Volume Title: Problems of Capital Formation: Concepts, Measurement, and Controlling Factors

Volume Author/Editor: Conference on Research in Income and Wealth

Volume Publisher: NBER

Volume ISBN: 0-870-14175-9

Volume URL: http://www.nber.org/books/unkn57-1

Publication Date: 1957

Chapter Title: Theoretical Aspects of Quality Change, Capital Consumptio and Net Capital Formation

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Chapter URL: http://www.nber.org/chapters/c5584

Chapter pages in book: (p. 215 - 284)

THEORETICAL ASPECTS OF QUALITY CHANGE, CAPITAL CONSUMPTION, AND NET CAPITAL FORMATION

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The measurement of aggregate capital formation, capital consumption, or capital goods stocks may be undertaken for many purposes, each of which may call for a particular definition. Frequently, the magnitude is one which influences economic decisions and actions so that its measurement contributes to an understanding of economic behavior. For example, if book depreciation, however computed, influences the amount business invests, or if profits based upon such depreciation charges are those businessmen seek to maximize or upon which taxes must be paid, these charges are clearly of interest. Alternatively, it may be believed that the magnitude to be measured does not in fact govern economic decisions because requisite data have not been available to those exercising economic discretion; but that if they were available they *would* influence decisions and *would* lead decision-makers to act more wisely in either their own or the public interest. The Machinery and Allied Products Institute seems to support much of its research in the field of capital measurement on this basis.[1] If the belief is correct, such a justification is clearly adequate.

Most measurements of capital formation, capital consumption, and capital stocks fall into one or the other of these categories. They are properly subject only to questions of usefulness, statistical accuracy, and, sometimes, internal consistency. The scope of such estimates in terms of commodities, types, and "grossness" of expenditures, and sectors of the economy covered, is dependent upon similar considerations.

However, one concept, real net capital formation, is often discussed as if it were subject to uniquely correct measurement. This measure, deeply imbedded in economic literature, seeks to value positive or negative departures from the situation in which "capital is kept intact." Underlying the interest in this measure is the idea

Note: The views expressed in this paper are those of the author and not necessarily those of the Office of Business Economics.

[1] See, for example, *Capital Goods Review*, November 1952, especially p. 8.

that, other things being equal, a society must at least preserve its capital stock (have zero net capital formation) or suffer retrogression —apparently in the sense that it will be unable to maintain its current rate of production in the future. Thus positive net capital formation is considered a requisite for economic progress.

Further, a theoretically precise measurement of national income (or net national product) requires knowledge of the circumstances under which capital would be kept intact because the very idea of income is associated with the amount which can be consumed without reducing the expected flow of future income—or, as it is often put, without being worse off at the end of the period than at the beginning.

If "the amount of capital consumption which must be replaced by gross capital formation for capital to be kept intact" is a measurable entity, and if deviations from it can be established as positive or negative values, there is a strong interest in their measurement. This is not only because of academic interest in appraising economic progress but also because the determination of whether we are augmenting or liquidating our capital resources is important in considering national policies presumed to affect the rate of capital formation.

There appears to be general agreement that, if net capital formation can be measured in a way consistent with the implications of the preceding paragraphs, its investigation belongs properly to the field of national income inquiries, and it is a component of the net national product.

At this point a basic divergence of opinion appears. Some investigators have gone ahead and attempted to measure net capital formation, producing estimates which, however qualified as to accuracy, are intended to report the amount by which the community's stock of capital has been augmented or depleted. Others, including most official investigators, have denied that the notion of "keeping capital intact," and hence of net capital formation, has been given "operational definition."[2] By this is meant that, given the complexities of the real world, no acceptable specification of the terms "keeping capital intact" or "net capital formation" has been developed which lends itself to quantitative measurement; even if all the data which exist in the real world were collected and at hand, we would not presently know how to put them together in a way which would meet the objective of the theoretical economists. If

[2]This phrase is used, for example, in *Survey of Current Business*, Dept. of Commerce, National Income Supplement, July 1947, p. 11.

this is true, any estimate of net capital formation must either be meaningless or else have some other meaning than that suggested.

These investigators, rather than purport to measure what appears immeasurable, have concentrated on values which can in principle be largely derived either from actual records of transactions or from business records of account. These are presented as data helpful in interpreting economic developments but not as providing a measure of net capital formation in the basic sense just discussed.

The most fundamental difficulties leading to denial that the concept of net capital formation has been specified in a way suitable for statistical measurement fall into two categories. First is the problem of quality change. How can the constant dollar values of machine tools made in 1930 and 1953 be compared? And how can the 1953 value of the capital embodied in the 1930 tool and used up in 1953 be subtracted from the 1953 value of a tool newly produced in 1953? Second is the problem of allocating capital consumption over time. If a house costing $10,000 was built in 1952, how do we know how much of that value was used up in 1953? It is primarily with these two problems that this paper will be concerned.

The following discussion deals with privately owned durable capital goods held within the business sector of the economy. The considerations with respect to quality change are much the same for government-owned instruments of production, but I do not consider here whether or not, in view of other considerations, it is desirable or possible to attempt measurement of government capital formation. Neither do I deal with inventories or net foreign investment. My interest is confined solely to aggregate estimates for the economy as a whole; I am not concerned with company accounting.

1. Quality Change and the Productivity of Capital

The decisions most important to actual measurement of net capital formation and to the interpretation of any data developed in this area concern the treatment of quality change and the relationship between the measurement of capital formation and that of the productivity of capital. The way in which the quality-change problem is handled can be of great quantitative importance, can influence decisively the interpretation of results, and can affect the answers to other questions of measurement.[3]

[3] One is compelled to rely more on instinct than numbers for proof of the importance of quality change, for the reason, developed at length later in this paper, that it is not measurable. However, the judgment that it *is* important seems to be almost universally shared.

E. Cary Brown gives some interesting illustrations and citations of

Example of Alternative Methods of Measuring Quality Change

There appear to be three major alternative procedures for dealing with quality change in measuring capital formation. They may be illustrated by the following highly simplified example. An industry utilizes only two factors of production, a particular type of machine and men of a given skill. In year 1, 1 machine requires 3 men to operate it and produces 4 units of output. Each man earns $1 a year, each machine (or its owner) earns $1 a year, and each unit of output is valued at $1. The cost of the machines is $25 each, and (for simplicity) the machines do not depreciate in any physical sense. In some later year 2, these machines have been replaced by others which, although of the same general type, have been so improved in design that each can turn out twice as much output (8 units), still with the use of 3 men per machine. Operation of the new machines requires no significant retraining of, or greater effort by, the men employed in their operation. The new machines can be produced and purchased in year 2 at the same cost as the old.

We can get to the heart of the problem of definition by asking this question. If there were a given number, say 20, machines in year 1 (requiring 60 men and turning out 80 units of product) how many must there be in year 2 for us to say that capital has been kept intact?

1. I think it is correct to say that all actual statistical work with comprehensive coverage, at least in the United States, implies that, the cost of 1 new machine being the same as that of 1 of the old, the number of machines must be kept unchanged so that the answer is 20. This answer implies that there has been no change in labor or capital input so that total output per unit of capital and total output per unit of labor have each doubled from year 1 to year 2.

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cases where efforts have been made to measure, at least partially, quality improvement (E. Cary Brown, *Effects of Taxation: Depreciation Adjustments for Price Changes*, Harvard University Press, 1952, pp. 131 ff.). A study cited by John W. Kendrick examined twenty-five types of farm machinery, all highly developed and in general use in 1910–1914, and concluded that from 1910–1914 to 1932 an average quality improvement of 67 per cent, or 2.6 per cent a year, had taken place (J. B. Davidson, C. W. McCuen, and R. U. Blasingame, *Report of an Inquiry into Changes in Quality Values of Farm Machines between 1910–14 and 1932*, American Society of Agricultural Engineers, 1933).

William H. Shaw, in implied contrast to the opinion expressed above, appears to believe his data, covering a long period of years, for all commodities (including producers' durable goods and construction materials) are not greatly biased by inability to account fully for quality change (William H. Shaw, *Value of Commodity Output since 1869*, National Bureau of Economic Research, 1947, pp. 8 and 288).

2. In most, if not all, investigations this result has been presented apologetically, however, and it is stated that adjustments should be made for quality changes in the machines, although the investigator has found this impossible in practice. The thought sometimes appears to be, although it is not often written with precision, that a proper adjustment would say that 10 of the new machines would suffice to keep capital intact since with 10 machines the total output of the industry could be maintained. By this method, 1 new machine is considered to represent the equivalent in capital of 2 old ones, so that—and this is the basic ingredient of the method—total output per unit of capital is unchanged.

However, at 3 men per machine, not only the number of machines but also the number of men required in year 2 to obtain the same output as in year 1 has been halved. Hence, if this method were adopted, it would either be necessary to say that total output per unit of labor had doubled or, if output per unit of labor is to remain unchanged as is more in harmony with the capital measurement for reasons stated later, that the work of 1 man in year 2 represents the same quantity of labor as the work of 2 men in year 1 (although nothing has happened to the quality of labor per se).

3. This second method, however, still does not show the amount of capital needed to maintain the year 1 rate of total production or to leave the industry in an unchanged position. The position with 10 machines in year 2 is clearly preferable to that with 20 machines in year 1 because only half as many men are needed to produce the same output. From the standpoint of the industry, costs can be lowered by laying off the unneeded men; from that of the economy as a whole the displaced men can be utilized to produce other types of output.

If this fact is to be considered in measuring changes in the stock of capital, additional assumptions are needed. Suppose it is assumed, (1) that in year 1 the ratio of output ascribed to a unit of labor input to the output ascribed to a unit of capital input is in proportion to the earnings of each, so that in year 1 prices the output of 1 man equals that of 1 machine; and (2) that any men displaced from this industry would be equally productive in other activities (an extreme assumption which will be examined later). Assuming that the original 60 men are available in both periods, the number of machines required in year 2 to obtain the same total output as was secured with 20 machines in year 1 is then 4. Thus 4 machines and 12 men could produce, at 8 units per team of 1 machine and 3 men, a total of 32 units of output. The remaining 48

men, by assumption, could add 48 equivalent units to output elsewhere. Thus 4 machines and 60 men can produce 80 units, as in year 1. Under these assumptions, capital would be kept intact, in the fundamental sense that the total output of the economy could be maintained, if the number of machines were reduced from 20 to 4; 1 new machine represents the same amount of capital as 5 old ones.

The same result can be achieved in a different way by supposing that in year 2 the industry continues to employ the 60 men in conjunction with 20 machines, securing 160 units of output instead of

TABLE 1

Illustrative Calculation of Net Capital Formation by Three Methods

(*dollars at year 1 prices*)

	Input			*Output*				
Type of Method	*Labor*	*Capital*	*Total*	*Total*	*Per unit of labor*	*Per unit of capital*	*Per unit of total input*	*Net Capital Formation Between Year 1 and Year 2*[a]
				Year 1 (20 Old Machines Utilizing 60 Men)				
	60	20	80	80	$1\frac{1}{3}$	4	1	
				Year 2 Under Situation 1 (20 New Machines Utilizing 60 Men)				
1	60	20	80	160	$2\frac{2}{3}$	8	2	0
2[b]	120	40	160	160	$1\frac{1}{3}$	4	1	500
3	60	100	160	160	$2\frac{2}{3}$	$1\frac{3}{5}$	1	2,000
				Year 2 Under Situation 2 (10 New Machines Utilizing 30 Men)				
1	30	10	40	80	$2\frac{2}{3}$	8	2	−250
2[b]	60	20	80	80	$1\frac{1}{3}$	4	1	0
3	30	50	80	80	$2\frac{2}{3}$	$1\frac{3}{5}$	1	750
				Year 2 Under Situation 3 (4 New Machines Utilizing 12 Men)				
1	12	4	16	32	$2\frac{2}{3}$	8	2	−400
2[b]	24	8	32	32	$1\frac{1}{3}$	4	1	−300
3	12	20	32	32	$2\frac{2}{3}$	$1\frac{3}{5}$	1	0

[a]Computed as (units of capital in year 2 − units of capital in year 1) × $25, the cost of 1 unit of capital.

[b]Alternatively, the quantity of labor and output per unit of labor by method 2 might be considered the same as in methods 1 and 3; if this is done, output per unit of total input is $1\frac{3}{5}$.

80, as in year 1. Since the skill and effort of the men is unchanged, in year 1 prices the output ascribable to labor must be $60 in each year while that ascribable to capital must have risen from $20 to $100. Since the number of machines is unchanged, this means that 1 new machine contributes as much to production as 5 old ones, and therefore should be counted as 5 times as much capital.

"Keeping capital intact" means keeping the stock of capital such that the total output of the economy can be kept constant, insofar as it is affected by the quantity and quality of capital goods. This third measure is clearly the only one which corresponds to the common meaning attached to this phrase.

By this method the measurement of capital is such that total output per unit of total input, capital output per unit of capital input, and labor output per unit of labor input are all unchanged. As in the first method, total output per unit of labor input in this industry will be shown to have doubled, but total output per unit of capital input drops sharply.

Table 1 summarizes, for this example, the situation in which each of the suggested methods of measurement gives zero net capital formation between year 1 and year 2, and for each situation the amount of capital formation between the two periods which is indicated by the other methods. The total output-per-unit-of-input implications for the industry are also shown.

The reader will have little difficulty following the calculations if he recalls that the three methods treat 1, $\frac{1}{2}$, and $\frac{1}{5}$ new machines, respectively, in year 2 as the equivalent in units of capital of 1 old machine in year 1, and that the value of an old machine in year 1 (one unit of capital) is $25.

It is obvious that the three methods yield radically different measures of net capital formation between years 1 and 2.

The indexes of total output per unit of input for each of the three methods are, of course, the same in year 2 for all three situations. With year 1 taken as 100 they are:

	Total Output Per Unit of:		
Type of Method	*Labor*	*Capital*	*Total Input*
1	200	200	200
2[a]	100	100	100
3	200	40	100

[a]If the alternative method for labor were used, the index for labor would be 200 and for total input 160.

The next step is to consider in a broader way the general implications of each method of measurement and the practical possibilities of making actual estimates which would correspond to each approach. The general question of timing capital consumption is, however, deferred, and until that subject is covered it will be convenient to ignore changes in the relationship of the gross capital stock to the net (of accrued depreciation) capital stock and to current depreciation charges. For the present, it is assumed that these three series move in proportion to one another.

Method 1: Capital Measured by Cost

The first method seems both fruitful and practical. It is worthy of consideration on its own merits and not merely as a statistically imposed substitute for some other measure.

The method, if generalized, leads to the following definitions. The value, in base period prices, of the stock of durable capital goods (before allowance for capital consumption) measures the amount it would have cost in the base period to produce the *actual* stock of capital goods existing in the given year (*not* its equivalent in ability to contribute to production). Similarly, gross additions to the capital stock and capital consumption are valued in terms of base year costs for the *particular* types of capital goods added or consumed.[4] This must be modified immediately, in the case of durable capital goods not actually produced in the base year, to substitute the amount it would have cost to produce them if they had been known and actually produced. But a similar modification is required in all deflation or index number problems.

Thus, by method 1, if the cost of two types of capital goods were the same (or would have been the same were both newly produced) in the year in whose prices the measures are expressed, they are considered to embody the same amount of capital regardless of differences in their ability to contribute to production. In dealing with current dollar estimates, the current year is the base year of the definitions. In current dollar estimates, therefore, the current dollar value of capital goods produced in the past on which depreciation must currently be computed is measured in terms of what it would cost currently to produce that exact type of good. Ordi-

[4]This definition fits most easily and naturally into a framework of measuring national income at factor cost. Use of a market price context involves no great problems, however, since base year taxes and subsidies can be brought into account and the deflation problem otherwise simplified; the only real difference is in possibly changing the weights attached to different components of the capital stock.

narily, in an economy in which technological advancement is rapid, that value will be higher than the value of the most efficient capital good currently available which could contribute an equal amount to production.

The principle is the same as that expressed by A. C. Pigou in discussing retirements: "When any discarding has occurred, in order to make good the depletion of capital implied in it, *that quantity of resources must be engaged which would suffice in actual current condition of technique to reproduce the discarded element.* But the direction in which this quantity of resources is engaged should be determined without reference to what the discarded element has been; it should be so chosen that the maximum possible addition is made to the present value of the stock of capital.... Here we have a clear principle. A basis for it may be found in the concept of capital as an entity capable of maintaining its quantity while altering its form and by its nature always drawn to those forms on which, so to speak, the sun of profit is at the time shining." (Italics mine.) [5]

Use of this approach implies acceptance of the idea that to appraise economic progress both changes in the available supply of each factor of production and changes in its output per unit must be considered. But this is surely in accordance with customary and common sense thinking and practice. Thus, in the illustration, it seems reasonable to say that total output per unit of capital has doubled, not that it is unchanged or has decreased. If in the example half the machines were of the new type and half of the old, total output per unit of capital by this method would be up by half. If in a real situation the old machines were gradually replaced by new, output per unit of capital would rise gradually. These results require that the new and old machines, having identical production costs, be considered to represent equal amounts of capital.

