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used for consumer expenditures and for nonwar capital formation were Kuznets' imputed price indexes for the period 1891-1949, extended to 1950 by splicing with Commerce's deflators. The series on military expenditures was deflated by Kuznets' imputed price index for gross national product for the period 1891-1939; for 1940 an average of Kuznets' price index for war output and Commerce's price index for federal expenditures was used; for 1941-43 Kuznets' price index for war output was used; for 1943-50 we employed Commerce's price index for federal expenditures, spliced to Kuznets' price index for war output at 1943.

I should point out that the margin of error in the deflation process is inevitably wide for the war period. The accurate measurement of the prices of civilian goods is more difficult under wartime conditions than it is in peacetime, and these difficulties are compounded in dealing with the prices of munitions. The deflated measures doubtless provide a better approximation to real product than do the undeflated measures, but fairly large errors of estimate are clearly present.

#### Note 2

#### ESTIMATES OF PRODUCTIVITY

Index numbers of productivity and estimates of productivity increments can be highly useful measures of economic change, but they are far from unambiguous. All the difficulties involved in the measurement of production changes attach to them, plus others that arise when the ratio of output to effort input is computed. Here I note some of these difficulties and certain limitations of the specific measures used in this paper.

*General considerations.* Index numbers derived from ratios of physical output to effort input  $\frac{Q}{E}$  are accurate measures of changes in the average unit effectiveness of work done when physical output is constant in quality and composition, when the scope of the measures of effort input is constant over time, and when available measures of effort input are identical in coverage with the meas-

ures of physical output with which they are compared, or when the two are constant and fully representative proportions of the totals to which they respectively relate.<sup>1</sup> When these conditions are met, changes in the ratio  $\frac{Q}{E}$  measure shifts in the average physical return to a unit of work time (I am assuming that effort input is measured in terms of manhours, manweeks, manmonths, or man-years of work done). The ratio may be altered by a diversity of factors. These may include changes in

- ▶ the quantity or quality of capital equipment used
- ▶ the quality of effort input (This may be a change in intensity or a change in average degree of skill. Such a change in average skill may result from a change in the competence of individuals or groups, or from a shift in the composition of the work force.)
- ▶ the ratio of effort input to productive instruments used or to natural resources used (A change in average productivity resulting from the play of diminishing returns would be included in this category.)
- ▶ the quality of natural resources or materials used
- ▶ the quantity of materials or intermediate products used to produce a standard unit of final product
- ▶ the amount of nonhuman power used or the manner of its use
- ▶ the organization of productive units
- ▶ working conditions
- ▶ the effectiveness of administration

A given change in productivity may reflect any combination of these factors. In particular, the interpretation of a given movement will be affected by the scope of the measures of effort input. In a special instance these measures could include only direct labor;

<sup>1</sup> For present purposes I am setting output solely against input of human effort. For other purposes productivity might be measured by comparing total output with the input of some other productive factor, or with the input of a combination of human effort and other factors.

variations in the role of indirect labor would then be one factor influencing the movements of the productivity index. In another case the labor equivalent of capital used up in the productive process might be included in the effort input (this would be logical when gross national product is used as a measure of output); the aim in this case would be to incorporate in  $E$  a measure of changes in the quantity of capital utilized or in the intensity of capital use, and thus to eliminate this factor as an influence on productivity. In measuring productivity in manufacturing, the effort equivalent of purchased power might be included in  $E$ , in order to eliminate the effect on productivity of possible shifts from internally generated to purchased power, or the reverse.

In the construction of closely controlled measures of productivity (of the type now being developed by the U.S. Bureau of Labor Statistics for particular industries) an attempt is made to hold constant some of the variables that bear upon productivity changes. More exact interpretation of the derived measures is then possible. In general, however, we must be content with measures of productivity that embody the results of the many indefinable changes that influence the effectiveness of work input, and that do not permit us to determine precisely which factors account for changes in productivity.

When the conditions set forth above are realized we can have accurate measures of changes in productivity, although we may not be able to specify the causal factors. When these conditions are not realized, when output is not constant in quality and in composition, when measures of output and of effort input differ in coverage, or change unequally in degree of coverage, productivity indexes become less reliable. It is fair to say that conditions for complete accuracy are seldom if ever met. Changes in quality of product are constant and elusive; any composite product of the kind represented by conventional indexes of production is subject to unceasing shifts in its make-up.<sup>2</sup> We may do something by judi-

<sup>2</sup> From an economy-wide or industry-wide viewpoint productivity may increase as a result of changes that shift labor from sectors of relatively low value of output per manhour to sectors of higher value of output per manhour, although there may be no change in the internal productivity of individual plants or

cious choice of weights to improve the comparability of indexes of output and of effort input, but full comparability is virtually never attained for comprehensive measures of production and of labor input. The best of our measures of productivity are imperfect and in some degree ambiguous in meaning.

*Economy-wide estimates.* In the present paper we have made use of measures of output, of effort input, and of productivity that purport to cover the whole economy. The estimates of output relate to a heterogeneous composite of goods and services, an aggregate that is not open to direct physical measurement. To portions of this aggregate the concept of productivity applies only equivocally. Apart from conceptual difficulties, estimating procedures are subject to considerable margins of error. Yet the question faced is important, and one to which answers will be sought: What changes have occurred over time in the economy of the United States in the average real return per unit of productive effort expended?

