clearly, the introduction of a sector producing quality change is a welcome addition to the study of growth accounting. However, it does not at all preclude incorporating the quality changes thereby produced into the measurement of capital inputs.

Tangible human capital is measured by the accumulated costs of rearing children to age fourteen, while intangible human investments are classified as those used to educate individuals, to provide them with training and health, and to improve labor allocation via job search and mobility. Kendrick's demarcation between tangible and intangible human capital is less than distinct. Though we can appreciate the quantity-quality issue confronted, this separation has the effect of splitting expenditures on the under-fourteen group into two categories: tangible (rearing) and intangible (education, health, etc.) and raises some more general issues of substitution possibilities between formal schooling and similar activities performed in the home. Kendrick does not base his estimates of rearing costs on a subsistence concept. Rather, increased consumption expenditures upon children in successive cohorts are used to impute larger stocks, thus implicitly letting increased cost of children generate measures of secularly improved bodies in the labor force. Intangible human investments also are valued at their costs of production, including foregone earnings of both students and the functionally unemployed. Again, increased real expenditures are used to impute increased productive capacity. Those quality improvements in child-rearing techniques, health care, and education not reflected in explicitly higher costs are ignored.

Kendrick's method for estimating the human capital stock is different from that used for nonhuman capital, and this asymmetry is the source of several potential biases in comparing relative productivities of each type of capital and in making inferences about rates of return. The estimates for nonhuman capital are based upon the usual perpetual inventory method, with goods counted as part of gross capital until retirement and depreciated over their life-span. The estimates of human capital are based upon attributing rearing costs, education, and other intangibles to survivors. The treatment of rearing costs has the unusual property that the secular decline in mortality before age fourteen increases the residual. Measured growth in human capital stock is biased downward on this account, because all costs of raising children until age fourteen are attributed to the relevant cohort and no deductions are made for the number who die before age fourteen. Variations in sur-

vival rates in a cohort after age fourteen are accounted for, however, in an altered stock of intangible human capital. Further, there are no imputations of the personal consumption value of changed life expectation, based on the appropriate willingness-to-pay concept, which would show a rising trend (the rate of return to human capital investment is too low on this account), nor is sufficient allowance made for the considerable short-run fluctuations in human capital owing to wars.[10]

Kendrick's estimates are original, useful, and important, and within the rules of the game they have a certain justification. We could ask many specific questions: Why should one-half of health care expenditures be regarded as pure consumption? Why not three-fourths or five-ninths? And, more important, why should this ratio be constant over time? Counting all expenditures on rearing costs and education as investment and none as consumption probably overstates the human capital stock. Rearing costs undoubtedly include a large component that increases consumption value to parents rather than adding to productive capacities of children. Kendrick's estimates imply that if hamburgers are purchased for dogs it is consumption, but more hamburgers consumed by children constitute investment. Further, the extent to which wage incomes are lowered owing to costs of on-the-job training remains empirically uncertain, but recent work suggests that the magnitudes exceed the components imputed by Kendrick, tending to reduce his measures of human capital stock and bias the rate of return upward. Some allowances for informal on-the-job investment come in by the back door, since Kendrick does not depreciate intangible human capital before age twenty-eight on these grounds. But surely this assumed equality of depreciation and on-the-job investment leads to understatements of gross investment. No doubt there are other specifics that might be questioned, but this does not detract from the importance of Kendrick's pioneering work.

In essence Kendrick's treatment of child-rearing costs in a free society raises issues similar to those that have been often suggested for a slave society, where the production of a labor force is treated as an investment. There always is some awkwardness in treating children as both consumer and investment goods, since it is not clear whether to regard their consumption as utility to children, to their parents, or to both. Also, the use of per capita estimates to measure welfare over time is complicated because it is sensitive to the mix of expenditures chosen by parents between more goods (or leisure) and more children: the former raises measured per capita welfare and the latter reduces it; yet revealed preferences yield an unambiguous result. A similar issue is involved in Kendrick's breakdown between consumption and investment, as noted above. Note, however, that the formal similarity to the account-

ing in a slave society does break down, since slaves are treated as intermediate investment goods whose own consumption never enters into output because they are not considered members of the relevant population.