Even technical definitions in economics seem often to require that capital be defined in accordance with this method. The idea of a "capital saving invention," for example, would have only the most limited applicability if the measure of the quantity of capital were tied to its productive ability.

This first method, it should be emphasized, is in no way dependent upon the ability to measure other factors of production whose quantity may or may not in fact be measurable. Just as it is possible and interesting to compute changes in output per man-

[5] A. C. Pigou, "Net Income and Capital Depletion," *Economic Journal*, June 1935, p. 239.

hour with no knowledge of the stock of capital or other agents of production, so this method permits a parallel measurement of changes in output per unit of capital without knowledge of other productive resources utilized. In both cases the measurement is neutral with respect to the *causes* of changes in output per unit, and in particular as to whether these changes are related to the quality of the factor considered, or to the quantity or quality of other productive resources with which it is combined, or to institutional factors, including the growth of knowledge and the scale of output.

If questions concerning the proper timing of capital consumption are withheld, this method of measurement appears to be statistically feasible within reasonable limits. It is in fact the only one for which estimates exist because of the character of the price indexes used for deflation. The price-gathering agencies have not found it possible "to measure the degree of quality change which takes place in a priced product when specifications are altered, and to adjust the price index accordingly."[6] In the case of producers' durable goods, only those changes in specification involving differences in production costs between the old and new type capital goods are generally taken into account; in such cases the adjustment is based upon the cost differential. When indexes for commodities which have not changed are used to deflate those which have changed, the effect is, of course, approximately the same: quality change is reflected only to the extent it involves a corresponding change in the price charged. In practice there is a strong and natural tendency to "load" price indexes with items in which quality change is not rapid.[7]

The Department of Commerce estimates of expenditures for producers' durable goods in constant dollars, in consequence, correspond closely to the definitions of this first method. The prices utilized in the Department's recent estimates of the deflated value of stocks and depreciation of producers' durable goods are similar in character.

[6] John W. Kendrick, "Deflation of Producers' Durable Goods," unpublished, Dept. of Commerce, Office of Business Economics memorandum, June 16, 1950.

[7] Where a firm introduces an improvement it may, of course, obtain a temporary special profit in the sense that the ratio of its price after the change to its price before the change exceeds the corresponding ratio for costs (excluding pure profit); to this extent some fraction of the quality improvement, beyond that involving differential costs, may be taken into account in the final estimates. This does not seem an important qualification to the statements in the text.

The situation for new construction is much the same; the deflated data make no attempt to reflect changes in the design and serviceability of structures or roads except insofar as they involve cost differentials. Deflation is based upon the prices of materials and labor entering into construction.[8]

Because they rely on the same or similar price series, other available estimates are of the same family, including among others Simon Kuznets' and William H. Shaw's commodity flow estimates for capital goods, Solomon Fabricant's estimates of capital consumption, and Raymond W. Goldsmith's estimates of capital additions, consumption, and stocks, worked out in the framework of his perpetual inventory.[9]

Thus the decision to follow method 1 would imply no basic change in the statistical procedures now followed.[10] What it would require is acceptance of these data for what they are; using them in those types of analyses for which they are appropriate—recognizing that consideration must be given *both* to the quantities of economic resources and their productivity; and foregoing their use in ways which imply that they correspond to method 2 or method 3.

The estimators mentioned have, of course, been conscious of the limitations of such statistics as measures of capital formation so defined that adjustments for quality change should be made. But the underlying idea that capital must be kept intact if the scale of

[8] In this case the indexes are faulty even for this method of defining capital in that, being based upon the prices of inputs into the construction industry, they fail to reflect productivity changes within that industry (see George Jaszi and John W. Kendrick, "Estimates of Gross National Product in Constant Dollars, 1929–49," *Survey of Current Business*, January 1951, p. 9).

[9] I believe there is little disagreement on this point. Discussions are found, for example, in Raymond W. Goldsmith, "A Perpetual Inventory of National Wealth," *Studies in Income and Wealth, Volume Fourteen*, National Bureau of Economic Research, 1951, pp. 26 ff.; Simon Kuznets, "Comment," *ibid.*, p. 67; Brown, *op. cit.*, pp. 17 and 23; Solomon Fabricant, *Capital Consumption and Adjustment*, National Bureau of Economic Research, 1938, pp. 159–163; Raymond Nassimbene and Donald G. Wooden, "Producers' Equipment—Growth, Replacement, and Stock," *Survey of Current Business*, June 1953, p. 13; Shaw, *op. cit.*; and Kendrick, *op. cit.* Not all of these sources are fully explicit as to the types of quality change not reflected in the price indexes. The comments by Kuznets, Kendrick, and Nassimbene and Wooden closely parallel the statement made in the text. Like the present paper, the comments by Kuznets lay heavy stress on this point in interpreting the results derived by use of such price data.

[10] Some changes in the measurement of capital consumption are indicated in principle, especially with respect to obsolescence. These are discussed later.

output is to be maintained has sometimes led others to emphasize unduly net capital formation, and particularly the zero figure, in isolation from productivity considerations. Actually, with the advances in the quality and use of capital which have taken place, it is clear that the scale of production could have been sustained with net capital formation, as measured, much less than zero for an indefinite period—even if aggregate labor hours had remained constant and the quality of labor were unchanged.

Although this article is primarily concerned with produced capital goods, some reference to the implication of this method for the treatment of land and natural resources is not inappropriate. Discovery and development costs, which do not differ analytically from producers' durable goods or construction, are excluded from this discussion, which is concerned only with the original properties of the land.

The parallel treatment to that accorded capital goods and labor by method 1 is to ignore changes which may occur in the quality of land.[11] It may be valued in accordance with its market price in any base year selected but its quantity, or value in constant prices, for a given area is forever constant. Hence, aside from changes in territory, positive or negative net capital formation in land is impossible for the economy as a whole.

The results of this treatment for land, as for capital goods, are in conformity with common usage. It is customary to speak of a decrease in the productivity of land if its fertility is reduced, or of a mine becoming less productive as the richer ores are exhausted.

One aspect of method 1 at first sight appears curious. It implies a procedure for measuring changes in the current gross output of producers' durable goods different in one respect from that desired for consumers' goods, and therefore also a difference in the measurement of productivity change as between industries producing the two types of output. Quality improvements in product not involving additional costs are usually considered as increases in output for industries producing consumers' goods but, by method 1, are not so

[11] If we were dealing with valuations in terms of factor costs (the Department of Commerce concept of national income), we could say unequivocally that the factor cost of producing land was zero and that therefore the only valuation which could be placed upon additions through new discoveries, or upon depletion as a capital consumption allowance, is zero, regardless of the method followed in evaluating capital formation in produced capital goods. In the present context, in an effort to avoid raising the factor-cost versus market-price controversy, I am assuming that the valuation in constant dollars is in terms of base period market prices.

considered in the case of durable capital goods.[12] Eventually the results of the latter would show up as productivity changes in the industries utilizing the capital good. Thus the effect on deflated gross national product is to defer the increase in total output resulting from quality improvement in capital goods until they are utilized in production over a period of years rather than counting it all at the time the improved capital good is first introduced.

The distinction derives fundamentally from the fact that in the one case we are dealing with final products and in the other with what in the long run become intermediate products. The logic of method 1 derives from considering capital goods as instruments of production, not as products desired for their own sake. A somewhat analogous problem arises if we attempt to allocate increased consumers' goods production of the type under discussion between industries producing a consumer final product and those producing raw materials entering into its production, particularly when the raw material is physically altered as a result of modifications in specifications for the end product. If changes in the inventory of the raw material occur, even an analogous timing problem for total national product arises.

It will be noted, however, that method 1 is not equivalent to valuing all capital goods in constant prices at their "real" cost of production in terms of labor and saving; it permits changes in productivity in the capital goods industries from any cause other than design improvements in their product. Suppose a machine can be turned out in year 2 with half the labor and capital required for an identical machine in year 1. The illustration already discussed would be of this character if the product were itself a producers' durable good. Then output of the producing industry varies in proportion to the number of units produced, and output per unit of labor and capital in that industry increases.[13]

Method 2: Capital Input Proportional to Total Output

According to method 2 of the example, since total output could be doubled by substituting the same number of new machines for the

[12] However, in actual practice, failure to catch quality change of this type is about as general in deflating consumers' goods as producers' goods, so that the actual estimates are comparable.

[13] Measures of the capital stock which would value it in terms of its real cost—either in terms of the real cost of labor and abstinence or in terms of consumption foregone—can be imagined but, I think, have not as yet been seriously recommended for national income measurement. The latter procedure is, however, sometimes approached through the deflation of saving by consumer prices and may have some utility in the measurement of consumption-savings functions.

old ones, 1 new machine should be considered the equivalent of 2 old machines; if total output doubles, not the productivity of capital, but its quantity, has doubled.

But only the same number of men is required to operate the new machines, so that output per man has also doubled. This is not, however, because of any change in the men. Hence common sense suggests that each man contributes as much labor input in each period, as in the footnote to the illustration. But this would mean that total output per unit of total input has increased by 60 per cent —a result which can be arithmetically defined but lacks economic meaning and provides a wholly inconvenient framework for analytical work. Holding labor input constant appears to be an erroneous attempt to reach the measurement objectives of methods 1 or 3 for labor without achieving a rounded system which handles all factors of production symmetrically.

A more consistent treatment would consider that the quantity of labor has also doubled if the number of men is the same since, like the machines, each man can turn out twice as much as formerly. The full system would seem to require that the quantity of each factor of production—land, labor, capital, and entrepreneurship, or whatever classification is desired—and of total input moves proportionately with total output.

If changes in the relationships among the gross and net capital stocks and capital consumption were ignored, this might provide a statistically feasible solution to the measurement of net capital formation, for a base year value of capital could simply be extrapolated to other years by the deflated net national product. The difference between the annual results would provide a measure of capital formation.

The process would not, of course, be quite this simple, for the deflated net national product cannot be obtained without deflated net capital formation. While this seems theoretically insuperable, some convention, such as substitution of gross national product for net national product in the extrapolation, could perhaps be evolved.

Unused resources also present difficulties. With a decline in production during a depression, net capital formation would, by this procedure, become strongly negative, even though the stock of capital goods were unimpaired and stood ready to provide services on demand. Presumably some adjustment to a capacity-operation basis of the economy could be attempted to avoid this, so that the stock of capital would move with capacity output and output per unit of capital would vary in accordance with the ratio of actual output to

capacity output. But capacity is at best a treacherous statistical concept to introduce into the derivation of basic statistics.

The fundamental objection to method 2, however, is not statistical. What value would there be in measures showing the quantity of land, labor, capital, and of entrepreneurship each moving proportionately over the years with total output (or with the capacity of the economy) and with one another? Yet this is the only framework in which measurement of net capital formation by method 2, which in the simple illustration equates two old machines with one new, may be fitted.

Nor are these results only uninteresting; irrespective of the method chosen for measuring the quantity of labor, the results for capital formation are absurd. Consider the common case where an innovation (or a change in interest or wage rates or any other cause) makes possible a reduction in total cost by an increase in capital outlays and a more than offsetting reduction in labor cost. If total output were unchanged, it would mean according to method 2 that the industry was using no more capital after the innovation than before, and that no net capital formation had taken place—irrespective of the extent to which capital had been substituted for labor.

Since method 2 takes no account of the freeing of other resources through the use of more or better capital goods, it does not conform to a measurement of net capital formation in which zero would imply that the community was as well off at the end of a period as at its beginning with respect to its capital stock. Method 2 has nothing to recommend it.

Methods 1 and 2 share one common characteristic; they do not attempt to allocate the responsibility for changes in output among particular factors of production. It is because method 3 does make this attempt that it is at once so attractive in theory and so impractical as a framework for measurement.

Method 3: Capital Stock Measured by Contribution of Capital to Production

Method 3 is the only method which corresponds to the ideas usually associated with "keeping capital intact," or with the idea of income as the amount which could have been consumed without leaving the community worse off at the end of the period than at its beginning, insofar as its ability to produce depends upon the quantity and the quality of its capital stock.

This method derives from the definitions of economic theory in which it is customary and clarifying to think of a unit of labor, or of capital, of given characteristics. When the characteristics of a

laborer or a type of capital instrument do in fact change, it is necessary within these definitions to think of the quantity of labor or capital as having changed.

Under this system, if total output changes, it must either be because inputs have changed or because something which cannot be identified with any particular factor of production has changed. Only in the latter case can the productivity of inputs as a whole change. The productivity of any one factor of production can never change.

Thus, in the illustration cited, the fact that by method 3 total output per unit of capital falls by 60 per cent from year 1 to year 2, a seemingly meaningless result, is not disturbing. It is necessary to determine the output of each factor separately.

In year 1, labor input and output, as measured by dollar earnings, was $60. In year 2, under situation 1 where the number of men and machines is the same as in year 1, the output which can be credited to labor in year 1 prices must still be $60 since the quality of labor is in no way changed. The true productivity of labor, therefore, is unchanged.

However, total output has increased from $80 in year 1 to $160 in year 2. Since in each year only $60 of output can be credited to labor, the only input change being that in capital, the output credited to capital has risen from $20 to $100. The rise in capital input is, by this method, the same and as a result the true productivity of capital is unchanged.

This being so, the measurement of net capital formation by method 3 is also logical. One new machine contributes to output the equivalent of 5 old ones. If 20 new machines have replaced 20 old ones, and old machines were worth $25 each, there is a net addition to the capital stock, after deducting the 20 old machines which have disappeared, equivalent to 80 old machines, or $2,000 in year 1 prices. Since the only change in the situation from year 1 to year 2 has been in the "quantity" of one of the factors of production, it follows that total output per unit of total input, output of capital per unit of capital, and output of labor per unit of labor, must each be, and by method 3 are shown to be, unchanged.

This need not always be the case, however, even under nonstatic perfect competition. For example, if multiplication of the scale of output permitted total output to rise more than total input, the measure of overall productivity could be permitted to rise even as that of the separate factors was shown to be unchanged in constant prices. If imperfection in markets is allowed, any adjustment from

disequilibrium to equilibrium conditions, involving an increase in real output, could be permitted to show up as an increase in over-all productivity. Any increase in real output deriving from specification changes in the price of final products (including, in the short run, capital goods) which made them more desirable to buyers and thus caused them to sell at a higher price but which involved no, or a less-than-proportional, increase in real inputs could be considered as in the same category.

On the other hand all such changes involve some action by the entrepreneur or his representative, and so could be considered the consequence of an improvement in the "quality" of entrepreneurship and therefore of its "quantity" when "quality" is held constant. If this convention were adopted, the constancy of output per unit of total input could be maintained over time (subject, as in case 2, to the problems raised by unused resources and by changes in the relationships among the net and gross capital stocks and capital consumption). This seems a less interesting theoretical convention than that suggested in the preceding paragraph; however, the decision here does not affect the measurement of capital formation.

The system outlined is, abstractly, coherent and of extreme interest because all changes in real output could be traced to the responsible factor of production or to causes for which the factors were not responsible. Furthermore it provides a measure of net capital formation which is theoretically meaningful. Zero net capital formation, or keeping capital intact, could be interpreted as that amount of capital formation required to maintain the economy's output potential if the supply of all other productive factors (considering, in ordinary terminology, both their quantity and quality) were unchanged, and there were no change in the institutional environment affecting productivity per unit of total input. This meaning differs from that under method 1 precisely and only in that quality changes in capital are considered within the capital formation measure rather than in the other conditions considered as constant.

It seems almost idle to indicate why in the real world a direct measurement of net capital formation following method 3 is not practical. It was necessary in the example to accept the earnings ratio in year 1 as reflecting accurately the contribution of the factors to production, but no such data corresponding to productive factors exist nor can exist and even the distributive share data available, representing in large part composite returns, are accepted by no one as accurately reflecting relative contributions to production by the different classes of income recipients.

It was also necessary in the example to assume that any labor displaced from this industry could produce the same amount elsewhere if the results were to be meaningful for the economy as a whole. If they could add less to output elsewhere—presumably a more plausible assumption since the ratio of labor to other factors in the remainder of the economy would be increased, and because skills of the men may be specialized—net capital formation should be smaller. For example, under situation 2 in which output in the affected industry was unchanged, net capital formation would be zero instead of $750 if the displaced men could produce nothing elsewhere. No solution to the measurement of capital formation for the economy as a whole is possible without knowing what the production of such displaced workers would be.

