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Concepts of Real Capital Stocks and Services

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THE measurement of productivity is one of the major purposes for which real capital stocks and services data are developed. The very concept of productivity implies that the contribution to output that a factor makes can differ for reasons other than differences in the quantity of that factor. The separation of such influences from quantity changes requires the development of indexes of factor inputs in quantity terms, which can be studied in relation to changes in output also expressed in quantity terms. This paper will consider the concept of capital in this context.

But the requirements of other uses of concepts of capital stock and services must not be overlooked. In the first place, the measurement of output in real terms requires a determination of the quantity of capital produced. Capital formation not only provides for future input into the economic system; it is also a major component of gross national product and national income, and valid output indexes for the economy as a whole cannot be obtained without considering the method of measurement of the capital produced in different periods. Second, there are some purposes for which a measurement of real capital stocks and services is needed that is based upon the concept of capacity to produce. In the comparison of two different economies, for example, steel capacity may be a good indicator of the relative amount of real capital available in the two countries for the production of steel. For individual industries within countries, also, changes in capacity and in the utilization of capacity provide information relevant to questions of output, employment and investment decisions. And for the guidance of governments spending for social capital, a much wider concept of this sort is needed. Finally, the effort to obtain data in constant prices should not blind us to the large number of uses for which constant price data are not relevant. In the analysis of the flow of funds, the financing of capital formation and decisions with respect to investment, the amortizations and revaluations engaged in by business are the realities of the situation. Deflation or other adjustments aimed at deriving "real" data may obscure relationships which have an important bearing on decision-making in the economy.

The Quantity of Capital as a Concept for Productivity Measurement

The concepts involved in measuring the efficiency of capital as a factor of production can be traced back to the basic notions underlying the theory of the production function. In the simplest case, the process is quite straightforward. For example, land, one form of capital, is considered to be one factor of production, labor another factor, and output the result of efficient combinations of varying quantities of these factors. Such a textbook presentation assumes a given state of technical knowledge and constant qualities of land and a constant quality of labor. No time period is involved, and both factors can be measured in physical units. Land can be measured in acres and labor in man-hours. Such a production function can illustrate the principle of diminishing returns as one factor is increased and the other is held constant. It can also be used to determine whether there are constant returns to scale. There are no ambiguities in any of these concepts.

The introduction of differing qualities of a factor does not complicate the problem very much if quantity is measurable along with quality, and an unambiguous transformation of quality differences into quantity differences is possible. Thus if one piece of land is twice as good as another under all circumstances, the analyst can still study the relationship between land and output with varying amounts of labor. He has a choice of two procedures. Land can be expressed either on a straight acreage basis, or in terms of its equivalent in acreage of a constant quality. In the first case, its varying quality will influence the capital-output ratios derived, but for many problems it is precisely this relationship which the analyst wants to study. The second case can also yield interesting results. It does not necessarily preclude productivity change, nor does it necessarily imply constant returns to scale, any more than the initial example cited.

Unfortunately, an unambiguous translation of quality into quantity is not always possible. It is more likely that as differing intensities of labor are applied to two pieces of land of different quality, different ratios of relative output will emerge. In other words, the marginal rate of substitution of one kind of land for the other is different with different quantities of labor. This general point is raised by both Joan Robinson and R. M. Solow in their discussions of production functions and the measurement of capital.[1] This presents the first so-called

[1] Joan Robinson, "The Production Function and the Theory of Capital," *The Review of Economic Studies*, No. 55, p. 95. R. M. Solow, "The Production Function and the Theory of Capital," *The Review of Economic Studies*, No. 61, p. 101.

index number problem in the measurement of capital. If we try to include quality differences in the measurement of the quantity of capital we are saying that the quantity of a given item depends not only on the item itself but also on how much labor is used with it. Thus the scale by which capital is measured shifts at different points on the production function.

But our problems have just begun. In this simple example no passage of time has been allowed, and thus no technical changes can take place. Also, we still have available a physical measure of the quantity of capital. Since the concept of a physical measure of capital simplifies the analysis so much, economists naturally try to extend it as far as possible. Thus when they turn from the discussion of land to capital goods they tend to talk about identical machines which can be used in different quantities. Such a framework, however, cannot provide a satisfactory conceptual basis for capital measurement where physical measurement is not possible or where different kinds of capital are expressed in different physical units. The only recourse in these circumstances is to measure capital in some sort of comparable unit in the same way we measure output—in value terms.[2]

Given this sort of measurement, and still staying within a single time period, there are again two alternatives. First, we can measure capital in terms of input costs. This would mean that an item which costs twice as much to produce as another item is twice as much capital. In terms of the allocation of resources this might be satisfactory, but it leaves one incongruous result. It assumes that in the production of capital there are constant returns to scale, and in some cases this is at variance with common sense reasoning on the basis of physical units. For example, if two pipelines of a given diameter were laid together over a desert, the cost would be less than twice that of installing a single pipeline, due to the economies achieved by putting them in simultaneously. Thus, measured in cost terms the two pipelines are not twice as much capital as one pipeline, even though they function identically. The question here is whether economies in the production of capital goods should reduce the output of capital. Solely for the purpose of analyzing capital as an input, however, the cost basis of measurement would seem to be internally consistent. The second alternative would be to base the measurement of capital on its ability to produce, i.e., either on output or on capacity. But this method also involves problems. An index-number question arises if the marginal rates of substitution between different kinds of capital are different in the periods being compared. Furthermore—and this more seriously impairs the usefulness of this measure for the study of

[2] This point is taken up by Boulding in his paper for this conference.

efficiency—since actual capacity or output is used as the measure of quantity, there can never be any change in the productivity of capital. Whereas the first of these alternatives attributes all increase in efficiency to the change in the productivity of capital itself, the second goes to the opposite extreme, attributing the increased efficiency to the greater economy with which capital can be produced.