Kendrick's discussion of a tangible human capital sector producing live fourteen-year-old bodies for the economy is in the best tradition of the often-discussed slave-breeding firm.[11] Yet Kendrick's procedure of accumulating the annual costs of production without interest amortization differs from the proper accounting for such a firm.[12] It also provides some asymmetry with the treatment accorded physical capital. Productive humans have a longer gestation period, or period of production (fourteen years in Kendrick's case, to be exact), than do most forms of physical capital. Thus there is a longer period of deferral between the initial investment expenditures and future flows of income than in the case of physical capital. Since "time is money," the slave-breeding firm would not sell at undiscounted accumulated rearing cost but would charge the going rate of its funds tied up in goods-in-process.[13] This problem need not be asymmetrical between human and nonhuman capital, since it involves handling the time needed to produce an asset. In the case of a firm producing durable goods and selling them to users, investment in durables (as opposed to inventory-in-process) is picked up at the time of sale and is measured at the cost of production, which includes an allowance for interest during the period of production. Kendrick's unamortized estimates of the value of human capital therefore understate the relative amount of resources devoted to childbearing investments, understating human caiptal, and thus introduce an upward bias in the rate of return. Since the accumulated value of an annuity of $1 per year for fourteen years at 10% is equal to about twice the undiscounted value, such a consideration is not trivial. And, given the importance of rearing costs in total human capital investment, Kendrick's conclusion as to the relative under- and overinvestment in different forms of capital seems unwarranted.

Kendrick presents three alternative concepts of the stock of human capital: the capital embodied in the total population; the capital embodied in the employed population; and a measure based on man-hours of employment. He does not estimate the rate of return by comparing net labor income with the stock of total population capital but uses the employed population instead. However, this procedure implies a very specific imputation for the value of production in the nonmarket sector: The rate of return on human capital not employed in production in the market is assumed to be identical with that found in the nonmarket sector, an assumption that must be true only at the margin and not on average. Further, one may question his use of employed human capital

to estimate relative rates of return, since its treatment is not symmetrical with that of nonhuman capital, which is assumed always to be fully employed. It also misstates expected returns to investment in human capital if employment variations are anticipated. Thus he has adjusted human capital for utilization, but no utilization adjustment is made for the rest of the capital stock, again tending to increase the estimated relative rate of return to human capital. Obviously, the social return to human capital was smaller in the 1930s than estimated by Kendrick, and, while it might be argued that this need not have been true had economic policy been appropriate, the same point can be made for the return to physical capital. Kendrick's method might be justified on the grounds of providing a better measure of productivity of factors actually in use, where output per employed worker provides a partial adjustment. Yet it seems that the comparison of rates of return would be more useful either if nonhuman capital was similarly adjusted or if the denominator for human capital stock was based upon some concept of a standard, normal labor force. Further since the concept he calls "utilization" adjusts for hours worked, the basis for a similar reasonable adjustment for nonhuman capital utilization is suggested.

In his estimates of the returns to human capital Kendrick reduces labor incomes by a provision for maintenance to obtain a net figure, justified as providing symmetry with the treatment of physical capital. Yet the orders of magnitude of these adjustments differ markedly for the two forms of capital, and, in linking maintenance of tangible human capital to a rising consumption standard, it seems that elements of increased consumption are deducted. While in the case of slaves, adjustments for "pure" maintenance might be based on some subsistence concept for those already generating incomes and the expenditures on those not yet employed are regarded as investments, we find Kendrick's discussion unclear on just whose maintenance has been deducted and how the cost of the goods-in-process were treated. The estimated rate of return to the employed stock of human capital evidently should adjust for the maintenance only of those employed, whereas the broader adjustments made by Kendrick appear to include the entire population. This treatment would introduce a downward bias in computed rates of return while also making them sensitive to labor fore participation rates.

We have not touched on many of the other interesting issues contained in both books. Gordon provides new information on the relationships between transactions and list prices and their cyclical changes over time. Kendrick provides much detail on changes in the sectoral composition of investment and their determinants, as well as information on the cyclical variability of various types of investment. Thus both

books will be major sources for empirical and policy studies for a long time. Here we have discussed only the broader themes related to the measurement of capital.