But the overwhelming difficulty is that the basic fact of the illustration—that nothing has changed but the machine—would not ordinarily be true, and even if true would rarely be known. The most that would be likely to be known—and this only to the plant manager, not to the national income investigator—would be the observed output, number of men, and number of machines, together with the fact that the machines were different.

In a real situation many other elements would also be present. The impact of an innovation may strike in many directions. It may raise some costs while lowering others. The savings may be in the use of any resource—labor, supervision, materials, power, lubricants, floor space required, etc. The technical requirements for each of these may be affected. Or the advantage may lie in improvements in the end product or service provided. The reduction in price or improvement in product may broaden the market and make possible additional economies—or create diseconomies. It may cause changes in production techniques in industries using the product of the industry directly affected. All of these conditions would simultaneously be subject to changing influences other than the impact of altered capital goods; it is idle to suppose that the various influences could be disentangled. But the exact role of the change in the capital goods in isolation must be known to measure net capital formation by method 3.[14]

[14]Capital goods have other aspects which, by method 3, should be considered but can scarcely be brought into this discussion. To name only one, safety features may be added which reduce lost time from injuries and thereby effectively increase man-hours worked. The logic of method 3 requires that this be counted as an increase in the quantity of capital, not that of labor.

It is also important to note that the presence or absence of a physical change in the capital instrument which can be construed as representing a quality change *in it* is not necessarily meaningful for determining whether an increase in output should be "credited" to capital or to entrepreneurship or to labor. There may indeed be simple cases where a machinery producer designs an improved model which can produce more output with no other change in the utilizing plant. Sometimes, perhaps, labor becomes more efficient solely as a result of better education or greater physical strength. But very often production is increased simply because someone—an entrepreneur or a hired manager, or anyone—has thought of a better method of organizing it. A more effective way to use a machine may be uncovered, either by chance, through the initiative of its operator, as a result of a time and motion study or other research project, or through an idea imported from abroad. The new way may involve no change at all in the machine; or it may require a very minor change in its design which involves little or no expense to the maker, or which can even be carried out by the user. The growth of the market may make economic the use of types of machinery or plant not previously warranted by the scale of operations. Or the use of a particular machine may be feasible only after a skilled labor force has been trained. The differences are those of continuous gradation, not of kind. If there were no other difficulties, these would suffice to prevent the acceptance of method 3 as giving meaningful results.

Before abandoning method 3 it is necessary to deal with one more question. If a measurement of capital formation corresponding to method 3 cannot be derived directly, can the quality-change problem be overcome by simply comparing the market prices of different capital goods? We know that this cannot be done by dealing with the prices of new machinery or buildings; this in practice leads to method 1. But could not relative prices of used goods provide the price bridge between machines of different qualities?

Many difficulties have blocked the use of this method in the past —including the general absence of such markets and the influence of interest rates upon relative prices. The fact that relative resale prices of new and old "commodities" tend to change radically shortly after the new good is introduced means that the results are greatly influenced by the date at which the link is established. Moreover, an "estimate of the value inferiority of an existing old asset as compared to the most economical substitute asset has no meaning except with regard to a specific service to be performed

for a specific owner."[15] Most fundamentally, however, the method must be rejected because it requires that buyers and sellers on the secondhand market have information which cannot be known to them, and some of which, like the potential output of displaced workers, is irrelevant to their price calculations.

Thus it seems that there is no alternative to rejecting method 3 as being operationally unfeasible.

Summary

The conclusions reached so far may now be summarized. Of the three methods discussed, the first, which values capital goods at cost, is (subject to questions concerning the measurement of capital consumption) both interesting and feasible. The second, which makes the stock of capital proportional to total output, is not interesting, although if certain rather arbitrary conventions were adopted, it might be barely feasible. The third, which attempts to evaluate the contribution to production of each type of capital good, has great apparent appeal but this is very much dimmed by close examination and is utterly beyond any hope of utilization for reasonably accurate measurement now or in the future.

Since it is method 3 which underlies the classical concepts of "keeping capital intact" and net capital formation, this conclusion amounts to rejecting these concepts, as they have been understood in the past, as measurable entities.

It is the suggestion of this paper that, for purposes of measurement, concepts conforming to method 1 be adopted and interpretation of the data be reshaped accordingly. Thus cost of production of capital goods rather than their ability to contribute to production becomes the common denominator enabling the values of different capital goods to be compared and combined.

2. *The Stock of Capital, Capital Consumption, and Productivity*

Thus far no clear distinction between the gross stock, the net stock, and the consumption of capital goods has been drawn. It is convenient at this point to consider in a broad way differences among the relationships between these measures on the one hand and output on the other.

[15]Eugene L. Grant and Paul T. Norton, Jr., *Depreciation*, Ronald, 1949, p. 13. Grant and Norton discuss (in Chapter 13) the difficulties and paradoxes which arise in appraisals based on replacement cost to secure future services equal to those of existing plant. I have not mentioned the appraisal method of trying to adjust for quality change since it seems to be clearly outside the realm of possibilities for the statistical investigator; even were it not, it would provide no solution to the problem.

The gross stock of durable capital goods refers to the original value when new (at prices or costs of any stated period) of the capital goods still in use. Capital consumption (as it is developed later in this paper) measures the value of the reduction which takes place during a stated period in the remaining services which can be extracted from the stock of capital goods. If we abstract from any changes in demand patterns and any technological changes which may occur in the economy, capital consumption can represent a reduction in either the physical ability of a capital good to contribute to annual production in the future or in the remaining number of years it will continue to contribute to production. The net stock of capital is the value of gross stock remaining after the deduction of capital consumption charges accrued since installation on all the capital goods remaining in stock.

In a static economy in which the stock of capital was kept constant by replacing each year the same fraction of the gross stock, the net stock of capital would always bear a constant ratio to the gross stock if any ordinary method of computing capital consumption were consistently followed. Capital consumption would always be equal to one-nth the value of the gross stock when n is the weighted average life of capital goods. In computing changes in the productivity of capital, it would make no difference whether output was related to the gross stock, the net stock, or capital consumption, since their movements would be proportional. In a rigidly static state, all would be constant over time.

But in a real economy it is apparent (1) that the average age of capital goods can change, altering the ratio of the net stock to the gross stock and capital consumption, and (2) that n, the average total life of capital goods, can change, affecting the ratio of capital consumption to both the net and gross stock and, during a transition period, the ratio of the net to the gross stock. Hence changes in output per unit of gross capital, of net capital, and of capital consumed will diverge.

If we can imagine a situation in which the only changes in the economy are those induced by the aging of the stock of capital goods, and in which capital consumption accurately reflects the two influences previously mentioned, we should expect: (1) capital output and total output, in the aggregate and per unit of gross capital, to decline to the extent that the actual ability of capital goods to contribute to current production has deteriorated with age; (2) capital output and total output per unit of net capital to rise to the extent that depreciation has been charged to reflect not this deteriora-

tion but the shortening of remaining service life; and (3) capital output per unit of capital consumption to be unchanged,[16] although the movement of total output per unit of capital consumption cannot be predicted with certainty.

Pigou has offered a definition of capital consumption which, during the life of a capital good, would take account only of actual deterioration in current service, not of the shortening of remaining life, and thus leave output per unit of net capital unchanged under the situation postulated here.[17] But this approach is quite unacceptable because a measure of net capital formation which does not take account of the using-up of the service originally embodied in the capital good is not satisfactory.[18] Nor, as soon as changes in the original lives of capital goods are admitted into consideration, does the method retain the desired property.

Life of Capital Goods

The original life of a capital good is an aspect of its value which is not always fully considered in discussions of the relationship among capital measures. Were it always possible to produce and install ready for use, at the same total cost, one capital good with a given life or two machines, each with half as long a life but identical in all other respects, it is clear that it would generally be more economical to use the shorter-lived goods. From the standpoint of the economy there are two advantages in the practice of installing one of the shorter-lived goods and replacing it with another when it wears out rather than initially installing the longer-lived goods.

First, in an economy in which the capital stock is growing (but not if it is stationary or declining), and with the same amount of current and past savings, a larger number (or more expensive quality with respect to all features except total life) of machines is available at all times. Second, losses due to obsolescence are, on the average, reduced in proportion to the reduction in the average

[16]While it is not usually stated in precisely this way, leaving capital output per unit of capital consumption unchanged (either at actual rates of output or some standard rate of output) as a good ages is, I think, actually and properly the essence of what most attempts at the proper allocation of depreciation changes are aiming at, if, for the present, we exclude obsolescence and interest from consideration.

[17]Pigou, *op. cit.*, p. 238. It may be noted, however, that Pigou's admission (p. 240) of normal obsolescence into capital consumption is quite inconsistent with this objective.

[18]See also Fabricant, *op. cit.*, p. 12, for a fuller statement of objections to this method.

life, or, to put the same thing a different way, more modern capital goods will always be in use. Both of these influences tend to augment the cumulative size of the net national product. (There is also the added advantage from the standpoint of the individual investor that interest expense can be reduced. This does not further affect the cumulative size of the net national product since interest expense is also interest income.) Hence any such change in the average life of capital goods is important to the economy.

Thus a change in the average life of machines is a factor which should be accounted for in complex fashion in *adjusting* for quality change by method 3. One car with a fourteen-year life is not the exact equivalent of two with a seven-year life, other things being equal.

But more importantly, consideration of the average life of capital goods must influence the choice of capital measures to be related to current output in the study of productivity changes. For it is clear that the net stock of capital remaining at the end of a period has contributed nothing to production during that period. It is simply a necessary adjunct to the capital which has been used during the year.

If depreciation accurately measured the physical using-up of capital during an accounting period, with a change in the average original life of capital goods, as with the aging of the capital stock, a closer relationship would be expected between output and capital consumption during a year than between output and the stock of capital (net or gross).[19] But this does not mean that the relationship between the net stock of capital and output is uninteresting; on the contrary, it is also a fundamental measure for judging output per unit of capital. It simply means that in and of itself long life is an undesirable property of a capital good if the investment per year of service is the same. If the cost of capital goods were proportionate to their lives, then the shorter the lives of capital goods the larger would tend to be total output per unit of net capital. Any shortening of average lives would properly show up as an increase in productivity by this measurement.[20] But, as already

[19]This relationship will be improved if (as suggested below, p. 244) obsolescence is subtracted from gross capital formation rather than added to capital consumption.

[20]Evsey D. Domar, ("Depreciation, Replacement and Growth," *Economic Journal*, March 1953, pp. 1–32) discusses two possible models relating changes in capital to changes in capacity. His preference is for one which assumes that an increase in capacity in terms of gross national product is proportional to net investment defined as gross investment net of discards. He contrasts this with models which make an increase in

noted, changes in the average age of capital goods will also affect output per unit of net capital. Hence this measure can hardly be interpreted unless consideration is given also to output per unit of capital consumption.

The gross stock of capital, in comparison to the other two measures, appears relatively uninteresting except as a stage in an estimating process. Though sometimes used as a measure of changes in capital capacity, it is less suitable for this purpose than depreciation charges. If straight-line depreciation is used, as in most existing estimates, movements of gross capital will diverge from those of depreciation charges only because of changes in the weighted average original lives of capital goods. Gross capital has some use, however, in appraising replacement demand, though even here it is chiefly useful as a step in estimating discards.

3. Capital Consumption and Net Capital Formation

The measurement of the consumption of durable capital goods is among the most difficult and frustrating of subjects. It has been explored, often brilliantly, from many viewpoints, with the result that many difficult problems have been clarified, but no fully satisfactory solution has been evolved. Only in part is this because of disagreement on the proper method of measuring capital consumption. More fundamentally, as is stressed by all writers, it is becuase any current measurement of capital consumption not only involves quality change problems like those discussed earlier but also must be based upon appraisal of unknown future events.

Furthermore, even after a piece of equipment has been retired, its history rarely is fully known. Hence even a later reconstruction

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capacity in terms of net (of depreciation) national product proportional to net investment defined as gross investment net of depreciation.

On the basis of the discussion above, a more reasonable assumption would be that increases in gross national product and net national product are proportional to increases in depreciation and hence also to each other.

A similar observation is pertinent to the discussion of the relationship between gross investment, replacement requirements, and depreciation charges by Robert Eisner ("Depreciation Allowances, Replacement Requirements and Growth," *American Economic Review*, December 1952, pp. 820–838). A time trend in the average life of capital goods (resulting from either technical changes in individual categories of goods or the conditions under which they are used or from a shift in the composition of gross capital formation) could powerfully affect (conceivably, if the average life is steadily lengthening, reverse) Eisner's major conclusion that in a growing economy with stable prices (prices presumably being defined to adjust for quality change, including changes in average lives) capital investment required to maintain constant productive capacity falls short of depreciation charges.

of a capital consumption estimate must be largely based upon surmise, and whatever could be learned from past experience as a basis for current estimation of capital consumption is largely lost. Modern statistical studies of life dispersions of capital goods are valuable even though they often pertain to obsolescent types but, as Grant and Norton have stressed, they suffer from the great weakness that they provide data concerning only two points in the life of a machine or building: the dates of its birth and of its death.[21] These facts are helpful in setting the outside time limits within which its total value must be charged off. They do not, however, tell anything of the experience between these dates: of the changing costs of operation, maintenance, and repair, of the continuity or quality of the service rendered, of the intensity of use at different periods, or even the date when replacement would actually have been economical.[22] These facts are only infrequently known by the owners of capital equipment; they are almost wholly unavailable to the student of the economy as a whole.

While these considerations raise problems for the measurement of net capital formation which in any rigid sense are insoluble, it does not necessarily follow that useful estimates are unattainable. If agreement is achieved on the method of measurement desired, it should be possible, by making alternative assumptions as to the economic facts, to discover how much difference alternative procedures might make.

It will perhaps be helpful to state in advance the main lines of the theoretical position which I shall take. The discussion is concerned with national product measurement, not company accounting, and presumes that quality change is to be handled in accordance with method 1 as previously described. The chief points are as follows:

1. In constant dollar terms, the change between any two dates in the net stock of capital goods should equal net capital formation in the interim. The method must be such that, in dealing with the full life cycle of an economy in which the net stock of capital began and ended at zero, net capital formation in constant dollars would also be zero for the full cycle. This implies that the concept of capital adjustment, as distinguished from capital consumption, has no place in constant dollar estimates, but is confined to adjust-

[21]Grant and Norton, *op. cit.*, p. 365.

[22]Grant and Norton cite a number of reasons for believing replacement is generally deferred beyond the date when it would be economical (*ibid.*, pp. 27–28).

ments required to reconcile current dollar (or "book") net capital formation with changes in the current dollar (or "book") value of stocks. The parallel with inventory measurement, as it is presently handled in the national accounts of the Department of Commerce, is complete.

2. The undepreciated value of capital goods which are discarded because of obsolescence consequently must be eliminated from net capital formation. This elimination should (a) take place at the time the capital good is discarded and (b) be handled as a deduction from gross capital formation rather than as an addition to capital consumption.

3. The phenomenon of interest has no place in the determination of capital consumption.

4. Capital consumption is viewed solely as a measure of the value of the reduction in the remaining services which could be extracted from the good as a result of physical factors—deterioration and shortening of the remaining service life.

Relation of Capital Consumption to Gross Capital Formation

I start with the general proposition that, measured in constant dollars, the framework of measurement should be such that the change in the value of the capital stock between any two dates must equal net capital formation in the interim and, over the full life of a group of capital goods, capital consumption must equal gross capital formation so that net capital formation is zero.[23] In principle this is enormously simplifying since it makes the measurement of capital consumption in constant dollars solely one of time allocation. The total amount to be allocated over time is given as soon as gross capital formation data are established.[24]

The importance of this principle is even more apparent if we recognize that capital consumption is, itself, essentially a measure of quality change—it is the value of the change from the beginning of an accounting period to its end in the remaining services which can be derived from a capital good. As such, its measurement encounters difficulties and ambiguities similar to those faced in adjusting gross capital formation for quality change by method 3.

[23]Salvage value must, of course, be taken into account. It raises no particular theoretical problems, however, and I shall not complicate the discussion by referring to it.

[24]For the present I ignore major destruction of capital goods by great natural disasters and wars—events which have not occurred in the United States on a scale giving rise to special problems. I shall return to these in a later section.