By introducing time (i.e., technical changes and changes in prices), additional problems are raised. It is commonly held that technical change in the design of capital equipment should not be incorporated into the measurement of the quantity of capital, since this again would be attributing all quality change to changes in the efficiency of producing capital, leading to a productivity index in the use of capital always equal to unity. But it is extremely difficult and often unrealistic to abstract from technical change, unless one goes all the way in the other direction, as in the first of the two alternatives in the preceding paragraph. Although it may be possible to estimate what the capital stock of 1900 would cost in today's prices if the techniques, labor skills, and materials of today were used to produce replicas of the buildings and machines of 1900, the reverse is not possible. The techniques, labor skills, and materials of 1900 could not produce perfect replicas of today's plant and equipment, since the necessary technical knowledge and equipment would be missing. Thus even though the problem can be stated in index-number terms it cannot really be solved in these terms, since comparisons can only be made in one direction. In order to get around this difficulty, it has been suggested that standard labor units expressed in terms of product be used to evaluate the cost of the capital stock in each period.[3] But this leads to the anomaly that two identical plants would be assigned different capital values if they were produced at different times, although at one moment of time they would have the same cost and the same capabilities.[4]

There does not seem to be any satisfactory general solution to this problem. The basic fact is that capital in general has no physical units, and any arbitrary solution will predetermine the answers. It will therefore be useful to examine the measurements of real capital stock that are currently being made or proposed to see what assumptions they involve, and how these assumptions affect the analysis which is based upon these figures.

[3] Robinson, *op. cit.* p. 86.
[4] Solow, *op. cit.*, p. 101.

The Rationale of Existing Measurements of Real Capital Stock

In a very stimulating paper presented at the 1953 Conference on Income and Wealth, Edward Denison set forth three possible methods of measuring capital.[5] The first measures capital by cost. The second measures it by the capacity of the system as a whole to produce output. The third measures it by the contribution which the capital specifically makes to total production. Denison strongly favors the first method. He feels that the second, which makes the stock of capital proportional to total output, is essentially uninteresting, although it might be feasible statistically if certain arbitrary conventions were adopted. The third method, which involves evaluating the contribution to production of each kind of capital good, he believes to be completely beyond any hope of accurate independent measurement. Furthermore, as has already been suggested, method 3 would necessarily lead to an unchanging productivity of capital. Thus Denison settles on the first method, which corresponds fairly well to the current practice of the Department of Commerce in measuring gross capital formation in constant prices.

Even the valuation of capital at cost, however, is not simple and straightforward. If the price of producing capital goods did not change over a period of years, the gross addition to the capital stock in any year would be equal to the value of gross capital formation in that year. Unfortunately, however, the price of producing capital goods does change, so a price index for capital goods is needed to deflate the current price data. It is in arriving at appropriate price deflators that the most difficult conceptual problems of this method become apparent.[6] Although Denison wishes to exclude from his index of the output of capital those quality changes in capital goods arising from such things as improvements in design and serviceability, he does not wish to exclude changes in productivity in the production of capital goods. Thus even though a machine can be produced in period 2 at half the price of the identical machine in period 1, the amount of capital represented by the machine should be the same in both periods. The price index for capital goods, therefore, should not be simply a weighted index of the prices of the inputs used to produce them. In practice this may be done in some areas (notably

[5] "Theoretical Aspects of Quality Change, Capital Consumption, and Net Capital Formation," in *Problems of Capital Formation*, Studies in Income and Wealth, Vol. 19, pp. 215–61.

[6] The problem is somewhat similar to that which would be involved in determining changes in quantities of labor used, given only wage bills in current prices and no direct knowledge of wage rates, man-hours, or employment.

construction, where the price deflator is a weighted index of labor and materials costs), but Denison considers this an unfortunate defect since the deflated data obscure the productivity changes that occur within the construction industry.

The crucial problem is the separation of design improvements from changes in the cost of production; that is, increases in productivity of capital goods from increases in productivity in the production of capital goods. Design improvement in capital equipment often occurs through simplification. Welding may take the place of riveting, plastic parts may be substituted for metal, or stampings may be used instead of machined parts. Whether these are in fact identical machines (to be counted as the same amount of capital) or different machines (to be counted as more or less capital) can only be determined on the basis of function. If with such changes the machine serves the same function, Denison would probably consider any associated cost changes to relate to the production of capital; i.e., the price index would change but the quantity of capital produced would not. On the other hand, if an increase in the cost of producing the machine were accompanied by improved functioning of the machine, Denison would allow these increased costs to be counted as increased capital because of changed technical specifications. In this case, the machine would be considered a different one representing more capital, and the price index for producing capital might remain unchanged.

The most ambiguous problem arises in a situation where changes in the design of a machine both reduce its cost and improve its functioning. One is then faced with two alternatives: (1) the cost of producing the machine has fallen, but the quantity of capital is unchanged, or (2) the cost is unchanged but the machine is now a different one that represents less capital. Thus if there is any change in the functioning of the machine, we are forced to decide whether or not it is still the same machine. This decision in turn determines the behavior of the price index for capital, and this in turn determines the measure of the quantity of capital produced. Resort to important physical or performance specifications cannot avoid the consideration of function, since it is this that determines what specifications are important. In fact, since specification changes are basically changes in quality—which we wish to exclude from our measure of the quantity of capital—strictly speaking even the most minor changes should require that the machine be treated as a different machine. Pushed to its logical end, this argument leads to the measurement of price behavior by prices of input factors, rather than prices of units of capital output. In practice, this has happened in the construction industry; the problem of identifying units of output has proved so

difficult that an output price index is recognized as unsatisfactory, and estimates of construction prices are based upon input prices instead.[7]

It should be noted that the index-number problem arising from cost-reducing technical change is different from the normal index-number problem; the latter would exist even in absence of technical change in the cost of producing capital. The problem arises because, although we might now be able to reproduce exactly the products made in 1900, the reverse is not true. The valuation of the capital stock in 1958 as if it could have been produced in 1900 therefore necessarily involves the assumption that price indexes for the cost of capital based on those particular capital goods that are present in unchanged form in both 1900 and 1958 are representative for products which did change.[8] This assumption is of course quite likely to be invalid, because the newly introduced capital goods tend to be those for which the cost of production has fallen fastest. The price index based on 1900 would therefore be relatively too high, and the resulting quantity of capital too low. Similarly, taking 1958 as a base, goods which have disappeared since 1900 tend to be ones for which production costs did not fall as fast as for the new capital goods which supplanted them. Thus, while the index using 1958 as base year may be very different from that based on 1900, it too will minimize the increase in the efficiency of making capital goods.