The adequacy of our answers to this question will depend upon the accuracy with which we can measure changes in the real output of the economy and in the amount of work done in obtaining this output. Two steps are involved in the measurement of changes in real national product — the estimation of total output (gross or net) in terms of current dollars, and the “deflation” of the elements of this total to correct for the effect of price changes. Neither of these operations can be carried through with complete accuracy. Current estimates of national product are built up from masses of detailed figures. For some processes the basic data are good, for others they are fragmentary. Errors of estimate are large for the earlier years covered, smaller for later years. No precise measure of the magnitude of these errors is available. The accuracy of estimates of national product as indexes of *change* from year to

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subdivisions of an industry. When detailed information is available on the constituent elements of the economy or the industry, the effects of such shifts may be estimated and separated from the effects of changes in productivity ratios for plants or industrial subdivisions. See Solomon Fabricant, *Employment in Manufacturing Industries* (National Bureau of Economic Research, 1942), pp. 335-7. The increasing accuracy and expanding coverage of the Census of Manufactures are providing information more adequate for this purpose in that important field.

year or decade to decade is greater than their accuracy in absolute terms — and it is as indexes of change that we use them here.

When we use these estimates as indexes of change over time we face the second problem noted above — that of correcting for fluctuations in prices. This is done by the use of a complex set of price indexes relating to different sectors of the economy. Here, again, we can be reasonably accurate in treating data for some economic processes, while for others deflation gives at best only a rough approximation to the truth. The accuracy of the deflation procedure varies over time; accurate correction for price changes in wartime is far more difficult than it is in peacetime. The economic upheavals of World War II, in particular, were so great as to render impossible accurate correction for price changes and accurate measurement of real output. All estimates of real product for the war period are subject to wide margins of error.

The measurement of total effort input as an aggregate of undifferentiated work time expended in production is in principle simple. If we know the total number of employed members of the labor force (including all degrees of skill and all kinds of persons engaged in productive operations) and the average length of the workweek or workyear we can determine the total number of manhours or manyears of effort entering into the national product for a given period. Here, again, we must depend upon estimates that are subject to error. For recent years estimates of the total volume of employment are based upon the results of monthly sample surveys, which are blown up to cover the whole economy. For earlier years we depend upon periodic census counts of the gainfully occupied, with various corrections and interpolations. National estimates of average working hours per week or per year are built up from data and estimates for different industrial sectors. Figures on employment and hours for later years are more accurate than those for earlier years, but both current and early estimates are approximations only.<sup>8</sup> Indications of major changes in nationwide totals and averages may be accepted with reasonable confidence; indications of minor changes and short-period movements are less trustworthy.

\*Details of the estimates employed in the present paper will be given in a forthcoming monograph of the National Bureau of Economic Research.

For present purposes I make no attempt to differentiate among grades of labor or degrees of skill in the total effort input. The effects on productivity of shifts in the composition of the work force should, I believe, be reflected in productivity indexes.

The final step in deriving indexes of productivity in the general economy is to express changes in total real product as ratios to changes in total effort input. Here the use of economy-wide totals avoids certain difficulties faced in dealing with separate sectors of the economy, and entails certain additional problems. The use of comprehensive indexes of effort input and of output means that labor involved in the provision of materials, fuel, services and other intermediate products enters in due proportion into the total, but without duplication when these intermediate products merge into final products. (The measurement of total product here employed is gross in that there is no correction for the value of capital consumed in the productive process, but net in that duplication of the value of intermediate products is avoided in estimating the aggregate value of all final goods and services.) It is easier on an economy-wide basis than on a plant or industry basis to set effort input against the actual output to which that input corresponds. On the other hand, some elements of the total national product are difficult to handle. The products of many government services (for example, the armed forces) cannot be measured in any satisfactory way, except by equating them to corresponding labor input. This, of course, assumes no change over time in productivity. The same problem is faced in dealing with certain of the service industries in the private sector of the economy, although in some such cases output can be measured directly. To these difficulties must be added those arising from continual change in the composition of the national product and in the quality of many of the goods entering into this product.

Consideration of these conditions leads to certain practical conclusions:

a) Measures of changes in real product per manhour for the national economy may be used to define long-term trends, or to indicate the magnitude of major movements. For short-period movements in such measures, even for year-to-year changes, the

margins of error in the indexes can easily exceed the actual changes in productivity.

b) For war periods, or other periods marked by great changes in the structure of a nation's economy, the margins of error in global productivity measures will be substantially greater than for periods during which structural changes are modest.

c) In the construction of productivity measures for a national economy few of the many variables that may affect the ratio of output to effort input can be held constant. There is little opportunity, therefore, to disentangle the diverse factors that influence productivity, or to attribute causal roles to specific factors.

These several qualifications limit the usefulness of economy-wide measures of productivity. In deriving such measures from estimates of the heterogeneous aggregates that constitute national product and of the correspondingly mixed aggregates of labor input we are working with unprecise instruments. My immediate justification for employing such instruments is twofold: the magnitudes of the movements that are the objects of this study are in most cases far greater than the magnitudes of the errors of measurement; experimentation with imperfect tools can point the way to better methods.<sup>4</sup>

In the study of economic development, measures of changes in the ratio of output to effort input — a salient relationship in economics — are tools of great value. They can illuminate the past; projected, they help to define expected resource needs in normal growth or in contemplated emergencies.<sup>5</sup> Such measures are crude today, but with the improvement of estimates of national product, of employment, and of hours of work we can expect steady advances in their quality and their usefulness.

<sup>4</sup> For an informed exposition of the logic of productivity measurement and of means of sharpening concepts and improving analytical tools in this field, see Irving H. Siegel, *Concepts and Measurement of Production and Productivity*, U.S. Bureau of Labor Statistics (1952). On a specific program of improvement, see *The Productivity Measurement Program of the Bureau of Labor Statistics*, U.S. Bureau of Labor Statistics (1950).

<sup>5</sup> For a discussion of the problems involved in the projection of national productivity measurements see John W. Kendrick, "National Productivity and Its Long-term Projection", *Proceedings of the Conference on Research in Income and Wealth*, May 1951.