When new capital goods of different types were compared, a unifying element was found in their production cost which permitted combination or comparison of their values without determining their relative abilities to contribute to future production. But in comparing the same capital good at different stages of its life cycle there is no such alternative; by capital consumption can only be meant the reduction in the ability of a capital good to contribute to production in the future. Only the long-run identity of capital consumption with capital formation sharply distinguishes the problem of measuring capital consumption for a particular capital good from that of adjusting aggregate gross capital formation, embracing a mixture of capital goods, for quality change. It does not guarantee against error but it does help to limit any a priori presumption of bias, and definitely prevents a long-term bias from continuing to compound indefinitely.

The identity of capital formation and capital consumption in a closed time period covering the full life of a capital good is inherent in estimates such as those of Goldsmith, which have been obtained by the general statistical procedure of deriving estimates of capital consumption directly from data for gross capital formation in earlier periods. It does not ordinarily result where accounting records of depreciation are adjusted for changing prices and, sometimes, other aspects of the accounting records.

Among investigators who have utilized the latter procedure, Fabricant is explicit in rejecting the *desirability* of equating capital formation and capital consumption. With respect to losses arising from obsolescence or accident, he utilizes the provision made by owners against such losses rather than actual losses incurred, throwing any difference between the two into his category of capital adjustment.[25] Thus only "normal" obsolescence, not unanticipated obsolescence, is defined as a charge against income. The tax authorities do not allow the equivalent of an insurance premium to be added to depreciation against the possibility that unexpectedly drastic obsolescence may occur. As a result, not merely a timing adjustment but a complete elimination of such obsolescence from capital consumption results when the undepreciated value of unexpectedly obsolete capital goods is written off.

With the general replacement in the 1930's of item accounting by group accounting such write-offs have become much rarer, and estimates for more recent years based on Fabricant's techniques

[25]Fabricant, *op. cit.*, pp. 14, 99, and 110.

apparently would permit much of this type of obsolescence to reenter the depreciation aggregate.[26]

It is possible that Fabricant was chiefly interested in avoiding unusual fluctuations in measuring the annual income flow and would not have objected to a capital consumption measure which accurately reflected the risk of unusual obsolescence. Such a measure would treat this risk like the risk of fire. If this were done, capital consumption would closely approach the equality with gross capital formation suggested above; it would diverge only to the extent that the average experience for the economy as a whole diverges from expectations. Nevertheless this difference could be significant statistically and is certainly so conceptually.

A more fundamental departure from the long-run identity of capital formation and capital consumption in constant dollars is the contention that obsolescence should not be deducted at all. This appears to be the position of Kuznets and Ruggles.[27] We must therefore dispose of this contention and deal generally with the treatment of obsolescence to determine whether that identity is valid.

Obsolescence

The conclusion discussed earlier that quality change in newly produced goods should be considered in measuring capital formation or changes in the stock of capital only to the extent that a cost differential is involved indicates that no obsolescence, normal or otherwise, should be charged against a capital good until it is actually retired from use. On the date that it is actually retired, any undepreciated value remaining which has been wiped out by obsolescence should be charged against capital formation and thus eliminated from the value of the capital stock. I shall consider these two statements separately.

First, deduction of obsolescence on existing assets would cause the stock of capital to shrink and hence output per unit of net capital to rise solely because an improved machine has been (or, under the system of charging "normal" obsolescence, may be) invented and the first unit produced, even though the new machines have not replaced the old and output has not increased. This is contrary to the meaning attached to the capital stock by the first method of

[26]See Grant and Norton, *op. cit.*, p. 97 ff.

[27]Kuznets, *op. cit.*, pp. 66–68. Richard Ruggles, "Concepts, Sources, and Methods of United States National Income Accounts," *Econometrica*, July 1952, pp. 469–470.

dealing with quality change, in which the present interest centers. A basic principle of the method is that (aside from the effect on particular capital measures, previously discussed, of changes in the average life and age of the capital stock) productivity change appears only when, and to the extent that, actual changes occur in either total output or the stock of capital goods. The method implies that at any time units of capital of greater and lesser efficiency are simultaneously in use.

With method 3, on the other hand, the opposite is true. For that method strives so to equate capital values that at any given time all units of capital added to, eliminated from, or standing in the capital stock have an equal ability to contribute to production. Under existing estimating techniques, if price indexes actually adjusted for quality change, the quality standard to which all units of capital (in the measurement of capital formation, capital consumption, or capital stocks) are adjusted would be the quality of capital goods newly produced in the year in the prices of which values are stated, not the average quality of the capital stock in that year.

This means that in any year the value of previously existing capital goods which have been rendered obsolescent by improvements or market shifts is written down so that, dollar by dollar, their use contributes as much to production as the use of capital goods newly produced in that year. Under this method it is this "marking down" which represents obsolescence.

Secondly, there seems to be little question that, under method 1, when a capital good is retired from service because of obsolescence, its depreciated value should be somehow eliminated from the value of the capital stock. The principal question is whether the deduction should be treated as capital consumption, an offset to gross output, or as a capital adjustment, which would yield a higher figure for net national product and net capital formation. Exactly the same question arises under method 3 with respect to the recurring "write-offs" of asset values discussed in the preceding paragraph; only the timing is different. Charging obsolescence against gross output conforms to the general proposition that in constant dollars net capital formation be zero for the full life of capital goods, while use of a capital adjustment departs from it.

The feeling that obsolescence is not a proper charge against the national product may be related to the well-accepted proposition that, in determining whether a new capital good should be introduced, neither from the standpoint of the firm nor of the economy as

a whole is the value of existing capital goods which may be displaced or reduced in value a relevant consideration.[28] If this is so, is it not incorrect to deduct from the net national product and capital formation the loss of value of old capital goods resulting from the availability of new types?[29]

Such a conclusion would be a misreading of the argument. Since the gross values of capital acquisitions take full account of the gross contribution to production of the new capital good, net capital formation—the net improvement in the capital position of the economy—must represent the difference between (1) the contribution to production by the new good, and (2) the contribution which could have been made by the displaced capital good.

It might clarify the subject to think of (2), which is the obsolescence charge, as a deduction from gross capital formation rather than as an addition to capital consumption. For what is really involved is not the using up of existing capital goods but the fact that, as noted in the preceding paragraph, the purchases method overstates the net advantage to the economy of securing the new capital good.[30] This is perhaps clearest where obsolescence results from the availability of improved capital instruments for the same or a closely similar service but, in a broader sense, it applies also to obsolescence from changes in the pattern of demand, relative prices of different productive resources, and similar more general causes. Were it feasible statistically, deduction of obsolescence from gross capital formation would also have the practical advantage of leaving the relationship between capital consumption

[28]A. C. Pigou, *Economics of Welfare*, 2nd ed., London, Macmillan, 1924, pp. 166–168, and most standard economics texts. Pigou (p. 167) goes so far as to state: "... there is no loss to the owners of the old machines, in respect to any unit of their former output, that is not offset by an equivalent gain to consumers. It follows that to count the loss to these owners, in respect of any unit taken over from them by the new machinery, as a part of the social cost of producing that unit would be incorrect."

[29]Pigou himself does not reach this conclusion (*ibid.*, p. 40, and Pigou, "Net Income and Capital Depletion," p. 241), but he does not bother to reconcile the two statements. In the latter source he recommends following business practice in charging "normal" obsolescence but gives no reason for the choice. In that source, Pigou, as already noted, is dealing with a definition of capital essentially similar to that discussed here as method 1.

[30]This is also the way a firm considering replacement must consider the matter. It compares future costs (and other considerations) if a new machine is acquired with future costs if the old machine is continued in use —not with what future costs would be if the latter were not available.

and output discussed previously undisturbed by irregular obsolescence charges.

For the reasons stated above in discussing obsolescence under method 3, I believe Kuznets is wrong when he suggests that Goldsmith's data for capital formation—and, surprisingly, even capital stocks—should be modified *both* so as to take full account of quality change and so as not to eliminate obsolescence.[31] For if quality change were taken into account in the price indexes used to adjust gross capital formation and capital consumption, it would be appropriate to compute net capital formation net of obsolescence at the time improvements appear in newly produced capital goods in order to keep the contribution of each unit in the capital stock equal.

A different reason for not charging obsolescence appears to be implicit in Ruggles' brief comment. Ruggles is also interested in a measure which adjusts for quality change, "based on the principle of keeping intact the physical productivity of the capital goods in some kind of welfare sense."[32] Since current dollar estimates which put depreciation on a current cost basis are derived from price indexes which do not fully account for quality improvement, depreciation (other than obsolescence) is overstated (in terms of method 3). This, he suggests, can be offset by the error, in the opposite direction, of not deducting obsolescence in deriving net capital formation. This position could be extended to argue similarly that since actual estimates of deflated gross capital formation fail to measure quality improvements, the deduction of obsolescence resulting from such improvements should not be made. If we insist on defining capital formation as if it did measure quality improvement, then Ruggles' position has some merit. But there is no real reason for the two errors—not adjusting for quality change and not deducting obsolescence—to be equal in size, although they are in opposite directions. And it must also be noted that depreciation must cease when a good becomes obsolete, even though its cost has not been fully written off, or the failure to deduct obsolescence will, in the long run, provide no offset at all.[33]

[31]Kuznets, *op. cit.*, pp. 67–68.

[32]Ruggles, *op. cit.*

[33]Kuznets provides an illustration (*op. cit.*, p. 68, footnote 1) designed to show that, by the perpetual inventory method, past failure to take account of quality improvement and past inclusion of obsolescence in capital consumption may tend to yield a correct figure (as defined by method 3) for the current dollar value of the net capital stock. But he gets this result only by omitting an allowance for physical depreciation which, by the use

Ruggles' objection to charging off obsolescence is, obviously, pertinent only to method 3, not to method 1, which measures the capital stock and capital formation at base period cost. In the framework of that method there is no sound reason to depart from the identity of capital formation and capital consumption over the life cycle of capital goods because of obsolescence. And if the desired results with respect to output per unit of capital or total input are to be achieved, this can only be accomplished by charging all obsolescence at the time capital goods are retired from the capital stock.

This treatment still leaves ambiguous the precise time when a capital good leaves the capital stock. So long as it remains in actual use it is clearly counted in; if it is physically destroyed or permitted to become completely unusable, it is clearly out. In between is a twilight zone of goods not in use that may possibly be used in the future.

Pigou suggests that, so long as it has positive present value based upon expected rentable value in the future ("rentable value" being defined as the "value of the total product yielded by the instrument over the aggregate wage of the labor engaged with it") an element stands "in the stock of capital; elements that have no present value are discarded from it."[34] Though not fully satisfactory, particularly since the results are likely to be influenced somewhat by the business cycle, this is perhaps as good a theoretical definition as any. The problem is rather similar to, and perhaps no worse than, that of defining the labor supply over the business cycle.

Interest

If it is agreed that capital consumption and capital formation in constant prices must be zero over the life cycle of capital goods, our problem is simply one of time allocation. The next question is

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of available price indexes, will have been overstated in the past because of quality improvements so that the present value of the net capital stock will be understated.

If the obsolescence deduction is correct, current dollar net capital formation and the current dollar net capital stock are, in terms of method 3, clearly understated by the usual procedure to the extent that the current value of physical deterioration fails to take account of the quality inferiority of existing goods as compared with newly produced goods. Thus, as Ruggles implies, failure to deduct obsolescence would provide an offset to this error, although not necessarily of the right size.

[34]Pigou, "Net Income and Capital Depletion," p. 237.

whether the phenomenon of interest and discounting has any bearing upon this time allocation.

There appears to be general agreement that changes in the market value of existing capital goods resulting from changes in the rate of interest have no part in determining either the total of capital consumption charges or their time allocation. They are in essence capital gains or losses. It is sometimes held, however, that the fact of an interest rate (as distinguished from changes in the interest rate) should influence the time allocation of capital consumption charges. Thus Fabricant states: "The fluctuations in depreciation charges on a given capital good... should be superimposed on a rising secular trend, to take account of the element of interest. That is, if output is constant, depreciation charges should rise, the rate of rise depending on the rate of discount implicit in the original capital value.... Here also the choice of the method of allocation must rest on what is believed to be the expectations of investors...."[35]

Fabricant's book does not seem to contain a clear statement of *why* this is so; it appears to be incorrect. As Hicks has emphasized, capital formation and national income statistics are of necessity *ex post* measures of what has happened in the past.[36] Introduction into the calculation of expected interest rates makes these measures needlessly dependent upon *ex ante* expectations as of some past date. These are wholly irrelevant to a measure of the economy's performance. There is no reason why the interest rate anticipated by the purchaser of a capital good in 1950 (if, indeed, he had any clear expectation) should determine the allocation of capital consumption charges in 1951, 1952, and on into the future.

It appears possible that Fabricant's proposal may arise from a confusion between the effect of his suggestion on profits and its effect on net national product. Suppose a firm spends $100 for a capital good which has a life of four years and furnishes equal service in each of the four years. By the straight-line method depreciation will be $25 in each year. Suppose also the firm borrows the $100 at 5 per cent interest on the unpaid balance, paying off $25 of the principal at the end of each year from the funds accumulated in the depreciation reserve. If sales each year were $100, there were no inventory change, and depreciation and interest were the only expenses, we should get the following results:

[35]Fabricant, *op. cit.*, p. 15.
[36]J. R. Hicks, *Value and Capital*, 2nd ed., London, Oxford University Press, 1948, pp. 178–179.

	Year			
	1	*2*	*3*	*4*
Sales (equal gross national product)	$100.00	$100.00	$100.00	$100.00
Less: depreciation	25.00	25.00	25.00	25.00
Equals: net national product	75.00	75.00	75.00	75.00
Less: interest expense	5.00	3.75	2.50	1.25
Equals: profit	70.00	71.25	72.50	73.75

Fabricant may feel that the rising profit trend in this example is unwarranted and seek some way of holding profits steady at $71.875 each year. But if this is accomplished by making depreciation rise to offset the declining interest charge, just such a trend (in this case downward) is introduced into net national product as he seeks to eliminate from profits. The point is that, for a firm, interest is a cost deducted in arriving at profit, but, for the economy, interest is not deducted in arriving at net national product or national income.

To say that the industry's net output declines each year during the life of the capital good (only to jump up again when it is replaced) simply because of the existence of interest would not seem to be an interesting or appropriate result. The value of the capital stock in terms of its ability to contribute to future output actually diminished by an equal amount each year. With periodic replacement of capital assets the discount procedure would introduce a wavelike fluctuation into measures of output and productivity—fluctuations whose length is dependent upon the life of the capital assets. These fluctuations could only confuse, not clarify, interpretation of the results. Interest has no place in the timing of capital consumption allowances.[37]

Physical Deterioration

My general conclusion is that the time allocation of capital consumption in constant dollars should rest exclusively upon physical factors—the extent to which the total services which can (not necessarily will) be extracted from a capital good have been exhausted in a given year. This should take account both of the partial exhaustion of the life of the capital good and of any deteriora-

[37]This is not, of course, to say that it is inappropriate for a business firm, in making financial provision for future replacement of assets, to take account of income which can be earned on funds set aside and reinvested or used to pay off debt.

tion in its efficiency which will be reflected in the future in rising operating or maintenance costs, expense due to lost time, etc.

Even if irregular maintenance, rising costs, and obsolescence are ignored, this position does not lead to a pure service output method of accounting for depreciation, which allocates depreciation over time in proportion to the number of units produced. That part of capital deterioration which is dependent upon the passage of time should be allocated by time, and only that part which is dependent upon use, by use. Temporary failure to occupy a house or utilize a fenced field because of lack of demand in a depression is a wasteful use of resources if the roof of the house and the fence continue to deteriorate, as they do, from weathering; the resources are nonetheless used up and should be included in depreciation charges in national income accounting. This cost cannot properly be charged to some other period when the house is occupied and the fence in use. To do so would be to present a distorted picture of the status of the capital stock at any given time.

This treatment diverges from the accountant's concept of depreciation for an individual firm as an allocation of cost against output, and adheres to the concept of net capital formation as a measure of what has actually happened to the stock of capital goods.

On the proper time allocation of depreciation so conceived I have relatively little to say. Detailed problems and procedures are the subject of a vast literature which certainly cannot be dealt with in the present context at even the theoretical level. In particular, I have nothing to add to discussions about the adjustment of annual depreciation charges to take account of differences between actual and usual maintenance outlays; such adjustment appears desirable in principle. But I do not suppose that all the theoretical problems involved in this procedure, and in particular in its simultaneous application with other desirable features of capital consumption measurement, have been solved.