A further consequence, as Denison points out, of adherence to the cost concept for measuring capital goods is that the principles of valuation that would be used for the output of capital goods are different from those commonly used for consumer goods. In measuring the volume of consumer goods we attempt, at least in theory, to include quality change as a part of output, where this measure of capital output tries to exclude it. Denison, however, is inclined to minimize the importance of this consideration. He suggests that quality change excluded from the measurement of capital goods will

[7] Although it is possible to ask what it would cost to construct some standard structure, this would bias the price index in several ways. First, different indexes of change would be obtained for different standard structures; the cost of building an 1890 Victorian house would have changed differently from that of a simple colonial house. Second, as long as construction methods are different there will be differences in supposedly identical structures, and the importance of these differences can only be evaluated in terms of function. For instance, handmade trim for houses differs from machine-milled trim in significant detail. If one asks how much it would cost, given the technology of 1900, to produce trim with the same specifications as today's machine-milled trim, the cost of obtaining the same degree of regularity, in terms of man-hours, might be exorbitant. It would only be because regularity is not considered a very important aspect of the function of house trim that one could consider machine-milled trim and handmade trim the same thing.

[8] The use of chained indexes, etc., would perhaps diminish the statistical magnitude of this problem, but it could not eliminate it.

eventually show up as additional production of consumer goods, and that as long as changes in the quality of other factors of production cannot be taken into account, neglecting such changes in measuring the output of capital goods scarcely seems a critical weakening of the income estimates. For the purpose of the measurement of efficiency, there is a good deal of merit in this argument, but, as will be pointed out below, the qualification becomes more important when we consider other uses to which these estimates of capital stock are put.

A final problem in the interpretation arises in estimating the net value of the capital stock. The measurement of the capital stock not only requires valuation of newly produced capital goods; it also requires consideration of what has happened to the existing stock of capital. Denison would value capital consumption at base year cost for the particular types of capital goods used up. He argues that obsolescence should be charged at the time the capital good is discarded, and that it should be handled as a deduction from gross capital formation rather than as an addition to capital consumption. His rationale is that "net capital formation"—the net improvement in the capital position of the economy—should be equal to the difference between (1) the contribution to production by the new good (as measured by its cost of production), and (2) the contribution which could have been made by the displaced capital good (as measured by the obsolescence charge).

On the other hand, a different treatment has been proposed by John Kendrick. He suggests:

> ". . . as nonpermanent assets age, their contribution to net output declines; this is the result of declining gross output capacity, increasing maintenance and repair costs, and creeping obsolescence. Obsolescence results in the reduction in the rate of return on old equipment, not only when the installation of new equipment leads to reduced product prices or higher factor prices, but also when the old equipment is utilized less intensively or in less productive activities. Empirical and theoretical considerations suggest that these effects may be assumed to occur gradually over the lifetime of groups of capital equipment."[9]

It might be questioned, however, whether such considerations are relevant to the concept of capital discussed here. In view of the decision to exclude productivity improvement (i.e., increase in efficiency) from additions to the capital stock, it seems incongruous

[9] John W. Kendrick, "Productivity Trends: Capital and Labor," *Review of Economics and Statistics*, August 1956, p. 250.

that decreases in the efficiency of existing capital due to aging should be so carefully taken into account. Just as there is logic in saying that improved design of capital good is not more capital but an increase in its efficiency, so also it is perfectly reasonable to say that the efficiency of capital varies with its age, and that deductions from the quantity of capital to make the productivity of existing capital a constant over its life are not consistent with the desired concept.

Furthermore, as Kendrick implies by his inclusion of "creeping obsolescence," the ordinary capital consumption allowance would considerably exceed the actual physical deterioration in a capital good over its useful life. Charging such obsolescence against existing capital is allowing for quality changes that have not occurred but are only expected to—those resulting from changes in the technical design of capital goods to be produced in the future. The same technical change that improves the quality of new capital will make the old obsolete. Kendrick's treatment of additions to the capital stock does not count the quality increase due to technical changes in new equipment, but it does take into account the reduction in the relative quality of the existing capital stock because of the increased technical efficiency of new capital equipment which could be constructed. Again, therefore, the treatment of new and old capital does not seem to be parallel.

A more consistent treatment would seem to require that if efficiency increases are to be eliminated from the measurement of the capital stock, efficiency decreases must also be eliminated. Capital should not be deducted from the total stock until its retirement, despite the fact that producers may, for financial reasons and in order to derive a meaningful profit figure, amortize it over its life. This procedure would carry Denison's method 1 a little farther, deriving net investment in each period as gross investment minus discards. Such a concept was used by Evsey Domar in discussing a model relating changes in capital to changes in capacity.[10]

To summarize, conventional measures of real capital favor a concept based on the cost of production rather than on capacity, partly because of ease of measurement and partly because one of the major purposes of developing real capital data is the analysis of productivity changes. "Cost," in these terms, is not simply the deflated value of the inputs; it is not intended that increased efficiency in the production of capital should reduce the amount of capital produced. This means that changes in the cost of producing capital must be analytically and statistically separated from changes in the efficiency

[10] "Depreciation, Replacement, and Growth," *Economic Journal*, March 1953, pp. 1–32.

of utilization of capital. Such a separation, however, requires a physically measurable unit of capital, and this in turn cannot be established without a consideration of the quality and function of capital equipment. Any attempt to separate quantity and quality without considering function is doomed to be arbitrary and subjective. It would perhaps be possible to derive a real capital measurement independently in terms of the quantity of input factors (labor, resources, and savings), but this approach does not appear to have much support.

