

Productivity (H52)

Productivity and Economic Progress

FREDERICK C. MILLS

(OCCASIONAL PAPER 38)

INSTITUTE OF
STATISTICAL RELATIONS

FEB 18 1953

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*(Resolution adopted October 25, 1926
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Productivity
and
Economic Progress

by

FREDERICK C. MILLS

OCCASIONAL PAPER 38

NATIONAL BUREAU OF ECONOMIC RESEARCH, INC.

New York 1952

Price: \$.75

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Typography by Oscar Leventhal, Inc.

Printing by John N. Jacobson & Son, Inc.

Library of Congress catalog card number: 52-14251

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PRODUCTIVITY AND ECONOMIC PROGRESS*

Over the last half century the real national product of the United States increased five-fold, while population doubled. Output per capita of the population increased two and one-half times. Here was the basis of a substantial advance in economic power and in levels of consumption. Over this same period the total volume of human effort going into production (measured by manhours of labor input) increased by 80 per cent. The great gain in total output was won with an increase in labor input well below the increase in population. Here is evidence of a gain in welfare in another dimension — a saving of effort and a lightening of the toil by which the material needs of life are satisfied.

The major instrument used in the winning of these dual gains was enhanced productivity. During this period there was an unbroken advance in average physical output per manhour of work done. Decade by decade the effectiveness of productive effort increased. In the final decade output per manhour of labor input was 2.81 times what it was fifty years before.

The movements thus briefly summarized reflect four basic trends in the growth of the economy of the United States (see table

* This paper is one of a series of National Bureau studies dealing with production and productivity. This series has been supported in large part by funds granted by The Maurice and Laura Falk Foundation of Pittsburgh. The Falk Foundation is not, however, to be understood as approving, by virtue of its grant, any of the statements made or views expressed herein.

In a paper presented at a meeting of the American Economic Association at Boston, in December 1951, I drew upon some of the materials utilized in this report, and presented preliminary estimates of some of the quantities here given. Concepts, procedures, and estimates have been modified somewhat in the present essay. A fuller discussion of the topics here dealt with may be expected in a subsequent National Bureau publication.

I am indebted to Maude R. Pech for assistance in this study.

REAL GROSS NATIONAL PRODUCT, POPULATION, LABOR INPUT, AND
PRODUCTIVITY, UNITED STATES, BY DECADES, 1891-1950

<i>Decade</i>	<i>Gross national product</i>		<i>Population</i> (relative)	<i>Total man- hours of labor input</i> (relative)	<i>Output per manhour</i> (relative)
	(billions of 1929 dollars)	(rela- tive)			
1891-1900	294	100.0	100.0	100.0	100.0
1901-1910	455	154.8	120.6	126.1	122.8
1911-1920	603	205.1	143.4	140.5	146.0
1921-1930	838	285.0	165.4	145.1	196.4
1931-1940	843	286.7	181.9	122.8	233.5
1941-1950	1,493	507.8	201.4	180.5	281.3

above). These trends are examined in the pages that follow. We there attempt to determine the magnitudes of some of the elements of growth, to outline the uses to which we have put our expanding productive power and, in so doing, to define some aspects of the pattern of progress over this half century of economic expansion.

I

FACTORS IN THE GROWTH OF PRODUCTION

Economic resources may be used for maintenance, for defense, or for material progress. Maintenance includes the support of the population (which may be a growing population) at an established consumption level and the full upkeep of an existing stock of capital equipment. It could, indeed, include defense, because military protection is necessary to the preservation of an existing way of life, but there are advantages in treating defense in a separate category of uses. Economic progress is possible when there is a margin of output over and above the needs of maintenance and defense.

Output, effort input, and productivity

Progress in this sense is not, of course, defined by the rate of change in total output. Yet, with a growing population, an increas-

ing supply of physical goods and services is a basic requirement of material growth. I first note, therefore, certain conditions bearing on the growth of production.

The aggregate physical output of an economy may be expanded by an increase in the input of human effort or by an increase in output per unit of labor input. We may expend more effort or we may resort to the diverse factors that render human effort more productive. Manpower input¹ may be increased by fuller use of an existing labor force (i.e., by drawing upon the unemployed), by expansion of the labor force, or by a lengthening of working hours. Except during limited periods, expansion of output in the United States over the last half century has been achieved primarily by means of rising productivity; the instrument of augmented manpower has played a secondary role. The forces enhancing output per unit of work time have been many. In their aggregative influence as elements of productivity they have been the major factor in our recent material growth.