Actual Measurement of Capital Consumption

A theoretical discussion of capital consumption is one matter; statistical measurement is another. Thus, as mentioned previously, consistency with method 1 requires that obsolescence should be deducted from gross capital formation when the good is retired. This has the apparent advantage of avoiding the hazardous forecast of future changes in demand, technological knowledge, and relative costs required by methods which allow for future obsolescence of existing goods. This advantage is in practice largely illusory,

however, since the only actual data concerning the lives of capital goods are based on retirements which are influenced both by physical factors and by obsolescence. This is not, to be sure, true of the great changes which render a whole class of good suddenly obsolete. In rare cases of this type it may be possible to handle obsolescence in the manner theoretically desired. But in general it seems possible only to follow the existing practice of smoothing obsolescence into capital consumption by utilizing the best estimates of the actual lives of capital goods without distinguishing between the influences of physical factors and of obsolescence.

This practice departs from the desired treatment by affecting the timing of net capital formation and by counting obsolescence as capital consumption rather than as a deduction from gross capital formation. These departures are likely to be serious only to the extent that discarding of capital goods is irregular or that there is a time trend in the stock of capital goods or the rate of obsolescence. The only fairly clear bias of importance results from the moving forward in time of obsolescence charges; with an upward trend in the capital stock this will lead to persistent understatement of net capital formation as defined by method 1. Only to the extent that the proportion of obsolescence in depreciation charges changes is the relationship between capital consumption and national product disturbed. With obsolescence smoothed in, this is unlikely to be a serious deficiency.

But with respect to physical deterioration, too, it is not possible to measure what actually takes place. Available information confines us, for the most part, to a choice among a few simple, conventional techniques of measurement, with the choice itself based upon the flimsiest of evidence.

Among these conventions, I should like to call attention to the persuasive case made by Grant and Norton in their comprehensive *Depreciation* for the use of the declining-balance method with a depreciation rate about two and one-half times the percentage which would be used in straight-line depreciation based on full service life. For example, if the average full service life of equipment in a certain account is ten years, so that the straight-line rate would be 10 per cent of gross assets, depreciation equal to 25 per cent of the net asset balance remaining in the account is charged each year. For assets with lives in the neighborhood of twelve years the method charges off about half the cost in one-fourth of the life, and about three-fourths in one-half the life. For longer-lived assets the write-off slows slightly; for shorter-lived assets it accelerates.

The declining-balance method appears to have solid advantages for use in estimating net capital formation by the perpetual-inventory approach (to apply Goldsmith's term to the whole class of estimates in which capital consumption is computed by the estimator from his own estimates of gross capital formation in the past). The declining-balance method corresponds to what seems to be the common pattern of a relatively sharp decline in value to the owner during the early years of life. Certainly the common experience is that maintenance, repairs, and out-of-service time losses are at first low but tend to rise over time and, to keep potential capital output per unit of capital consumption constant over the life of a capital good, the pattern of depreciation charges should be such as to offset these rising costs. For many items manufacturers' or dealers' guarantees covering a limited period (whose value really should not be capitalized at all in accounting for the economy as a whole) strengthen this tendency.

The method minimizes the effect upon net capital formation of an arbitrary break, based upon length of life, between those items which are capitalized and those which are not. It also avoids the abrupt change, at the end of the assumed average life, from a constant depreciation charge to no charge which is inherent in straight-line item accounting, although this is a minor defect of the straight-line method in aggregative analysis because of the averaging effect of using different average lives for numerous types of goods. In these respects the declining-balance method is less sensitive than straight-line item depreciation to moderate changes in the average lives utilized and in the cutoff point between capital goods and current expenditures. The method is also simple to apply.

The use of two and one-half times the straight-line depreciation rate obviously rests upon the judgment and experience of the authors; its general applicability cannot be rigidly demonstrated. For very short-lived goods a ratio as high as two and one-half charges off what seems to be an unreasonably large amount in the first year (for example, with a four-year average life, 62.5 per cent; with a two and one-half-year life, the entire cost). In such cases some downward adjustment is probably indicated. An alternative which would be practical in statistical work would be to fit a curve for each average life period in such a way that half the cost is written off in one-fourth the life, or some similar relationship would be maintained.

The timing problem is most serious for very long-lived assets. For shorter-lived assets, the practical differences which result

from the use of straight-line depreciation or the declining-balance method, or of reasonable changes in service lives, are not usually extreme in a going economy. Particularly is this true if emphasis is placed less on year-to-year changes than upon the status of net capital formation over a period of years. As Nassimbene and Wooden note, however, with the large purchases in the postwar period following low private acquisitions during World War II, the declining-balance method would yield a significantly higher capital consumption figure for producers' durables in the postwar period than the straight-line method. If the straight-line method is used, sensitivity to errors in average lives can be reduced, and a slightly more realistic pattern developed by use of a life dispersion table.[38]

The hope that a conventional formula will not greatly impair estimates of capital consumption is, of course, dependent upon the basic proposition that, over the entire life of capital goods, total capital consumption must equal capital formation. The shorter the span of years over which this cost must be allocated, the greater is the statistical gain from this identity.

For very long-lived goods, particularly buildings, the long-term growth of the economy makes the estimates more sensitive to differences in both depreciation methods and lives used. Because of its very great quantitative importance and long life, and the inadequacy of existing information, residential housing provides, in fact, the most important statistical problem.

Houses are customarily replaced piecemeal and are infrequently abandoned *in toto* except where the site is wanted for other uses. The roof and the furnace of a new house may have an average life of ten years, the paint three years, the foundations two hundred years, etc. If each component part could be separately depreciated, a much more accurate evaluation of total depreciation would almost certainly be attained than is possible in dealing with a house as a whole. Full use of this method implies capitalizing at least major expenditures for replacement and repairs, for which present data are woefully inadequate. Thus application of this method may be delayed until statistical sources are improved. Even today, how-

[38]The effect on the estimates is similar to that which would be achieved by straight-line group accounting. The latter cannot be used directly in the perpetual-inventory method in the absence of actual data for retirements of individual assets—a type of data which, in general, cannot be secured. This method has been introduced into the Machinery and Allied Products Institute estimates of plant and equipment. It has also been used by John W. Kendrick in estimating farm capital.

ever, experimental investigation along this line might well prove fruitful.

Goldsmith has pointed the way to a different approach toward improvement: determining the time period within which one-half (or some other fraction) of the value of a house should be written off. He notes, on the basis of data from the Financial Survey of Urban Housing, that houses reach about forty-five years of age before their value falls to one-half that of new houses.[39]

This cannot be taken to indicate that only one-half the cost of a house should be charged off in forty-five years, even if no expenditures on houses after their original construction have been capitalized in the past or are currently counted as gross capital formation in the set of estimates under consideration. A durable good which has as yet suffered no obsolescence should have a market value more than one-half that of a new good when its physical ability to contribute to production is half exhausted. This is because it is subject to (1) less discounting of future services and (2) less risk of future obsolescence. Also a possible factor is that a buyer with given financial resources can control greater housing capacity by buying used rather than new property. Obsolescence already incurred is, of course, an offsetting influence.

The discounting factor is in itself of great importance—as is generally the case when compound interest is at work. Considered separately from other considerations, it would prevent the value of the future services of a house with a sixty-year life from falling to half its original value until it was about forty-five years old, if it yielded equal services each year of its life and a 4 per cent interest rate were applied.[40]

Since none of these considerations, in my view, should influence the timing of capital consumption, the half-life of a good as determined by market values should be very substantially shortened for use in computing depreciation; for houses, it would appear that it should probably be less than thirty years.[41]

[39]Goldsmith, *op. cit.*, pp. 24–25. Goldsmith's comments with respect to major alterations, full costing, etc. must be considered in interpreting this and the following paragraphs, but do not affect the points being made.

[40]This calculation is less affected by the interest rate chosen than one might instictively suppose. At interest rates of 3, 4, 5, 6, and 7 per cent a series of increments loses half its original value at 45 years if the original length of the series is, respectively, 64, 60, 58, 56, and 55 years.

[41]The factors cited, and particularly the discounting factor, will tend (in the absence of obsolescence or actual deterioration of the house or neighborhood) toward making the curve of market value plotted against age concave to the origin whereas the depreciated value should be at least linear

From a statistical study of retirements it is probably impractical to select an accurate average life for houses because of their very long lives. Furthermore, the average life would in itself be of limited value because it provides no information as to the proper pattern of depreciation within the period. Goldsmith's approach toward the determination of the half-life, making some rather pronounced downward adjustment for the reasons already cited, appears more promising. Experimentation with Census of Housing data of 1940 and 1950 classified by year built suggest that, if the number of years in which half the value of a unit is written off is the same, it makes no great difference in the resulting estimate of aggregate depreciation whether the straight-line or declining-balance method is used. Further research to establish the half-life as firmly as possible, to relate it to the proper valuation base, and perhaps also to determine additional points in the life cycle gives some hope of providing improved results for residential depreciation.

Usable Estimates Feasible

Despite the many difficulties of measurement, the perpetual inventory approach provides the basis for estimates of net private capital formation and of the stock of capital which, though necessarily crude, are sufficiently good to be usable if they are defined in terms of production cost rather than ability to contribute to production. The work of Goldsmith, Nassimbene and Wooden, Terborgh, and others goes far to meet the need. Further research and experience should bring improvements, particularly if intensive effort could be devoted to houses and other structures. Clear recognition that quality improvements are to be taken into account only insofar as they involve cost differentials would bring a more consistent approach, possibly involving changes in procedural detail.[42] Thus, if this is an acceptable decision, it is to be hoped that estimates which are sufficiently reliable within broad limits to warrant introduction into the official estimates of national product can in time be derived.

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and probably convex. Interest, as already illustrated, tends to make the curve concave because the last remaining year of future service, which drops out as each year passes, is progressively closer to the present as the house ages and therefore it has a higher present value. How closely the market actually reflects this circumstances is conjectural.

[42]It appears that on isolated occasions rather arbitrary adjustments have been made in price indexes in an effort to allow for quality change; such adjustments impair their use for the present purpose.

Nevertheless there is one great reservation with respect to this course of action. The ideas associated with method 3 are so deeply imbedded in general thinking as to justify the fear that such data would be misunderstood and misused. Thus the introduction of such measures into the national accounts would be a disservice if they are interpreted to mean that gross capital formation equal to capital consumption allowances is required to maintain the future production of the economy at a constant level, that replacement demand required to maintain a given output can be derived from them without consideration of changing capital productivity, or that the difference between depreciation in current prices and depreciation at original cost measures the amount by which business firms fail to provide or overprovide for capital replacement sufficient to maintain their scale of output.

Possibly these results could be avoided by the introduction of an entirely new terminology; certainly the change from existing procedures, which rely largely on accounting records and do not pretend to measure real capital formation, would require careful consideration.

4. Interpretation of Results

It is useful to look at some actual results which I believe to be roughly consistent with method 1 and see what interpretation can be placed upon them.

The private gross national product, measured in constant (1947) prices, increased 47 per cent from 1941 to 1952. Gross stocks of producers' durable equipment, measured in the same prices, increased 86 per cent and net stocks 110 per cent in that period, according to the estimates of Nassimbene and Wooden cited earlier. Depreciation—the measure of producers' durables "used up" in the year's production—increased 90 per cent.[43]

On the basis of these data total output per unit of gross capital in the form of producers' durables dropped in 1952 to an index of 79 when 1941=100; output per unit of depreciation, or capital used up, dropped to an index of 77; and, with a reduced average age, output per unit of net capital fell to an index of 70. As previously indicated, the change in output per unit of depreciation is perhaps the most interesting among these three since in principle it already takes account of any changes in either the average original life of,

[43]The stock figures are as of the end of the year; depreciation, more appropriately, is for the year as a whole so that these percentages are not precisely comparable.

or in the percentage of life remaining in, the producers' durable goods in stock. What might the drop in this figure mean?

1. The drop in output per unit of capital consumed could mean that the quality of producers' durables has in some sense deteriorated. But this is contrary to all observation and experience.

2. It could mean that the stock of capital was being used more intensively in 1941 than in 1952 but that by the method of measurement (straight-line depreciation) this is not reflected in the capital consumption figures. From a combination of Goldsmith's estimates with those of Nassimbene and Wooden, it appears that, on a net capital basis, output per unit of producers' durables was about the same in the late 1920's as in 1952; from this one might deduce that in 1941 the stock was abnormally small as a result of the depression and hence very intensively used, despite large unemployment of labor. But can the size of the wartime expansion of output then be explained by still higher utilization? Nassimbene and Wooden note that in 1952 some effort toward the creation of standby capacity was being made and that this may have been a factor. The 1952 capital stock may also have contained more provision for future growth than that of 1941. Nevertheless it seems unlikely that the difference in rate of utilization can explain much of the drop in output per unit of capital consumed, and there is no certainty that the change in the utilization rate was even in that direction.

3. It could simply mean that each unit of producers' durables was being employed in conjunction with smaller quantities of other productive resources. This seems clearly to be true and probably provides much and quite possibly all of the explanation. Our measure of the quantity of land is unchanged; hence the ratio of land to producers' durables consumed is down by 47 per cent. Man-hours worked in the private sector increased about 14 per cent; hence the ratio of man-hours to producers' durables used up is down by 40 per cent. Capital invested in inventories and construction also failed to keep pace with the 90 per cent increase in depreciation on producers' durables: for example increases are about 60 per cent in deflated nonfarm inventories, 23 per cent in the total number of dwelling units, and, according to Terborgh's estimates,[44] 12 per cent in deflated business plant. Of that elusive factor, entrepreneurship, we have no measure.

4. The quality of the other productive factors could have deteriorated or the rate of their utilization decreased.

[44]Charted in the *Capital Goods Review*, May 1953.

5. The social framework—the state of knowledge, the legal structure, the size and composition of markets—could have become less favorable to production. But neither of these seems likely; what little is known suggests the opposite.

6. Finally, the finding could be the result of changing industry weights. The industrial distribution of producers' durable goods is assuredly very different from that of gross national product. Thus it would be theoretically possible for output in each industry to keep pace with the stock of producers' durables in that industry and yet for the aggregate decline to take place.

These questions are raised only to indicate the care which must be taken and the further reflection and investigation required to interpret the results derived in such a study. Any of these possibilities could in principle have created the observed results. In practice some factors presumably operated to raise and some to lower total output per unit of producers' durable goods consumed. Some, certainly questions 2, 3, and 6, are open to exploration.

This discussion of possibilities is not intended to disparage the utility of Nassimbene's and Wooden's findings; on the contrary, like the estimates of Goldsmith, Terborgh, and others, they are highly valuable. The questions they raise are parallel to those that must be asked about output per unit of labor; as we increase the number of productive resources for which quantity series are available, our knowledge is multiplied, and each series helps in the interpretation of the other. That the quantity of producers' durables has increased more rapidly than that of labor is a fact helpful in the interpretation of unit output data for each. The data have other uses and will be widely analyzed.

It should also be observed that these investigators have at least derived results which are of interest in themselves and can be subjected to further study and analysis. If measures taking full account of quality change were to be insisted upon, a quantity series could not be derived for any productive resource.

It is proper also to ask what more we would know if the study could have been carried through by adjusting for quality change through either methods 2 or 3, the methodology being the same in other respects.[45]

By method 2 the quantity of capital consumed would presumably increase by around 47 per cent, the same as private gross product,

[45]Nassimbene and Wooden note other qualifications to their estimates, particularly use of straight-line depreciation and uncertainty concerning the average lives used, in addition to that concerning quality change.

unless the result were changed by industry weighting. The index of output per unit of capital would be 100. Net capital formation from 1941 to 1952 would be less than one-half that shown by Nassimbene and Wooden—an adjustment certainly in the wrong direction if adjustment for quality change is intended. These results are surely uninstructive.

What the results would be if method 3 could actually be carried out can only be speculated upon. But presumably the percentage increases from 1941 to 1952 in constant-dollar gross and net capital and capital consumption would be larger, and in output per unit of capital and per unit of capital consumption smaller, than that actually secured.[46] To select a number at random, suppose the index of output per unit of capital consumed were 65 instead of 77 in 1952. To interpret that figure we would still need the answers to precisely the same questions, except the first dealing with quality change in capital, which have been raised about the actual estimates.

Even then, a measure of the quality (productivity) improvements in capital would still be of intense interest. If it were feasible, we should like to measure capital by both methods 1 and 3, and particularly to know the difference between them.

Implications for Income

What practical difference does it make in a measure of income, defined as the amount which can be consumed while keeping the expectation of future income the same at the end of the year as it was at its beginning, whether we measure capital consumption in accordance with method 1 or method 3? National income and net national product as now measured take no account of changes during a year in the quantity or quality of productive resources other than capital goods, or of changes in the social framework of the economy which alter the economy's productive ability. For this reason, in a growing and progressive economy our income measures are understated by reference to such a generalized income definition. What is omitted, or much of it, is often referred to loosely as intangible capital formation, although it has nothing to do with capital as a factor of production.