Time and technical change also create problems in the interpretation of the conventional measures of real capital stock. The thesis that real capital can be measured by what it would cost in the base year to produce the given year's stock is not meaningful if technical changes make the comparison an impossibility. If the most recent year is chosen as the base year, the comparison may be possible, but this may also produce a trivial and uninteresting measurement. Finally, in evaluating the *net* capital stock, one may question the practice of deducting a capital consumption allowance before a capital good is actually retired from service. Such an allowance is in fact an attempt to measure the decrease in the quality of the equipment, whether from physical deterioration or from potential technical obsolescence. Such changes in quality are intended to be excluded from this concept of the quantity of capital.

The Use of Capital Stock Measurements

Despite these theoretical objections, one cannot help being impressed by the intrinsic interest of the real capital stock series that are obtained by the usual cost deflation procedures. For example, the capital-output ratios for manufacturing from 1880 to 1948 as given in Creamer's study are most illuminating and give rise to a number of hypotheses.[11] One may reasonably ask why these results are so interesting if their theoretical structure is built on such shifting sands. In part the answer may be given by Creamer's effective demonstration that a number of variants of measures of capital and output yield the same general conclusion as to the pattern of change in capital-output ratios over the years. Creamer points out, for example, that the pattern of change of the capital-output ratios derived by measuring both capital and output in constant prices does not differ very significantly from that for capital and output expressed in the current prices of each period separately. This result would be expected if the

[11] Daniel Creamer, *Capital and Output Trends in Manufacturing Industries, 1880–1948*, NBER, Occasional Paper No. 41, 1954.

price index used to deflate capital did not differ substantially from the price index used to deflate output. Relative to the other changes that occurred during the period, these differences in the price indexes were, in fact, rather small.

Some of the alternative measures discussed above might well yield quite different patterns of change. One cannot say how the ratio of capital to output would be affected in these instances. If the price deflator for capital had been based on the price indexes of input factors alone, not allowing for the change in efficiency in the production of capital, the price deflator would have been raised and thus gross capital formation over time lowered. On the other hand, deduction of retirements instead of an allowance for depreciation and obsolescence would probably increase the volume of the capital stock. If quality changes in consumer goods and perhaps capital goods were reflected more fully, output would have been larger throughout the period. The net effect on the pattern of change of the capital-output ratio is highly debatable. Capital-output ratios measured this way would not necessarily be more meaningful than Creamer's, but they might be less arbitrary and more internally consistent.

Furthermore, capital-output ratios based on current price data may also be quite meaningful, because they measure the capacity of the economy to produce in relation to its current efforts. An economy with a small capital-output ratio in this sense could turn out the equivalent of its capital stock in a brief space of time, whereas one with a high capital-output ratio would take many years to build up the capacity needed for the current level of output. By studying current relationships, the difficult problem of price deflation could be avoided. Most dynamic problems concerning capital and capital formation, furthermore, can more usefully be cast in current than in constant prices, since it is the actual flows of income and values in the various periods which are related in a time dimension.

Thus before we attempt to solve the problem of measuring real capital, we should face the question of how to measure capital stock at a given moment in the prices of a single period. This is not nearly as perplexing as the measurement of capital over time, since many of the index-number problems are absent. It is still true that a concept of capital that will be useful in the analysis of efficiency should probably not be measured in terms of capacity. Nevertheless, it would be useful to know what it would cost, given existing technology and capacity, to reproduce the *function* of the various capital goods existing in the economy. This does not require that products of another period be reproduced in their exact technological form, but rather

brings into play the concepts of capacity, function, and substitutability. In a normally competitive economy, this reproduction cost of capital goods (in terms of economic function) would approximate market value, so that we could also ask how a given increment in the volume of capital, valued at the cost of production, would affect annual rates of output. The relationship between the stock of capital thus measured, in current prices, and the current output or income of the economy in various periods would be somewhat similar to Creamer's measurements in current prices. Thus changes in capital-output ratios over time could be calculated without the use of indexes of the quantity of capital or of output.

The Measurement of the Real Services of Capital

In the analysis of questions relating to the efficiency of capital, it is of course the services of the capital stock rather than the capital stock itself with which we are really concerned. Many analysts, however, use capital stock data, on the ground that, although the measurement of real capital stock is open to question, the measurement of the real services of capital is even more difficult. As Denison points out, in measuring real capital services, production cost is not available as a principle of valuation.[12] One is forced to evaluate capital consumption in terms of the ability of capital goods to contribute to production in the future. For this reason it seems necessary here also, before evaluating real capital services, to consider how the services of capital can be valued in current prices.

When a producer purchases a capital good he expects to use it over a given period. At the end of its useful life he expects that it will have repaid in services at least its original purchase price. The apportionment of the cost over this useful life is a matter for philosophers and revenue agents. It may be argued, for instance, that the machine should be charged off in a manner which would equalize profit over the period, given no unexpected changes in prices, demand, or costs. It is on this basis that peak load facilities of power plants and local transit systems are charged off against their period of use. Alternatively, it may be argued that the services of equipment are greater in its early life when it needs less repairs and maintenance and is utilized more fully. The essential consideration, in either case, is that expected returns be separated from unexpected returns in order to differentiate between operating income and capital gain or loss. If a plant burns down this should be a capital loss, and not a charge against the operating income of the plant in the year it happens. Similarly,

[12] Denison, *op. cit.*, p. 241.

unexpected obsolescence, or unexpected capital gain in monetary terms due to general price level rises, should be excluded from current services of capital and reflected instead as capital gain or loss. The services of capital thus should be valued (in current price terms) not in terms of original or historical cost but rather in terms of replacement cost, and the difference between historical cost and replacement cost should be considered capital gain or loss.