Notes

1. See the original articles, replies, and final comments in *Survey of Current Business*, vol. 52 (1972).

2. For Denison's most recent estimates, see Denison (1974).

3. Thus the value of net human tangible capital stock employed in the United States private domestic business to persons engaged rose from $3,032 in 1948 to $3,839 in 1966 (in 1958 dollars). The ratio of net human capital stock employed in the United States private domestic business economy to the estimated number of persons engaged rose from $2,561 in 1929 to $3,032 in 1948. For total net human capital the increases are from $10,319 in 1948 to $15,440 in 1966, and $7,546 in 1929 to $10,319 in 1948.

4. For an extensive discussion of these points and a critique of some of Gordon's earlier work on these problems, see Triplett (1975, pp. 19–82).

5. See, e.g., the work of Nordhaus and Tobin, *Is Growth Obsolete?*, in the NBER Fiftieth Anniversary Colloquium, *Economic Growth* (New York, 1972).

6. See the points raised by Robin C. O. Matthews in his discussion of the work cited note 5.

7. See the discussion of this in Machlup (1962, pp. 52–56). Machlup's book, in addition to discussing many aspects of the conceptual treatment of knowledge, includes calculations of the output of knowledge production in 1958 based upon various adjustments and reclassifications of the national income accounts. His estimate of the final product is $109.2 billion (but no breakdown is provided between consumption and investment). Kendrick's investment in intangibles (which includes health expenditures) is $97.5 billion.

8. See the articles in Griliches (1971).

9. See, however, Fogel (1964) and Fishlow (1965) for discussions of the substitution of railroads for other transport modes.

10. See Usher (1973) and the discussion by Willis.

11. For estimates of the returns to slave females, including the value of their offspring, see Conrad and Meyer (1958). On this see also Fogel and Engerman (1974).

12. Note that Kendrick does not discuss the question whether the appropriate social rate of discount should be zero for his calculations.

13. See also the discussion in Dublin and Lotka (1946, chap. 4).

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Comment

John W. Kendrick

Engerman and Rosen have written a thoughtful and balanced review of my new book. They have certainly read and pondered it with care. I am gratified that, despite the deficiencies they have noted—and others will doubtless be found—they consider it a useful pioneering effort that will be a source for empirical and policy studies for some time to come. I hope, further, that the basic approach and conceptual framework will be adopted by others—perhaps eventually by government statistical agencies, at least in part—and the concepts and estimates refined and improved.

The reviewers note that one of the analytical uses to which I put the new estimates was to test the Schultz hypothesis, referred to in the preface, that economic growth can be wholly explained in terms of the accumulation of total capital, broadly defined. At the same time I was also testing the more constrained hypothesis developed in the mid-1950s by Fabricant and me that the growth of the intangible capital stocks resulting from investments designed to improve the quality and efficiency of the tangible factors would account for a significant portion of the increase in total tangible factor productivity. We were, of course, measuring the tangible factor stocks and inputs without adjustment for quality change. The new estimates do support our hypothesis, although I was surprised that less than half of the residual appears to be explained by the growth of real intangible stocks and inputs. I would not expect all of it to be so explained, given the existence of non-investment growth forces, such as increasing returns to scale, changes in economic (allocative) efficiency, and changes in intensity of use of resources. But I also suspect that my estimates of the growth of real total stocks may be understated.

I did not, of course, adjust the tangible investments and capital stocks for quality changes (except to the extent that they were associated with changes in unit real costs), since, as the reviewers recognize, the estimates of real intangible investments and stocks, human and nonhuman, provide an alternative approach to estimating the effect on output of changes in quality and efficiency. If Gordon is right, however, that the construction and producers' equipment price deflators have a significant upward bias, above the quality improvement factor, then my nonhuman tangible investment and stock estimates have a downward bias. The same is probably true of the intangible investment and stock estimates, since the deflators are based largely on input prices. Correction for these biases would result in a larger rate of growth of the real total capital estimates and thus a narrowing of the residual. This factor and several

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others were discussed in the volume as reasons for believing that the growth of real total capital stocks and inputs accounted for a larger share of the growth of real product than we calculated, although I am convinced that a final residual would, and should, remain.