[46]Net capital formation for the whole period 1941–1952 in current dollars of each year would have been larger by method 3 (because capital consumption in current dollars would have been smaller) than the figure implied by Nassimbene's estimates. The constant (1947) dollar figure for net capital formation might have been larger or smaller, in dollars, depending upon the relative importance of quality improvement before and after 1947.

If tangible capital formation is measured by method 1, our income measure takes account of changes in the quantity of capital (quantity being defined in terms of production cost) but any changes in the quality of the capital stock occurring during the year as a result of the replacement of old goods by new and improved ones are thrown into the category of intangible capital formation not taken into account. By method 3 the income measure takes account of both quantity and quality changes in the stock of capital.

As long as changes in the quantity and quality of other factors of production cannot be taken into account, similar treatment for quality changes in capital goods scarcely seems a critical weakening of income estimates.[47]

Conclusion

The principal conclusion of the main body of this paper is that to arrive at an operational definition of net capital formation, two decisions are required. First, the fruitless attempt to adjust estimates of capital formation for quality change must be abandoned and a concept of valuation based on cost of production substituted for one based upon productivity. Second, the principle that capital consumption must equal gross capital formation over the full life of a group of capital goods must be accepted. Even then, only estimates which represent crude approximations can be obtained, chiefly because of the difficulty of accurately timing capital consumption. But these will be estimates which at least approximate the definitions assigned to them.

5. *War Damage*

There remains to be discussed, as an addendum, the treatment of war losses. Major natural disasters raise identical questions and need not be considered separately.

The depreciated value of capital assets destroyed in war can be (1) counted as capital consumption when destroyed, (2) counted in capital consumption on some kind of a risk or benefit basis which will provide for a spreading over time of the loss, or (3) not counted as capital consumption at all. Unless a form of (2) is selected which requires a current deduction for the risk of future destruction, the question does not importantly affect current or past estimates for the United States.

[47]We could, of course, go one step further—omit also changes in the quantity of capital goods and, like Irving Fisher, define income as consumption. This would treat changes in all productive resources similarly, but nothing seems to me to be gained from this course and much lost.

Personally I prefer the first alternative. Net capital formation should measure the value of the change in the capital stock each year and not be concerned with the reason for the change. If the roof of a temporarily vacant house deteriorates from the weather, this is capital consumption even though it is unrelated to the current production of the house, which is nil. Consistency requires that war damage be treated in the same way. As compared with omitting war losses from capital consumption entirely, alternative (1) is also in harmony with the idea that capital goods are intermediate and should not add to the net national product for their life span as a whole. Provided gross capital formation and gross national product data are also available, the method provides the same information in ordinary years and more information in years of war loss than alternative (3). It does not, as does alternative (2), distort output and productivity measures in years when war damage has not occurred.

On the other hand it is usually held that war losses are not properly a charge against production in the year they occur. This position could lead to spreading them over some longer time period. This is undesirable because (1) there is no real basis for allocation, (2) the method shows deterioration to have taken place in the stock of capital in peacetime when in fact it has not occurred, and (3) it destroys any reasonable relationship between output and capital resources or capital use in peacetime.

More usually, war losses are simply omitted from capital consumption. Though this procedure seems illogical from the standpoint of net capital formation, the reluctance to see the net national product or national income drastically reduced, or even turned negative, in years of widespread destruction is understandable (although I do not share it). So long as the method followed is made clear and the destroyed assets are somehow eliminated from the capital stock, the choice between the first and third alternatives is not of great moment.

If the expectation of war appreciably affects the course of peacetime capital formation, this raises additional difficulties. Suppose a country deliberately creates two facilities where the output of only one is needed so that the destruction of one would not disrupt the conduct of a war. Suppose that, in wartime, one actually is destroyed. Has it not fulfilled its purpose of providing for national security in the same way as shells blown up in battle? But if it is deducted at any time as capital consumption, this will not appear to be the case.

The United States, at extra cost, has incorporated special features into merchant ships to equip them for wartime use. Dispersion of industry even if it involves economic disadvantage is being urged and to some extent has occurred. Less durable construction than would be warranted by everlasting peace may be justified by war risks. If the extra costs associated with such precautions are capitalized and depreciated in the usual fashion, and no war develops, they do not appear to contribute to the net national product in the long run but rather serve temporarily to increase the value of the capital stock and to lower productivity. But certainly they have contributed to the national security in the same way as a standing army.

In principle such cases as these can be handled in reasonably satisfactory fashion by counting additional costs incurred for defense purposes as end-products when incurred rather than by capitalizing them. In practice this seems to be feasible only when, as in the case of the United States merchant marine, a private firm incurs the costs associated with normal operations and the expenses associated with defense features are isolated and met by the federal government.

COMMENT

ERIC SCHIFF, Machinery and Allied Products Institute

Edward F. Denison has made an important contribution to the clarification of fundamental conceptual problems in the field of capital formation statistics. The service he has rendered thereby is particularly valuable at a time when, thanks to the work already done by Simon Kuznets, Raymond W. Goldsmith, George Terborgh, Raymond Nassimbene, and others in measuring the development of real wealth and real capital, it may soon be technically feasible to combine the existing system of annual national-product/national-income tabulations with that of annual national-real-wealth/national-money-claims tabulations into a unified body of national accounts.

Since it is impossible, within the time here available, to do full justice to Denison's paper, I shall limit myself to raising a few special points for further discussion.

Note: The views expressed in this Comment are those of the author and not necessarily those of the Machinery and Allied Products Institute.

The Problem of Quality Changes

Denison's main thesis has a positive and a negative side. The positive aspect lies in the fact that the broad principle underlying practically all statistical work done so far emerges from the critical analysis without a scar. That principle is to measure capital formation in terms of cost values (whether in original cost, at constant prices of some base year, or at current prices) and to take account of efficiency-raising quality changes in the capital stock only to the extent that they involve cost differentials. Denison examines hypothetical alternative statistical techniques which would allow for increases in the income-producing power of capital goods having identical cost values. He finds that the results of such methods would be uninformative or the technical requirements involved unworkable. In fact, as far as the principle is concerned, the criticism presented in Denison's analysis of his method 3 is convincing: while hypothetically specifications for taking account of quality changes in the measurement of capital values could be set up, their application for statistical purposes in a really consistent and rounded manner would require so many unverifiable assumptions as to not warrant attempts along this line.

The negative aspect of Denison's thesis concerns the question of whether it is defensible to take half a loaf when the way to taking the whole loaf is barred. He not only dismisses attempts to replace the present method of measuring capital values by any fundamentally different one; he even recommends the rigorous elimination from the present system of certain procedures which attempt to build some allowance for quality differentials into this system, thereby violating the logic of method 1. In offering these recommendations Denison is on unassailable ground measured by logical purity, but sometimes one doubts whether this is the best criterion. A good case in point is the question of how to account for obsolescence. Needless to emphasize, Denison's problem here is not what practice business should follow, or what practice the Bureau of Internal Revenue should allow for tax purposes, but solely what treatment of obsolescence appears theoretically most appropriate for building up a logically consistent system of national accounts. Of the three possible courses which he examines, the first—to charge obsolescence against output by allowances spread over the service lives of existing assets along with the allowances for physical depreciation—is the prevailing American business practice; the capital consumption series available in this country, based as they are primarily on business depreciation records, must be assumed to re-

flect this pattern. The second procedure is to disregard the obsolescence accruing on existing capital goods and to charge it off *in toto* against output when the assets are being retired. The third conceivable course would be to deduct only wear and tear allowances on existing capital goods and to remove the terminal net book value on assets discarded as obsolete by a capital adjustment rather than by a deduction from income. Denison favors the second course, with the modification that when the assets are being retired, the obsolescence charge should be subtracted from gross capital formation rather than added to capital consumption.[1]

To judge the merits of the reasoning behind this conclusion is hardly possible without first making a decision as to what criterion should be used. As far as formal logical consistency is concerned, Denison makes a valid point when he says that the accrual method of accounting for obsolescence of capital in place does not strictly fit into a system where, generally, quality changes not reflected in cost differentials leave the measurement of capital values unaffected. In a national accounting system where quality changes did affect this measurement, the values of *all* capital goods—standing, incoming, and outgoing—would be so adjusted that equal value would mean equal ability to contribute to production. And the ability of newly produced capital goods would serve as the standard for this measurement. In such a system we would allow in some way—say, by use of price deflators allowing for the greater efficiency of newly installed capital goods produced at unchanged costs—for the fact that $100 newly installed more than merely replace an outgoing capacity which, measured at cost and adjusted only for changes in the general price level, would be entered at $100. We would enter a somewhat lower final figure for this capital consumption.[2] On the other hand the valuation of the capital goods that remain in service would have to be lowered also in order to make their use value, dollar for dollar, likewise commensurate with that of the more efficient current capital goods. To account in this way for the obsolescence currently accruing on the existing stock would here be quite appropriate, in fact logically indispensable. However, it is not entirely logical to account for the relative productivity loss accruing on the existing capital goods in a statistical system where, generally, we do *not* adjust capital values for productivity

[1]Questions connected with this modification need not detain us here. The effect of the allowance on net capital formation, net capital stock values, and net national income is not changed thereby.

[2]Cf. Simon Kuznets, "Proportion of Capital Formation to National Product," *American Economic Review*, May 1952, p. 515.

changes. To this extent Denison's critical analysis seems irrefutable.

However, there is another aspect to the matter. A good case can be made for the view that any effort to make current statistics reflect current economic realities as fully as possible is legitimate even if it does not quite fit into the general conceptual framework of a system. In capital goods economics, the current ability of productive facilities to contribute to the production of real income *is* the most relevant of all realities; if we can, within any methodological framework whatever, give this phenomenon some effect in our statistics, it is questionable whether considerations about formal consistency should deter us. This is all the more questionable because in this field ironclad logical consistency is probably unattainable in any case. If one insisted on keeping method 1 absolutely unadulterated, it is difficult to see how one could avoid recommending method 3, under which obsolescence is not being charged against output at *any* time. This treatment Denison rejects because it clashes with another important postulate, the fundamental value identity (in constant dollars) of gross capital formation and capital consumption over the full life of capital goods. This is a weighty argument no doubt, but its introduction shows that we are here moving in a world of conflicting postulates and inevitable logical compromises. This is confirmed by other considerations. It is highly probable that from the standpoint of an uncompromising logical puritanism, even deductions for physical depreciation would have to be partially banned as alien to method 1—that part of them which allows for the current service deterioration (as distinct from the part which accounts for the shortening of the remaining service life). For after all, as Denison himself emphasizes, even our accounting for physical depreciation is to this extent only a rough attempt to allow currently for a gradually "accruing" relative change in the ability of existing capital goods to contribute to production when the ability of newly installed facilities is used as the standard of measurement. If we enter these allowances, it is only a natural supplemental step to try to allow also for that part of the productivity differential which is due to the new facilities' superior design rather than to their lower age.

The undeniable problem lies in the fact that, within the existing statistical system, this supplemental step calls for two (opposite) adjustments, only one of which is practicable. If we take maximum possible approximation to economic reality rather than maximum methodological purity as our guiding criterion, the ultimately rele-

vant question boils down to this: If at the present time we are unable to adjust our capital consumption figures downward to allow for the relative productivity decline accrued on the currently *outgoing* capital values, does an upward adjustment of these figures to allow for the relative productivity decline accruing on the currently *remaining* capital values bring us closer to, or farther away from, what we would get if both adjustments were made? That depends, of course, on the relative size of the two adjustments; while they (or a failure to make either of them) act in opposite direction, there is, as Denison says, no reason to assume an exact offset as a general rule. If in a given year the theoretically required productivity adjustments of the capital consumption charge are −5 on account of the disappearing capacities and +20 on account of the remaining ones (obsolescence allowance), the net adjustment called for is +15. If we are unable to make the first adjustment, are we not keeping in closer touch with the facts of life if, throwing formal logical consistency aside, we make the second adjustment? While in this case our final capital consumption charge is 5 points too high (by reference to a desired but supposedly impracticable all-round adjustment), failure to make the obsolescence allowance would make it 15 points too low. If the plus and minus adjustment figures were reversed, the conclusions for policy would be different. Again assuming that the downward adjustment is impracticable, the final capital consumption figure would be 20 points too high if we made the upward adjustment and only 15 points too high if we did not. There are reasons to think that normally the relative efficiency loss currently accruing on the standing capital values is numerically more important than the countervailing relative efficiency loss accrued on the currently eliminated capital values. If this is so, the downward bias which we would impart to our capital consumption figures by failing to make either adjustment would be greater than the upward bias we now obtain by making only the upward adjustment for obsolescence of the remaining facilities.

In this country the whole question is probably of limited practical significance, because the practice of spreading allowances for (normal) obsolescence over the economic service life of capital goods is firmly established. Denison probably would agree that as business practice in a highly competitive economy the method is superior to the alternative system. Since nobody would expect or demand that business, in providing for obsolescence, should switch from the accrual basis to the realization basis merely to enable statisticians to achieve maximum formal consistency in setting up

national accounts, and since all available data on service lives of capital goods likewise reflect the obsolescence factor, it seems, and in fact Denison expects, that even the statistician's capital consumption figures will have to stay on this basis. Nevertheless it is interesting to speculate on the effects of such a switch on the national accounts. In itself it is only the *timing* of the obsolescence charge which is different in the two systems. However, a trial experiment which I ran on a simplified model seems to indicate that the difference in the time pattern of allocation may affect the net value of the capital stock and the ratio of net to gross capital quite substantially. It may be of some interest to present the result of the experiment.

Suppose that a group of homogeneous durable capital goods, each having a life expectancy of ten years, is installed at some time at a total cost of $100,000. The life expectancy takes obsolescence into account; on the basis of physical wear and tear alone the service life expected would be, let us say, fifteen years.[3] In agreement with normally prevailing conditions let us further assume that actual retirements are distributed around, rather than concentrated at, the tenth year, which thus represents an *average* service life. As one out of a variety of possibilities, let us assume that the chance distribution of the retirements around the average conforms to one of the bell-shaped, symmetrical distribution curves fitted to a large number of recorded retirement/age observations by the Iowa Engineering Experiment Station.[4] The development of depreciation accruals and net asset accounts under the two systems of allowing for obsolescence is as follows.[5] If we want to accumulate reserves for obsolescence as it accrues, we must write off annually 10 per cent on the survivorship at the given year, plus the undepreciated value, at retirement, of the items that are being retired before the ten-year life average. (Retirements after the average will not lead to any depreciation entry since the whole investment is written

[3]In general we do not know by how much the obsolescence factor shortens the economic life of capital goods, as compared with the physical life. The proportion assumed above—one-third—has occasionally been suggested in the literature as a rough conjecture.

[4]The distribution assumed here (identical with that underlying the investigations in George Terborgh, *Realistic Depreciation Policy*, Machinery and Allied Products Institute, 1954) is the S_3 curve described in R. Winfrey, *Statistical Analysis of Industrial Property Retirements*, Iowa Engineering Experiment Station, Bull. 125, 1935, pp. 71 and 98 ff.

[5]For strict comparability let us assume that under both systems straight-line depreciation with item accounting is used and that salvage value is always zero.

down to zero at the end of year ten.) If on the other hand we wish to account for obsolescence only when it is realized, we shall write off annually only 6.67 per cent on the survivorship, plus the undepreciated value at retirement of all items retired before year fifteen (at which point the investment will have been completely written off). The undepreciated remainder values to be written off on retirements will here be greater than under the first technique since they now counterbalance the whole obsolescence accrued up to retirement.[6] However, the combined annual deductions for capital consumption will be smaller and the curve of net asset values will decline much less steeply. The first panel in Chart 1 shows the net account curves under the two systems as well as the curve of gross survivors. If the annual input of $100,000 is repeated year after year and average life and retirement distribution are always as indicated, it is obvious that the gross plant value will build up during twenty years to $1 million, where it will then remain stable (gross additions being from then on exactly offset by retirements).[7] The net values will also stabilize, but time and level of stabilization will differ markedly according to which system of obsolescence accounting is used. Under the system which allows for obsolescence *pari passu* with its accrual, the stability value of the net account is 48.5 per cent of the gross value (also at stability). Under the alternative system this percentage turns out to be 64.5 per cent (see the second panel on Chart 1).