A problem does arise in relation to gains arising from expected price level changes, but even here it seems reasonable to distinguish operating income from the gain or loss arising from the producer's dealing in assets and liabilities. We follow this practice in national income statistics in adjusting the income concepts for inventory price changes, and it seems reasonable to make a similar adjustment with regard to capital consumption allowances.[13]

The problem of converting capital services in current prices to capital services in constant prices is not simple. The same dilemma in the construction of a price index faces us here as in the measurement of real capital stock. To include all quality changes as changes in the quantity of capital is to make the resulting index meaningless for the measurement of productive efficiency. On the other hand, the attempt to eliminate those quality changes due to the technical design of capital and to retain those due to changes in the efficiency of production of capital and in its economic usefulness leads to serious difficulties. Of course, if the index for deflating capital services is about equal to the GNP deflator (as seems to be the case in the actual calculations) the relationship between capital services and output in constant prices will be the same as that in the current price data. The results of such a calculation, therefore, may not be meaningless, but what they will reflect will be the relationships in the current price data.

Capital Goods Production as a Component of Output

In recent years the gross national product has steadily increased in favor as a measure of total output, and gross capital formation is a major component of GNP. In the valuation of capital formation as a component of output, certain problems arise in addition to those considered above.

Thus far in the discussion, we have considered only those forms of capital which have market value, and have been content to consider social capital in general as part of the setting within which

[13] See, for example, *The National Economic Accounts of the United States*. Hearings before the Subcommittee on Economic Statistics of the Joint Economic Committee, October 29 and 30, 1957, especially pp. 189–93,. 153, and appendix tables A-1, A-11, and A-13.

self-liquidating capital is placed. It has long been argued, however, that certain government expenditures are of the nature of capital, and should be included in any general measure of capital formation. Such a procedure would result in (a) shifting some items from current government expenditures to gross capital formation, and (b) including the services of government capital on the expenditure side as part of product and on the income side as an addition to capital consumption allowances.[14]

In the most obvious case, where government enterprises sell their products on the market, such arguments are very persuasive; the form of industrial organization should make no difference in computing gross capital formation. In these cases the government has produced an asset which, like privately held assets, yields a stream of money income for future periods, and the parallel with the private producer is complete. The government may make a loss in the operation of the enterprise, but this situation is no different from the case where the government subsidizes a private industry. The extension of the argument to non-self-liquidating expenditures of the government on hard goods (i.e., goods made of wood, steel, or concrete) is less clear, however. This procedure would include roads and other public works as gross capital formation. To the extent that such assets are in fact directly revenue producing (other than by taxes) and it can be determined whether or not they are paying for themselves, such a procedure is legitimate. Thus toll roads might well be considered part of gross capital formation. Government buildings also could be set up as a sort of government enterprise, charging each agency rent at appropriate market values for the space it occupies, thus treating government buildings much in the same way that owner-occupied housing is. This has, in fact, often been suggested as a desirable budgetary reform.

On the other hand, the argument is much less clear for other government expenditures on durable goods. There seems little reason to treat non-self-liquidating roads and public works differently from government expenditures on research, education, and public health, all of which also improve the amount of social capital available in the economy. The fact that an expenditure is embodied in physically durable materials is not really relevant, and there would be considerable disadvantage in trying to develop a concept of government capital formation which covered all improvements in social capital, since this is a question not of objective fact but of political philosophy.

[14] It can be argued alternatively, with respect to government enterprises but not to general government, that the services of government enterprise capital goods should not be added to the market value of output but, instead, the surplus of government enterprises should be reduced by the amount of capital consumption taking place.

Expenditures by business on research and development, unlike those by government, are treated in the national income statistics as intermediate products, and so do not add to final product. Such expenditures are becoming increasingly important in changing the setting within which the economy operates, and they are not fully reflected in the changing market value of assets which are counted in output. It would seem highly desirable, therefore, to include research and development in the list of final expenditures on goods and services, even if we exclude it from the concept of gross capital formation. It could, for instance, be carried as a separate item of current expenditure.

Another serious omission from the list of final expenditures is the amount which producers spend on current account for the repair and maintenance of existing capital stock. If these expenditures were constant or were proportional to output this omission would not be serious, but in fact they vary considerably over time. When producers are making high profits they often take that opportunity to refurbish their plant and equipment. Conversely, in periods when they are having difficulty in paying dividends or even in meeting payrolls, they may postpone maintenance and repair expenditures. In the housing industry this cyclical fluctuation in repair and maintenance is well known. By omitting changes in repair and maintenance from our measure of gross production we may be neglecting something that is just as important as changes in inventories. Overmaintenance unquestionably adds to the value of the capital stock, and undermaintenance reduces it.

In view of the importance of these two elements—research and development expenditures and repair and maintenance expenditures —serious consideration might be given to the development of a grosser concept of total output than we now have. This need not mean altering the present concept of GNP, but perhaps we could include information on research and development and repair and maintenance in a grosser concept of output which we might term "gross national expenditure."

In deriving indexes of real output of capital from the measure of output in current prices (however the latter is defined), many of the problems of deflation considered above are still relevant. If we adopt the solution proposed by Denison, changes in the quality of capital goods would be excluded from output. Output of capital goods would therefore be measured quite differently from that of consumer goods. If we are trying in measuring output to approach some sort of welfare index, it seems reasonable to argue that the well-being of a nation is related to its ability to sustain or raise its standard of living in the

future, and that omitting the quality change in a nation's productive facilities drastically understates its real progress in this respect. Especially in the case of underdeveloped countries, where a great deal of effort is being put into developing productive capacity, a measure which grossly understates the change in this dimension does considerable violence to the basic purposes of the measurement.