With respect to a general comment by the reviewers that growth studies tend to neglect imputations, I should mention that in another NBER study I have been involved in developing estimates of imputed values of most nonmarket outputs. In the total capital study, I did develop a number of imputations required for consistency—for examample, the rental values of nonbusiness durable goods and the opportunity cost of students. Since I did not then have completed estimates of the imputed value of unpaid household work, however, I did not include housewives and other unpaid household workers in the employed human capital stock to be related to the income and product estimates.

Engerman and Rosen raise a number of specific questions on concept and methodology that I shall try to address briefly. First, I believe they are right in arguing that rearing costs should include an implicit interest charge, just as the cost of nonhuman capital goods includes an allowance for interest during the period of production. The rearing cost estimates might also have included the value of parents' time devoted to rearing, if such estimates had been available. These adjustments would affect the levels of the tangible human stock estimates, but would have little effect on the movements of the real stocks.

Following the logic of viewing the rearing of children as an alternative to consumption or saving and investment in other forms by the parents, I should probably also have imputed a rental value to the rearing stocks to add to personal consumption outlays. The same should be done for household pets, of course. This would eliminate the paradox noted by the reviewers that under my current procedure, hamburgers purchased for children are counted as an investment while hamburgers for dogs are consumption! If both are investment, the rental values of the resulting stocks represent the consumption utilities to parents and owners.

The reviewers note that I increase both the real basic consumption per child in estimating rearing costs, and that of employed adults in estimating real maintenance costs (for computation of rates of return), in line with the upward trend of real personal consumption expenditures per capita. This has the theoretical justification that customary or conventional subsistence standards are influenced by attained levels. But I must confess that this procedure gave me more reasonable results in estimating rates of return on human investment. Use of the alternative assumption of unchanging minimal subsistence levels resulted in an upward trend in rates of return on human capital.

I would take issue with Engerman and Rosen on one of their points—the criticism of my asymmetrical treatment of human and nonhuman capital in adjusting the former for rates of employment and utilization but not the latter. In a private enterprise system, labor is a cost only when employed, while capital carries a charge, explicit or implicit, regardless of rates of utilization. In productivity analysis, falling rates of utilization tend to reduce productivity, particularly of the capital factor, but also of the labor factor, since there are also "overhead" types of labor. Certainly in calculating private rates of return one should use the employed human capital stock rather than the total as a denominator, since the labor compensation component of national income relates only to employed labor. In the case of capital, it seems to me that declining (rising) rates of utilization should be reflected in declining (rising) rates of return, particularly since nonhuman capital has no alternative use. In the case of human capital, there are alternative uses—nonmarket economic activity and leisure. If a value were imputed to the nonmarket human activities, then it would make sense to relate total compensation of the human factor to its total capital value. But the calculated rates of return in that case would merely reflect the compensation rates used in the imputations for the nonemployed portion of the adult population.

The reviewers inquire about the reasoning behind several of the estimating conventions. Why, for example, do I count all educational outlays as investment? The short answer is that I consider the element of current consumption to be entirely minor compared with the longer-run benefits of increased earning capacity and enjoyment in the future. Why do I assume that half of medical and health outlays are investment? In perusing the literature and talking with experts such as Fuchs and Mushkin, I was persuaded that a substantial portion of such outlays represents consumption in that it does not result in long-term benefits. But another substantial portion does represent investment, in that it increases longevity, reduces time lost owing to illness, and increases vitality. But the experts are not able to allocate the totals. So I decided on half-and-half as the least objectionable and most convenient assumption. More research on this is needed; in the meantime, those who feel strongly that some other allocation is better can easily adjust the estimates.

One final point: the reason we calculate depreciation on educational capital only after several years of work experience is not because of offsets in the form of on-the-job training (for which separate estimates are prepared), but rather because it represents a crude attempt to take some account of learning-by-doing. This is undoubtedly a significant investment aspect of work experience. But innovative as we may have been in developing concepts and measures for various types of invest-

ment and capital not hitherto counted, we did not venture to estimate the value of the knowledge and know-how generated by work experience—or the consumption values of productive activity for which the reviewers would also like to have imputations.

If my book sparks additional efforts to refine the concepts and improve the estimates of total investment and capital, I shall feel rewarded. Even though total capital formation does not appear to be the entire proximate cause of economic growth, it is big enough to merit much more work.