This experiment deals with a plant which has a period of growth before stabilizing. Besides, the result depends of course on the

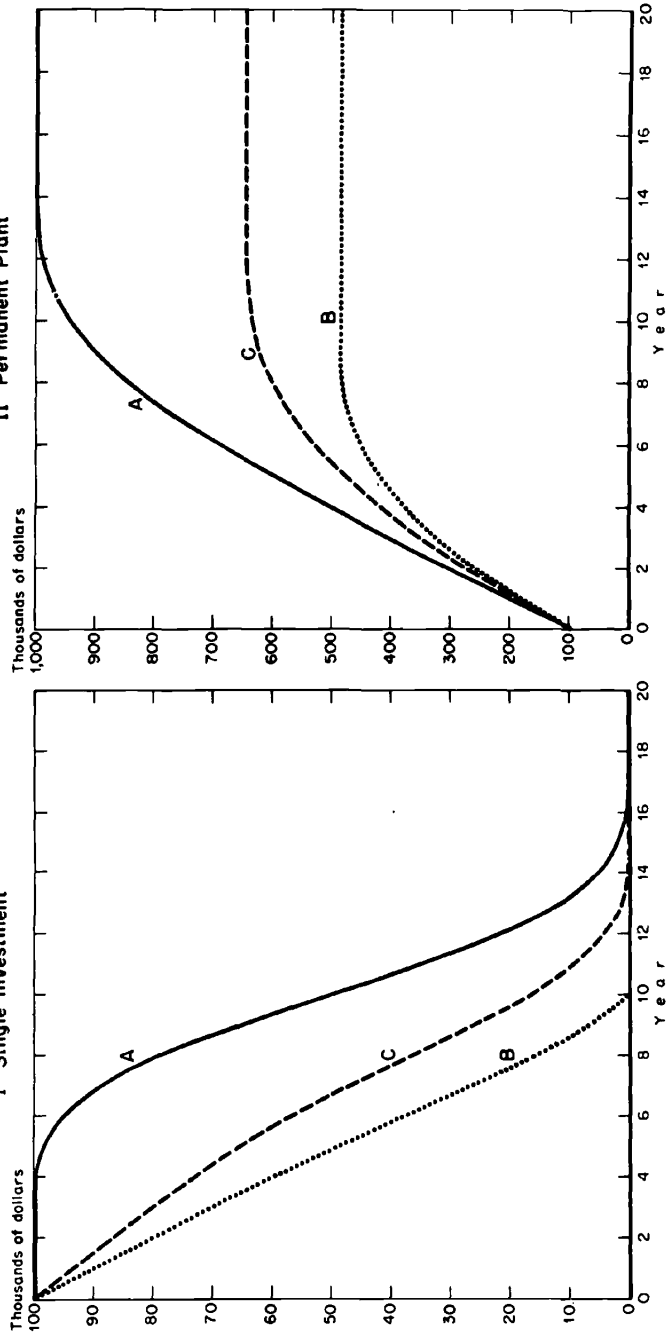
[6]For symmetry of exposition and simplicity of computation, it has been assumed here that the allowance for obsolescence is added to capital consumption in either of the two procedures compared. This deviates slightly from Denison's line of thought since he suggests that the allowance for "realized" obsolescence should be deducted from gross capital formation. In this latter case the stabilization ratio of net to gross capital values would differ slightly from that given in the text below for the second procedure, but its excess over the ratio obtained under the "accrual" method would certainly be of about the same order of magnitude as the excess arrived at under the assumptions made here.

[7]In this model the gross plant is not kept stable right from the beginning by immediately replacing each retirement. Instead the plant is being built up to eventual renewal stability by successive repetition, at a uniform time interval, of gross investments having uniform size, life average, and retirement distribution. In an alternative model, where each retirement would be replaced as and when it occurs, the gross capital value would be stable from the start after one single original investment of $100,000, but the succession of total annual renewal investments (consisting of renewals of original units, plus renewals of renewals) as well as the succession of depreciation accruals built on it would present complications which are not worth dealing with here.

CHART 1

Gross and Net Capital Values under Two Methods of Accounting for Obsolescence

Curve A: Gross value of stock
Curve B: Net value of stock, if charge for obsolescence is spread over service life
Curve C: Net value of stock, if charge for obsolescence is concentrated at retirement



specified assumptions about average life, retirement distribution around the average, and degree of disparity between economic and physical service life. Even so, the resulting wide divergence of the stability ratios of net to gross capital value under the two methods of accounting for obsolescence is noteworthy.

The Interest Factor

Is it appropriate, for purposes of capital formation statistics, to allow for interest in computing annual capital consumption? Denison's analysis leads him to the flat statement that interest has no place here. He points out that, as soon as we allow for interest, we are, by implication, introducing anticipations of the future—the flow of prospective gross revenues and costs. This seems to him to violate the basic principle that "capital formation and net income statistics are of necessity ex-post measures of what happened in the past." Here a question inevitably arises. In defining capital values for theoretical as well as statistical purposes, is it always *possible* to avoid referring to the future? Denison's own discussion at several places seems to imply a negative answer. His fundamental definition of capital consumption as representing "either an actual reduction in the physical ability of a capital good to contribute to annual production in the future or a simple reduction in the remaining number of years the good will continue to contribute to production" clearly refers to future net service values. The same is true of his general conclusion that the time allocation of capital consumption "should take account of both the partial exhaustion of the total life of the capital good and of any deterioration in its efficiency which will be reflected in the future in rising operating or maintenance costs, expense due to lost time, etc." The question is whether the current value runoff so defined should be measured by the annual decline in the simple sum of the prospective service values still "stored" in the capital goods or by the annual decline in the sum of these values discounted to the given time. The shape of the curve of annual depreciation is of course affected by the decision. If the services still in prospect are assumed to have equal net values each year, the annual depreciation is constant when interest is neglected, and rising when interest is taken into account. If there is an annual decline of prospective net service values by equal amounts each year down to zero at the end of the service life, annual depreciation declines (the curve of net asset values is convex to the origin) whether interest is zero or positive, but the rate of decline is smaller in the second case.

The whole problem comes into sharp focus in Denison's discussion of the valuation of houses. According to him, the market for houses and durable goods in general discounts future net service values; if these are expected to remain equal, the market value of the asset at the point where 50 per cent of the (undiscounted) service values are exhausted will be more than 50 per cent of original cost. But the statistician, Denison warns, should not follow the market in assuming a net value curve concave to the origin. He should disregard the interest factor and accordingly think in terms of a depreciated-value curve running straight-line downward, or even—because net service values must be expected to decline as the building ages—convex to the origin.

The result seems correct but the reasoning not fully convincing. If the decline in future net service values over time is substantial, as is generally the case in houses, a linear decline of net asset values, or—if anticipated net service values shrink to or close to zero—a net value curve convex to the origin, results even if a positive rate of interest is assumed (although the convexity is less marked than at zero interest). If market valuations of assets show the reverse pattern, Denison's warning that statisticians should not accept them as the "true" contour is perfectly justified, but the fault of the market would then seem to lie not in the use of a discount factor but rather in its application to a series of prospective service values whose gradual shrinkage is neglected or at least underestimated. This way of looking at the matter makes it possible to avoid what seems to me to be an unnecessary cleavage in our thinking about the valuation problem. Why should it be natural for the market to discount prospective values and unnatural for the appraising statistician to do so? Here is a question on which further discussion may be fruitful.

The Curve of Net Capital Values in General

As a general proposition, apart from the question of interest, Denison suggests that a declining-balance schedule of depreciation accounting with a rather high rate is more likely to approximate the true contour of the value runoff on durable capital goods over time than the straight-line method does. While this suggestion apparently is not a corollary of his main theoretical result in the problem of quality-adjusted values versus cost values in capital statistics, it is well supported by quite a number of considerations. Since the suggested change in the depreciation method has much to commend it even from the business point of view, the day may well come

when it will be possible to obtain figures based on declining-balance depreciation directly from business records.[8]

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The very sharpness with which Edward F. Denison takes his position on the several controversial questions in measurement of capital formation and capital consumption stimulates further thought and provokes disagreement. The limitation of the comments below to points of dissent is due partly to an attempt to fulfill my proper duty as a discussant, and partly to the difficulties of accepting Denison's conclusions. These difficulties should be stressed in the hope that further consideration will lead to partial resolution.

Three sets of comments are presented: (1) on the purposes of measurement; (2) on the treatment of quality changes in measuring capital formation; and (3) on the treatment of obsolescence in measuring capital consumption.

1. The Purposes of Measurement

Denison's remarks on the purposes of measurement are quite brief, but they raise a major question that should be stated explicitly. He appears to contrast the approach in which accounting entities are recorded because they influence—or could influence to more effective ends—business decisions, with the approach of economists bent upon gauging net capital formation as a change from a situation defined as "capital kept intact." But surely the capital formation totals, gross or net, that we try to secure in national income measurement cannot be viewed as mechanical sums of bookkeeping entries by business firms and individuals (*qua* business units) even though the latter may be used for lack of better data and resources for proper estimation. Even if the purpose were to study capital purchases and consumption as items that influence the decisions of businessmen, the desired figures would not necessarily be the entries in the accounts of the company; there would be little sense in adding these figures into totals except for groups subject to similar conditions in making their capital program and other decisions; and there would be little need for adjustment for changes in prices. This purpose would call for "motivational" entries which, by and large, are neither additive nor capable of

[8]Since this was written, the new depreciation provisions in Section 167 of the Internal Revenue Code of 1954 have greatly accelerated the development which will make this possible.

manipulation mathematically, except within a framework of distinct motivational structures.

Clearly the purpose in measuring capital formation and consumption in the national product estimates is quite different; and Denison, although he doesn't state it, recognizes it and proceeds to wrestle with the problems encountered in attempts to satisfy that purpose. The aim, I think, is to gauge the performance of the economy in the way of input of resources and output of product. Resources and product are defined here in accordance with recognized social purposes and weighted in a scale that has meaning to society, partly because that scale is in fact used and partly because it represents a projection back in time of what is accepted today. The concern about keeping capital intact, which Denison properly emphasizes, is one aspect of the basic aim of capital and income measurement on a nationwide scale. It may well be, as he argues, that the criterion cannot be applied, that it is essentially a nonoperational concept. But all concepts in the field of national income are, in one way or another, nonoperational: they are goals that forever elude measurement and for which measurable approximations are substituted. We never measure compensation of labor or capital: we estimate wages and interest (and/or dividends). We never measure total product: we estimate the sales of goods which we classify as final. All these operational measures assume meaning only because they are approximations to the "purer," nonoperational concepts behind them. The question then is not whether such a pure concept as "keeping capital intact" is operational in this sense, but whether an operational substitute that would provide a sufficiently useful approximation is available or can be designed.

We dwell on these general points to avoid the danger of dismissing important problems by arguing that the analyst should include in his measurement only what the operating units count in their operations and that the concepts evolved in economic theory are, in essence, nonoperational. Denison does not, in fact, ignore these problems, but only because, happily, the discussion in the body of his paper is not consistent with the general view expressed in the introductory pages. Yet the tendency to substitute business accounting for economic analysis is evident and should not be dismissed too lightly.

The suggestion that we measure the entities that enter the decisionmaking of operating units may result in a paradoxical—and unfortunate—situation in terms of countrywide totals. These operating units—whether they are big business corporations,

governments, or the community at large—may be using the totals of national income, capital formation, and the like because they are assumed to be approximations of economic concepts that stand for clear-cut notions in the analysis of the performance of the nation-wide economy. In other words they are used by the operating units precisely because they are approximations, no matter how crude, of economic concepts. If the economists who undertake the measurement use as *their* guide the totals used by the operating units, we have a vicious circle—vicious in the neglect of continuously present and changing problems that arise in obtaining empirical approximations of theoretical concepts. It is the economists' responsibility to keep the concepts pure and sharp and to keep the estimates which are empirical approximations of such concepts continuously geared to them. The task should not be delegated to the operating units in the economy.

2. *Quality Changes in Measuring Capital Formation*

In reading Denison's discussion of quality change and measurement of gross capital formation, I had difficulty in (1) seeing the scope of quality changes and (2) tracing the implications of the principle of valuation at cost.

The Scope of Quality Changes

From Denison's discussion I gather that quality changes mean changes in a still recognizable capital item which affect its productivity, i.e. its contribution to output. If a machine tool can be reproduced with half the resources formerly needed, no quality change is introduced. But if the machine tool is changed and its performance is affected, we have a quality change regardless of whether production of the new tool requires greater resource input. Since a large part of capital is residential and related housing, the same reasoning applies to this consumer type of capital whose productivity is measured by yield of services desired by consumers.

The character of a quality change may be important in the application of Denison's principle of cost valuation. Some quality changes require larger resource inputs; others do not. Some quality changes originate with the producer of capital; others with the user—e.g. re-arrangement of a plant layout may raise productivity, and at least part of this increase should be assigned to the capital tool unless it is all imputed to the factor of "enterprise" (which does not appear in Denison's examples). Some quality changes increase the durability of the capital items; others increase the pro-

ductivity for a given time unit. The very multiplicity of such quality changes and the difficulty in imputing changes in productivity lead Denison to reject the principle of valuing capital in terms of its specific productivity as both impracticable and uninteresting.

I agree with Denison that to measure capital by its productivity is hardly an easy performance. But quality change as reflected in changing productivity is a pervasive feature of any economy that can take advantage of the potentialities of technical and social progress. One cannot escape quality change, in this meaning of the term, even in applying the principle of cost valuation to gross capital formation.

Valuation at Cost

This point will become clear when we consider the implications of the cost principle advocated by Denison. De we evaluate the input of resources or do we count the physical units?

If we think of cost as input of so many man-hours—treated as units of equal weight—we immediately face a problem. Assume that 20 machine tools were produced in year 1 with 10,000 man-hours; whereas 40 machine tools, without any quality change, were produced in year 2 with 10,000 man-hours. According to Denison, gross capital formation in year 2 is double that in year 1 since no quality change occurred and since this represents the usual practice of estimators. The cost did not change but Denison would presumably depart in this case from the principle of cost valuation.

If this interpretation of Denison's position is correct, what happens if with the same 10,000 man-hours, the economy produces 20 machine tools which will last twice as long as the earlier tools and give twice as much service because better metal is used? Here is a change in quality but not in resource input or in cost. In this case, Denison would treat gross capital formation as the same in both years, as he would do if, instead of longer life, we assumed greater current capacity, e.g. greater steam pressure. As far as I can see, consistency would require Denison either to treat capital formation as equal in the two years in the first example—which is a radical departure from accepted estimating procedure—or to allow for the effect of quality changes in the second example.

Denison mentions a second difficulty: "Quality improvements in product not involving additional costs are usually considered as increases in output for industries producing consumers' goods but, by method 1, [based on the cost principle] are not so considered in the case of durable capital goods" (page 226). He argues that this in-

consistency is acceptable since the changed productivity of capital goods is eventually reflected in the greater output of consumers' goods. He recognizes that this position brings him perilously close to that of Irving Fisher, who argued for the exclusion of *all* capital goods from the scope of national income or product. Denison is willing to accept Fisher's arguments to avoid the bothersome problem of quality changes in capital goods, but not to the point of excluding *all* new capital goods. In his reluctance to go the full way with Fisher, Denison betrays his concern about keeping capital intact, about the general question of whether society does or does not add to its capital stock; he is thus open to pressure to accept any reasonable approximation of capital formation in terms of productivity.

Cost and Productivity

This leads me to the third and most important point which bears upon the valuation of resources and the cost principle. To begin with, the contrast that Denison draws between cost and productivity, between methods 1 and 3, is puzzling—unless one distinguishes between the measurement of input in physical terms and of output in value terms. If input is a measure of the productivity of the economy, the only way to gauge it is in terms *independent* of productivity—otherwise a tautology results. It is for this reason that measures of productivity usually compare input of man-hours, direct and indirect, i.e. embodied in materials and machinery, with product in constant prices. But if we wish to gauge the value of a component of final product, such as capital formation, by the input into it, *because this is the easier way*, the basis of cost valuation should not be different from that applied to other components of final product.

Theoretically the price entrepreneurs are willing to pay for a new capital item, i.e. the cost, is equal to the capitalized value of returns; changes in the latter, in which changing productivity of capital goods is a determining element, would therefore be reflected in the cost. In other words methods 1 and 3 should yield identical results. It does not in Denison's examples because he is measuring input in physical terms whereas he should measure them in terms of the *value* of resources, which is approximated by their opportunity cost. In Denison's example, the productivity of labor, i.e. the ratio of output to input, rises from $1\frac{1}{3}$ in year 1 to $2\frac{2}{3}$ in year 2, or doubles (I am disregarding the productivity factor in the production of the machines themselves). Hence the opportunity cost, the value

of resources devoted to the production of machinery in year 2, under situation 1, is *by method 1* not 20 but 40. Likewise, if the entrepreneurs are willing to pay, in terms of command over resources, 40 units for the 20 machines, the productivity imputable to the capital goods cannot be 100, the figure under method 3 in Denison's example; it must be 40. In other words a proper interpretation of the cost principle, and allowance for the changing value of resource input which is a result of the very increase in productivity that Denison includes under quality change and wishes to omit, would remove any difference in principle among the three methods used in his illustrative analysis.