As a final point in the discussion of capital as a component of output, consideration must be given to the derivation of net, as opposed to gross, product. The concept of net product is commonly assumed to be based upon the principle of keeping capital in some sense intact. But there are ambiguities in this concept too. In the first place, if real capital is measured by the cost method, the conventional concept of keeping capital intact is inapplicable. However, as Denison points out, from many points of view the concept of net product remains interesting and meaningful. Second, if, as suggested above, we extend the concept of gross investment to include repair and upkeep, it is necessary to consider the various levels of both maintenance and replacement required to maintain productive efficiency. But there is no unique level that will "maintain capital intact." Finally, a concept of real capital which includes reductions in the relative quality of existing capital (obsolescence) but does not include increases in the quality of additions to capital does not appear to be internally consistent. As Domar has pointed out, our concept of net capital formation as it has conventionally been handled assumes that depreciation equals replacement, and to the extent that this is not true models based upon such a thesis may not be fully relevant to the questions they are designed to answer.[15]

Capital and the Measurement of Capacity

Denison rejected his method 2—measuring capital by capacity—not only because it made the concept of productivity of capital tautological but also because it posed serious problems of measurement. There are many circumstances, however, in which capacity is an extremely useful tool of analysis. Industry studies have long worried about capital coefficients, asking what amount of capital would be required, with existing technology, to obtain a given increase in capacity. Such studies are important for problems of economic development and for developing the capital portion of input-output matrixes. They are also useful in analyzing the effect of a change in demand for specific products on the capital goods industries. For growth models, also, capacity measurements are extremely important

[15] *Op. cit.*, footnote 10.

since such models involve an estimation of the impact of an increment of saving and investment on the future stream of income, saving, and investment. Recently, capacity measurements have also been used in analyzing short-run fluctuations in income and employment. The underutilization of capacity for the economy as a whole has serious repercussions on the level of investment, which in turn affects the level of income and employment. Both private and government agencies are now engaged in making capacity estimates for various parts of the economy, and in view of the obvious usefulness of capacity as a basic concept in economics, it does not seem reasonable to suggest that efforts to obtain better capacity figures should be abandoned.

This does not, of course, mean that changes in capacity can be identified directly with what we have considered to be capital formation in this paper. Changes in capacity also can result from such things as research and development expenditures, government expenditures on education and health, and other expenditures which may carry with them a social product conducive to quality improvement.

Financial Flows and Integrated Economic Accounting

Before concluding this discussion, attention should be drawn once again to the desirability, in any measure of capital stocks and services, of maintaining consistency and comparability with other forms of economic accounting. In studying the financing of capital formation, for instance, it would be useful if capital formation were measured in such a way that it could be assigned directly to decision-making units and financing institutions, so that financial flows and real output could be related to one another empirically as well as theoretically. There are no serious conceptual problems standing in the way of such an integration. The measurement of the capital stock could very well be embodied in the national balance sheets developed for various institutional sectors of the economy. These balance sheets in order to be useful in studying financial flows, must of necessity extend beyond the concept of national wealth (the capital stock), embracing in addition the financial assets and liabilities held by each sector, but this poses no special problems of integration. The objective of valuing capital in current prices set forth above could be met simultaneously with the maintenance of a record of actual historical financial flows, by carrying assets on each of the balance sheets at market value but showing in addition both realized and unrealized capital gains and losses.

COMMENT

EVSEY D. DOMAR, Massachusetts Institute of Technology

My strongest reactions to the Ruggleses' paper were feelings of relief for having been spared myself, and of gratitude to them (if a paper on this subject had to be written) for having done the job. For the Ruggleses' theory of capital measurement grew in soil where harvests, at least in recent years, have been meager in relation to the effort and ability of the workers.[1] An attempt to work out the definition of the capital stock in general seems to me hopeless. But several useful definitions can be designed, each to fit a particular problem.

This conclusion is reached sooner or later in most aggregations of heterogeneous items. If we were satisfied with a microstudy of industrial processes, engineering specifications would be required of the various pieces of participating capital (including their age, condition, etc.) but not with their aggregate value in real or money terms, at original or replacement cost. But so much disaggregation might overwhelm even the most microminded economist.

As an object for aggregation, capital possesses several particularly nasty attributes:

1. Longevity, so that aggregation involves items of different vintage, bought at different prices and produced under different technological conditions.

2. Impermanency, hence the depreciation and replacement problems.

3. Technological change, both in its production and in the quality of the finished product. The second attribute is particularly important because new capital is a major source of technological change in industries where it is an input.

4. Future income. This affects both its cost of production and, of course, its present value.

5. A limited secondhand market (most examples usually consist of automobiles, trucks, and farm machinery) with an unhealthy fondness for brand-new items. Evaluation of the existing stock of capital is therefore of limited use.

But why bemoan the defects of capital? Labor also possesses longevity but not permanency, and is also subject to depreciation (as

[1] This is true even of the fine paper given by Edward F. Denison on "Theoretical Aspects of Quality Change, Capital Consumption, and Net Capital Formation," given at this Conference five years ago (Volume Nineteen, pp. 215–61), and also of Joan Robinson's *The Accumulation of Capital* (London, 1956), and a paper by J. R. Hicks on "The Relation Between the Measurement of Capital and the Measurement of Other Economic Aggregates" delivered at a meeting of the International Economic Association in Corfu, Greece, September 4–11, 1958.

shown by the life cycle of earnings in various occupations) and retirement. The cost of its training, let alone of reproduction and upbringing, also changes. The heterogeneity of labor is striking; it is also a source of future income.

All these difficulties do not prevent our labor friends from merrily aggregating man-hours among industries and over time. They are, it is true, helped by several circumstances, unfortunately not available to students of capital. The first is the feeling of shame which would arise if they began depreciating the labor force (including themselves), treating labor merely as a source of earning power. The second is the well developed and evidently reliable secondhand market for labor. While some companies prefer to buy brand-new college graduates, used labor carries no stigma (unless the person changes jobs too often), and with some exceptions is thought to be more valuable than new. For that matter, the secondhand labor market is practically the only one there is; the wages it sets are not questioned, which relieves labor statisticians of having to estimate the value of labor power. They don't even try to evaluate the existing stock of labor. But perhaps we can take a lesson from them and try to minimize the use of the stock of capital. For many problems only increments in the capital stock are needed. Why then not leave the devil alone whenever possible?

But if the stock of capital must be measured, let me suggest two thoroughly unoriginal approaches. The first would define the problem with some precision, and then select the proper definition of capital. Thus for one type of production function it may be desirable to eliminate changes in the quality of capital itself; for another this painful method may not be needed. Similarly, if the stock of capital is treated as a source of future productive power, depreciation of a one-hoss shay should be deducted, even if this wonderful instrument is equally useful to its very end. But from the capital productivity point of view, no such change should be made.

The second approach is even more pragmatic. Let us take existing figures, manipulate them, and then look around for suitable uses for them. Here are a few examples.

1. The stock of capital at original value of acquisition (not necessarily new), with or without depreciation. This will not do for estimates of capital productivity, but it is a standard measure of capital in accounting, financial, and legal circles.

2. The stock of capital deflated by a price index of inputs. Technological progress either in the production or in the quality of capital goods is not eliminated (though much will depend on the definition of

the inputs). For the study of capital productivity this concept may not be useful, but it can estimate the magnitude of social effort going into capital formation.

3. The stock of capital deflated by the price index of capital goods (Denison's method 1).[2] This would eliminate changes in the production of capital goods, but not in the quality of capital goods themselves.

Both methods 2 and 3 have their place in the evaluation of Soviet capital formation, as an example. The fraction of Soviet gross national produce, expressed in current prices, invested in the interwar period was 20 to 25 per cent. Prices of capital goods, however, were rising less rapidly than other prices. Hence if each sector of gross national product were deflated by its own price index (method 3), the fraction of Soviet product invested would be much higher.[3] Capital formation as a source of productive capacity can be estimated more meaningfully by method 3, but as a measure of effort or sacrifice method 2 is proper, though I wish that investment were charged with the cost of technological progress (education, training, and research) from which Soviet capital formation benefited more than any other sector of the Soviet economy.

4. Stock of capital deflated by a price index in which quality changes of capital itself have been accounted for. The result would be a "pure" input of capital, very useful from the productivity point of view, but as shown by Denison, quality changes are hard to define, let alone measure.[4]

5. Capital stock as an inventory, in which new goods are weighted more heavily than old ones. The proper weighting could take care of almost anything, including technological change, depreciation, and obsolescence, but where would these weights come from? A well developed second-hand market could give a set of weights, but in its absence (is it really as bad as we usually think?) this method remains merely a good wish. This is unfortunate, because, among other things, it could give a good estimate of the stock of capital as a source of future earning power.

There must be many other examples. Instead of citing them, let me mention only three fields in which further research seems desirable.

1. Evaluation of publicly owned capital. Comparisons with privately owned capital can be misleading. A new highway saving transportation cost will appear in such a comparison as an increase in

[2] Denison, *op. cit.*, pp. 222–7.
[3] See my *Essays in the Theory of Economic Growth* (New York, 1957), pp. 236–40.
[4] Denison, *op. cit.*, pp. 217–22.

the productivity, while in reality it is merely an increase in capital input.

2. Investigation of the role played by current capital formation in the introduction of technological change.

3. Investigation of the accumulation and use of knowledge, that is of research, education, and training (but not necessarily of economics of education).

MILTON GILBERT, Organization for European Economic Cooperation

The Ruggleses have carefully probed the conceptual difficulties of measuring the stock of real capital. I feel they have left a few matters unclear, however, and would like to make some points which I hope they will find acceptable.

The stock of capital consists of a variety of goods (and structures) produced over a series of years, during which prices have changed. The only way to measure this stock in real terms is to view the goods as a series of outputs that must be combined by the same rationale and the same procedures used in constructing any index of real product. Of course, the annual figures for the real capital stock are aggregated, while the indexes of production are expressed as relatives, but they are still conceptually the same.

Also, there is no conceptual alternative to this index of production approach for measuring the total stock of capital; what may seem like alternatives are either meaningless or impossible.

A measure derived from inputs of factors of production is not possible because quantity units for all the factors of production cannot be conceived of. This would be similar to trying to deflate the national income by distributive shares independently of output; it cannot be done, and not merely because of lack of data.

A measure derived independently on the basis of output, such as by making the stock of capital proportional to total output, is by definition not a measure of capital at all, but only a measure of output.

A measure in terms of capacity, while it may yield interesting information for particular industries, is not possible for total capital. There is no common denominator for adding up the parts, even assuming that it can be applied to all categories of capital goods separately.

In the index number approach, the data needed are quantities (or quantity indicators) of the various kinds of goods and unit value or price weights for combining the quantity data. Quantities often have to be determined indirectly as a practical matter—by deflating current value figures with an appropriate price index or by using material input as an indicator of the quantity of output. These tricks, however, do not change the conceptual basis of the process. In fact, if the

quantities are known, as in the Ruggleses' pipeline example, that settles the matter. In that example, two pipelines must be taken as twice as much quantity as one pipeline. If it costs less per unit to construct two than one, this can only affect the price weight, not the quantity indicator.

In this connection, cost and price at the time of production are the same thing; differences between cost and market are only significant for different periods of time.[1] Furthermore, the unit cost or price weight must be taken as the average for all the units produced. Prices for identical units may differ because of market inperfections, trade practices with regard to quantity discounts, differences in mark-ups for different kinds of outlets, etc. But this can affect only the average price weight, not the quantity indicator.