In the light of these comments, the following suggestion seems to warrant exploration. We assume that the indexes available for adjusting current values of capital formation for price movements are inadequate for handling quality changes—or at least are so much more inadequate than those for consumers' goods that significant inconsistency is introduced. In other words we start with the premise that the price-adjusted volume of consumers' goods is a tolerable measure of final output, with quality changes taken into account. We could calculate the productivity of resources devoted to the output of these consumers' goods, relating output to, say, man-hours put in and the man-hour equivalent of other costs (derived perhaps by dividing current price estimates of such costs by a wage unit, i.e. some unit price of a man-hour). Next we could divide the current dollar volume of gross capital formation by the wage unit of the base year, i.e. the unit price of a man-hour, thus deriving the number of man-hours represented by gross capital formation. Then we could multiply the latter number of man-hours by the productivity per man-hour calculated in the analysis for the consumers' goods industries. The product should approximate the opportunity cost of capital formation, i.e. the output that might have been produced if the resources had been used directly in turning out consumers' goods. This opportunity cost would not only reflect the quality changes in capital that increase labor productivity in consumers' goods industries but would also constitute an estimate of what purchasers of capital goods intend to secure from them, adjusted to the changing price of a money unit converted via the wage unit. There may well be some inconsistencies and statistical surprises in this proposal, which could be revealed only in an attempt to follow through a sample calculation. Disregarding these, if the change in prices of capital goods is parallel to that of the wage unit, the procedure will yield a greater upward trend in deflated capital

formation than adjustment for price changes alone, as long as productivity per man-hour in the consumers' goods industries is increasing. Gross capital formation in constant values would show a steeper upward trend than our present measures do, and hence its share in national product in recent periods would be larger compared with the past.

3. Obsolescence in Measuring Capital Consumption

Obsolescence, as the term is used here, excludes any and all physical deterioration. So limited, it means a decline in the value of a capital good associated either with a change in the structure of tastes or with technical improvements that make newly produced capital goods more efficient than older capital goods used for exactly the same purposes. Both sources of obsolescence are likely to be important only in a progressive, developing economy: it is the interrelated technological and social changes that produce shifts in the structure of tastes (which apply largely to capital goods used by consumers) and yield ever new and more efficient tools (which apply largely to capital goods used by business and governments).

The question of whether an allowance for such obsolescence should be made at all, on a systematic and continuous basis, or as a single lump deduction when the good is withdrawn from use (as Denison proposes) should be considered in the light of information or reasonable inferences on their effects on current use of capital goods. Discussions at the National Bureau of Economic Research in connection with the present study of longer term trends in capital formation and financing and the stimulus of Denison's arguments lead me to go somewhat beyond the comments I made in *Studies in Income and Wealth, Volume Fourteen.*[1]

Because of changes in tastes, many older capital units lose value and are assigned lower weights than originally attached to them. For example, older houses shift to use by lower income groups, who may fully appreciate that they are paying less for what is even to them a less desirable good compared with the newer units which are better adjusted to prevailing preferences. In this connection we disregard groups whose tastes may differ but whose demand is too small to influence market values. If, then, in attempting to estimate capital formation in constant prices we adopt some recent base year with its specific structure of tastes, we should correct for a reduction in the value of older units due ex-

[1]National Bureau of Economic Research, 1951, pp. 65–68.

clusively to the shift from the structure of tastes that existed when they were produced. Shifts in tastes are not necessarily sudden; they may well reflect the gradual spread of tastes from the upper to the lower levels of the income pyramid. A consistent, gradual deduction for such obsolescence is probably the most effective crude approximation of the actual underlying processes.

In connection with the obsolescence of business and government productive equipment, a different factor must be stressed. If, with technical progress, new tools are produced that are more efficient than the existing ones, an entrepreneur may decide to use the old tools below capacity and purchase the new—even if it means underemployment of the old stock of capital. If an old tool can be used with a total cost of $1 per unit of product and a new tool with a total cost of only $0.5 per unit, it may pay a firm to purchase new equipment, use it at full capacity, and use the old tool at a much lower rate. For example, if 1,000 units are to be produced and each machine can turn out 500 units, purchase of a new machine may lower the average cost, although two old machines capable of turning out the full output are available. If the depreciation charge is $0.05 per unit for both the old and the new machines, the total depreciation charge would rise from $100 to $150, but the total cost would be reduced $250 (i.e. $0.50 multiplied by 500) by the full utilization of the third new machine. What is true of a single firm is even more applicable to a whole industry where new firms equipped with new machinery may be running at higher rates of capacity utilization than old firms with old machinery. In other words there is a direct functional connection between the degree of obsolescence and the rate of utilization of the durable capital goods. Thus, even if obsolescent machines *can* produce as much as they did originally and at the same costs, rational calculation will not permit them to do so. Even in considering government capital, we must allow for rational calculations to produce a difference in the rate of utilization between modern and obsolescent equipment. From the economic standpoint, non-use of existing capital stock is equivalent to its physical deterioration, i.e. less effective use because of physical wear and tear. Here again, since the process of obsolescence is gradual, mirroring the gradually cumulative effects of technical progress, a gradual, systematic deduction is the most acceptable practical approximation.

This discussion bears not only upon Denison's proposal but also upon the argument concerning the differences between depreciation and replacement in a progressive economy advanced in the recent

writings of Evsey Domar and Robert Eisner.[2] The wonderful one-horse-shay assumption implicit in their analysis corresponds to the notion that obsolescence is a single lump-sum phenomenon; that there is no gradual decline in service value reflected in a gradual decline in rates of utilization; and that replacement occurs only at the end of the full life of a capital item. We would urge that both withdrawal and replacement processes are gradual and that the use of relatively continuous functions to describe the capital consumption process is more realistic than the single lump-sum alternatives.

There is naturally some arbitrariness in assuming that obsolescence proceeds gradually, and particularly that it is *irreversible*. It is conceivable that a reversal could occur in the structure of tastes, not necessarily back to the original structure but a to closer approximation to it. If this happens, we may find that, again disregarding physical wear and tear, some capital goods which declined in value between times x and $x + n$ because of a major change in tastes, increased in value between times $x + n$ and $x + 2n$, because tastes shifted back closer to their structure at time x. How important such a phenomenon may be, one can only guess. In extreme form, it emerges in the case of antiques whose values are far higher today than they were in earlier times. But in disregarding such reversals we doubt that we do too much violence to the broad features of economic reality.

In the case of capital goods in the hands of business and governments, a similar qualification is introduced by situations in which rational calculations of the type suggested above are upset by extraordinary disturbances. In relatively "normal" times even monopolistic industries are subject to pressures generated by such calculations, if only because obsolescence may originate from competition via possible substitution by products of other industries, e.g. passenger cars or trucks for steam railroads. But in times of war, technical progress in production of the usual type of capital goods may cease because output is discontinued, and the suddenly increased demand may require maximum capacity utilization of both old and new items in the stock of capital goods. In other words obsolescence is temporarily suspended—perhaps only to return with increased force once the war and postwar reconversion are over. But this is only further evidence that any

[2]See Evsey D. Domar, "Depreciation, Replacement and Growth," *Economic Journal*, March 1953; and Robert Eisner, "Depreciation Allowances, Replacement Requirements and Growth," *American Economic Review*, December 1952.

rough and ready procedures we use in approximations can never provide an accurate measure of what happens in real life, and may even be misleading during periods marked by conditions that can be viewed as exceptional. Neither "sudden" obsolescence nor sudden "rejuvenation" can be covered in the customary measures of regular or systematic obsolescence.

4. *The Need for Further Analysis*

The judgments and inferences suggested in these comments are not in any sense final and conclusive. Their purpose is merely to emphasize that there are major problems in the field not easily resolved by the arguments Dension advances, and that further analysis and experimentation are required to assure that our empirical work does not stray from the analytical notions to the point where, by measuring what we can, we shall be getting results that are either equivocal or misleading in terms of what we want.

My general impression is that the measure of capital formation and consumption we have now are far removed from what we need for economic appraisal and analysis. Present measurement practices tend to understate capital formation in developed countries much more than they do in the underdeveloped, and to understate capital formation in recent (nonwar) periods in the advanced countries more than in earlier decades. This impression may be faulty, but it explains my emphasis on devoting further effort, at least in national income measurement proper, to experimentation that would use the available raw data to obtain closer approximations to the entities and processes with which economic theory and analysis are concerned.

MORRIS A. COPELAND, Cornell University

There is a definite connection between George O. May's paper and Edward F. Denison's. Both are concerned with the measurement of capital consumption in a way that will provide a reasonable income computation. May is interested in the financial statement for an individual concern, Denison in a statement for the whole economy. But both have concentrated mainly on the measurement of assets. However, May indicates that recent developments in income accounting should require a thorough overhauling of our conceptions of the balance sheet.

I do not suppose anyone would seriously support the implication that the balance sheet has become worthless. Obviously we need balance sheet information both for the individual enterprise and for

the whole economy. Indeed, in recent years there has been an increasing recognition of the need to develop a national balance sheet statement. We do not yet have our social accounting conventions and techniques fully worked out, so far as the national balance sheet is concerned. But clearly decisions regarding the way we measure capital consumption in our national income and product accounts involve commitments in respect to wealth valuations. I suggest that we investigate more fully what these commitments are before we get our social accounting conventions regarding capital consumption too firmly fixed.

REPLY BY MR. DENISON

Eric Schiff's comment clearly indicates the areas of his agreement or disagreement with my paper and states my position accurately, so that little further discussion is necessary. However, a brief comment seems desirable with respect to two points.

My position on obsolescence, it will be recalled, is that if in measuring gross capital formation quality change is handled by method 1, to be consistent obsolescence should be charged when a capital good is retired; if quality change is handled by method 3, obsolescence should be charged as it actually accrues; but in statistical practice neither is possible, and obsolescence can only be smoothed in by using average lives which are affected by obsolescence. Schiff does not quarrel with the logic of this position, but argues that it would be best on pragmatic grounds to accrue obsolescence, in line with a method-3 treatment, even if it were feasible to charge it at retirement and even though the estimates otherwise correspond to method 1. This seems reasonable only if existing estimates of capital formation can properly be used as if they did reflect quality change, and in his discussion of upward or downward biases in his obsolescence section Schiff seems to tend toward that position. In contrast, I think the quality change limitation sufficiently basic as to call for redefinition rather than mere qualification, and Schiff does not dispute this directly.

Second, Schiff favors introduction of the interest factor into the time pattern of depreciation, but does not come to grips with what seems to me the main issue—whether this would make estimates of net national product more or less meaningful. Hence it is difficult to respond to his criticism. However, his question—why should it be natural for the market to discount prospective values, and unnatural for the appraising statistician—raises a much broader question. Since the market discounts all future income flows, if it were proper to discount service values flowing from capital goods

why would it not be equally proper to discount not only depreciation but the whole national income, or, at the very least, all property income deriving from assets which have a market value? The answer, as I suggest in my paper, must be that we cannot look at the national income in a given year from the vantage point in time of some earlier year, but must consider each year's income from the viewpoint of that same year.

If the existence of interest raises any dilemma, it is that pointed up in my example: that both total income and profits (or pure profits) cannot remain constant with constant output, if the interest charge (or implicit interest) changes because net investment declines as capital ages. But the difficulty is not real. Interest, explicit or implicit, is indubitably a cost properly deductible in computing profit. But national income is not a measure of profit but of total cost, including both interest and profits. It is the latter, not profit alone, which should be constant if output is constant with no change in prices.

My response to Simon Kuznets' remarks will center upon his Section 2. With respect to the first point of this section, I simply note that I use the term "quality change" in the broadest sense and do not confine it to "changes in a still recognizable capital item which affect its productivity." However, his second point, which is intended as a criticism of the logic and consistency of my method 1, calls for a point by point reply. The discussion appears to indicate a partial misconception of what I mean by measuring capital at cost, although this is stated quite carefully in my discussion of method 1.

Kuznets first considers the case where twice as many identical capital goods can be produced in year 2 as in year 1, when the aggregate real cost in man-hours remains unchanged. He asks why, by method 1, I consider capital formation in the second year to be double that in the first. The answer is simply that the very essence of method 1 is to equate the value of capital goods by their production cost at a given date—the year in whose prices capital formation or the capital stock is expressed—not, as is specifically noted on page 227 of my paper, by some "real" cost at different dates. Since in this illustration the types of tools produced in years 1 and 2 are identical, their production cost at any given date must be identical and therefore one year-1 tool must represent the same output as one year-2 tool.

Kuznets next considers the case where 20 tools are produced in year 1 with 10,000 man-hours and 20 in year 2 with the same number

of man-hours, but the year-2 tools are of higher quality. This is insufficient information for a method-1 solution. We must further assume that the production cost of 20 of the lower-quality machine tools would be the same as that of 20 of the higher-quality tools if they were produced at the *same* time. Then, by method 1, 20 of the old tools represent the same quantity of capital as 20 of the new. There is no inconsistency between the two examples; the tools are equated by their relative production costs at a single date.

After a discussion of the way in which method 1 narrows the definition of capital formation and thus brings national income closer to Irving Fisher's consumption concept of income (my own views do not involve acceptance of Fisher's argument and are stated in the next to the last section of the paper) Kuznets comes to what he considers his most important point. Methods 1 and 3, he states, should yield identical results because "theoretically, the price entrepreneurs are willing to pay for a new capital item, i.e. the cost is equal to the capitalized value of returns". But all that his argument shows is that this is so in terms of current dollars at the date a tool is newly produced and sold. In other words a tool newly produced and sold for $10,000 is, in the prices of that date, worth $10,000 by either methods 1 or 3. This is of course true, and is the reason that in the example shown in my Table 1, which is stated in year-1 prices, one entry for year 1 serves for all three methods. But as soon as the value of a capital good is expressed in the prices of a year other than that in which it is actually produced and sold, as the capital goods of year 2 are expressed in year-1 prices in the example, and as is necessary in measuring gross capital formation in constant dollars, and capital consumption, net capital formation, or the stock of capital in either current or constant dollars, the different methods give different results. Today's cost of producing *any* type of capital good which has been produced in the past but is not produced today is different from the price at which it could be sold and which Kuznets takes as measuring the capitalized value of the future contribution it could make to production. The cost must, indeed, *exceed* the price at which it could be sold or it *would* be produced. If anyone doubts that the difference is substantial, let him consider whether the cost at today's prices of reproducing in identical form the nation's present stock of capital goods would be the same as the cost of producing a stock of capital goods of the most efficient types, geared to today's demand patterns, which could make an equal contribution to the value of production. Method 1 implies the former as a wealth estimate, method 3 the latter. In a

progressive economy, the current dollar value of the capital stock and of capital consumption must always be higher, and that of net capital formation lower, by method 1 than by method 3.

The idea of measuring capital formation in terms of consumption foregone, which Kuznets next raises, is an interesting one, which I relegated to footnote 13 only because it seems to me more a special-purpose measure than one suitable for national product measurement. What is not clear from Kuznets' discussion is why it is necessary, in deflating by this method, to go through the intricate processes of manipulating man-hour data which he proposes instead of directly deflating capital goods by a price index for consumption goods, which yields the same answer much more easily. Whichever technique is used, a basic objection to the procedure *as a solution for the quality change problem*, for which Kuznets proposes it, is that, as noted in my paper, price indexes for consumer goods do not appear to catch most quality improvement not associated with corresponding cost changes. The procedure, therefore, would not bring capital formation estimates much closer than they now are to a method-3 solution. It may also be true that quality change, not involving comparable changes in cost, is less rapid in consumers' goods than in producers' goods, which would prevent the method from accomplishing Kuznets' purpose, even if consumers' price indexes did catch such quality changes. Thus the device Kuznets proposes would be at best statistically arbitrary, a solution by assumption.

Kuznets' expression of views in Parts 1 and 3 of his comment are welcome supplements to his previous expressions of views on the subjects covered. His strong endorsement of my position that available estimates of capital formation are far removed from those which economic theory (as expressed by method 3) would require should be underlined; this seems not to be questioned by any of the participants. It is therefore the more surprising to find such a strong reaction to an attempt to define what these estimates actually do measure, and to describe them accordingly. Kuznets' references, in this connection, to other series we should like to measure, but cannot, seem hardly pertinent. For example it is true that we should like to have a measure of the return for all labor entering into production, whatever form it may take, but we do not pretend that the compensation of employees is such a measure. Instead we sensibly define it as the compensation of persons working for wages and salaries. Insofar as disagreement with my position is expressed by Kuznets' other comments, I am content to let my paper speak for itself.