The crux of the Ruggleses' argument is that capital in general, presumably because of technological changes, has no physical units, and that any arbitrary solution will predetermine the result. It is always possible to reach this dead end by focusing attention on the worst cases, that is, new products—and equally so for consumption goods as for capital goods. But it seems to me that quantity units can be established for a very wide variety of capital goods, enough to make a production index (or a capital stock measure) possible. Locomotives, freight cars, trucks, ships, motors, standard machine tools, textile machinery of various kinds, office buildings, standard factory space, dwelling units of various categories, thermal electricity capacity, hydro-electricity capacity, blast furnaces, etc., all have recognizable quantity units. The real problem is to adjust for quality changes, and this becomes possible once it is recognized, as I believe it is by the Ruggleses, that quality improvements arising from better knowledge, but not requiring increased costs, cannot be given an economic value and therefore cannot be included in a quantity index or aggregate. The rest is a matter of data and statistical estimation. In the end, one will obtain some number of quantity indicators covering some percentage of the universe. It is only at that point that one can say whether a meaningful measure for the total is possible. And it usually is.

The Ruggleses are disturbed by the fact that it may not be possible to compute Laspeyres as well as Paasche indexes over a long period of time because the new products of the current period may not be able to be priced in the earlier period. I mentioned the same problem in comparisons between developed and underdeveloped countries, and am in favor of making comparisons with more than one set of weights whenever possible. However, to conclude with the Ruggleses that

[1] I am referring to "cost or market" as bases for valuation—not to factor costs or market prices as alternative price weights.

using only current weights may produce a trivial and uninteresting measurement seems extreme.

The Ruggleses may be right in their view that the gross capital stock will correlate better with output than the net. This is an empirical question and to answer it one needs both the net and gross figures.

Finally, I must insist that current price data alone will not do. This illusion seems reasonable sometimes when prices are not moving much. But as soon as prices move significantly, we distrust every inference made from the data unless we feel we know the distortion introduced by changing prices.

G. WARREN NUTTER, University of Virginia

I disagree with the Ruggleses' argument that depreciation of capital should be ignored if improvements in quality are also ignored. The rationale in weighting capital at base-year cost is that capital should be standardized in efficiency units of the base year. Unit costs in the base year are assumed to measure both cost and efficiency: there is an implicit assumption of competitive equilibrium. New capital items should be expressed only in base-year efficiency equivalents, and this is done by translating the new item into an equivalent number of base-year items that could have been produced at base-year costs. The point of this exercise—leaving aside the technical difficulties—is to keep the capital stock from reflecting changes in efficiency of *existing* capital. Depreciation should certainly be deducted as it occurs, though obsolescence should be charged only on replacement of the obsolete item. On this matter, Denison seems to be entirely correct; Kendrick and the Ruggleses seem to be half wrong—taken together, I suppose entirely wrong, since each is wrong about the other half.

On a more trivial matter, I am not swayed by the reasons given for the relevance of capital-output ratios in current prices. I don't see the usefulness of such estimates of periods of production, since they all depend on a stable technology, constant returns to scale, and so on. Calculation of capital-output ratios is useful in showing that they are not very useful.

EDWARD F. DENISON, Committee for Economic Development

Richard and Nancy Ruggleses' instructive article treats most generously the paper I presented to this Conference in 1953. Although they appear to agree with most of my analysis, they do reach some quite different conclusions or judgments upon which I should like to comment.

I find puzzling their sharp distinction between the difficulties of estimating the current value of the capital stock and capital consumption and those of estimating constant dollar series for the same items.

It is true, as they note, that the current value of the capital stock can be construed as its market value—if one can forget all the valuation problems associated with lack of organized markets, transfer costs, and specialization and indivisibility of capital goods—but a method of establishing the current market value of the capital stock directly is yet to be found, and the authors suggest none. Unless market value can be estimated directly, some variant of the perpetual inventory method is necessary, and the problem of estimating current value for any year is identical with that of obtaining deflated series in prices of the same year. Both involve trying to get some common denominator between capital produced this year and that produced in all prior years. Further, the constant dollar series that corresponds to a market valuation of current value is a method 3 solution in the terminology of my 1953 article, which I think the authors agree is the most difficult of all to apply.

While present methods of measuring capital stocks or services are certainly crude, the authors' appraisal of them, when they are construed as measuring capital in terms of base-year cost, seems unduly harsh. Also, the criticism that only a recent-year base can be used seems only moderately disturbing. In practice, deflated series are *usually* presented only on a recent-year base. I wonder whether the authors might have been less critical if they agreed that a flight to current-dollar comparisons provides no escape from the problems of equating capital goods produced at different times.

The recommendation to substitute retirements for capital consumption in measuring the net capital stock, while correct with respect to obsolescence and perhaps tenable with respect to deterioration in the quality of services provided, does not meet the problem of the simple exhaustion of service life. I don't see how this can be ignored in measurement of net capital formation. The authors appear to reach their position as a result of the rejection of the argument that the ratio between output and capital consumption, not output and the capital stock, is the one that would be expected to have some degree of regularity and is relevant for the measurement of productivity or capital capacity. The reason given for preferring the gross capital stock to capital consumption for these uses—that it is less difficult to measure—is not persuasive since the movements of the two series usually differ only because of changes in average service life. For measurement of net capital formation, capital consumption appears clearly to be the appropriate offset to gross capital formation.

I continue to have doubts as to the meaning of capacity (as measured by capital stock or capital consumption) for the economy as a whole. Capital capacity, in terms of physical units of output,

makes sense for a single plant or product in some few highly capitalized, mostly continuous-process, industries. But I don't see the sense of adding up capital stock figures, in dollar terms, to obtain the "capacity" of the economy. And if one did do so, I should think he would add up the values of the products that could be produced with existing capital, not the capital stock figures, since capital-output ratios vary so widely among industries. But in reality the capacity of an economy has real meaning only in terms of all the factors of production available to it, and measurement is best approached in terms of the national income or product. If a single-factor measure of under- or overutilization of the capacity of the economy is essential, it seems to me that labor force and hours data are much more appropriate, since for the economy as a whole labor probably provides the limiting factor on total output at any point in time and is much more transferable. I find it hard to reconcile the authors' relative enthusiasm for the amorphous capacity concept with their disparagement of the capital stock estimates of the type now being prepared.