The distinction between effort and the unit effectiveness of effort as factors in the productive process cuts across the conventional classification of factors into land, labor, capital, and enterprise, and corresponds in no wise to that division. From the present view we have but two interacting agents: on the one hand, the mental and physical effort exerted by all grades and levels of producers; on the other, the combination of elements that determine the effectiveness of this effort in production. The latter, the productivity factor, comprehends the quality and magnitude of available natural resources, the amount and quality of capital equipment used, the skill, intelligence and training of all personnel, and the quality of organization and management. Effort and the productivity factor are, of course, not additive; they are related in a multiplicative way. They are integral components of every unit of the ultimate product.

¹ In this study I use manpower input, as defined by manhours of work time on the part of the total employed labor force, as a measure of human effort expended in production. This quantity is meant to include all labor entering into the productive process. It includes the efforts of managers as well as wage earners, of proprietors as well as employees. No attempt is made to distinguish qualities of work input.

In their usual form, indexes of output, of effort input, and of productivity define relative changes in these elements over time.² Such measures were cited in the opening paragraphs of this paper. In addition, it is useful to deal with absolute increments to output, and to divide them into two components, one associated with increases in the quantity of effort input, the other with increases in output per manhour of work done. These two components of a production increment are termed, for convenience, the *labor input increment* and the *productivity increment*. The former is the absolute increase in output between two stated periods that would have resulted from the recorded increase in labor input, had the employed labor force been working at a productivity level equal to the average of the two periods compared. The latter is the absolute increase in output that would have resulted from the recorded gain in output per manhour, had this gain been utilized by a working labor force equal to the average of the two periods compared. (Either of the two components may, of course, decrease, in which case we should have a decrement instead of an increment.) The productivity increment is the "technological margin", the concrete resultant of the diverse influences that determine the effectiveness of productive operations. It is, at once, the substance for which producing and consuming groups compete and the mainspring of material progress.³

I should emphasize that the productivity increment (or decrement) is restricted to the yield of *employed* resources. Its sign will depend upon the direction of change in manhour output; its size will depend upon the absolute amounts of work input in the two periods compared. There may be such an increment (as in fact there was in the thirties) during a period of extensive and growing unem-

² See Note 2 at the end of this paper for a discussion of measures of productivity.

³ It should be clear that neither the labor input increment nor the productivity increment is to be regarded as the marginal product of any of the conventional factors of production. The labor input increment could be negative when the marginal product of labor (which in this situation must relate to the result of changes over time) is positive; it could be positive with a negative marginal product. Both increments are, of course, joint products of all productive factors; neither increment is in any sense the specific product of any one factor. See Note 3 at the end of this paper for a discussion of the method here employed in estimating these quantities.

ployment. Neither a productivity index nor a productivity increment is a measure of the effectiveness with which total available resources have been used; nor does either indicate the output that might have been won had all resources been employed.

In tracing changes in a given economy we are concerned not only with the sources of the increments to national product; we are equally interested in uses. Progressively, in a growing economy, additional productive resources are opened up and new productive power is won. These resources and this power may be put to diverse uses. To some extent, too, resources carried over from earlier periods may be shifted to new uses. The pattern of resource use, as it is modified from decade to decade and from generation to generation, is one of the most revealing aspects of economic growth. We shall turn to the subject of uses after tracing the expansion of national product over the last half century and defining the parts played by labor input and productivity as contributors to changes in total product.

II

INCREMENTS TO NATIONAL PRODUCT, AND THEIR COMPONENTS

The growth of the gross national product of the United States, in real terms, has been conspicuously uneven during the twentieth century, with the major fluctuations coming in the last three decades. Decade increments and the two components of each such increment are given in the following table and are charted in Figure 1. All values relate to decade aggregates.⁴

⁴ The basic national product estimates here used are those of Simon Kuznets. To Kuznets' figures, on his peacetime concept, M. Slade Kendrick's estimates of the war and defense expenditures of the federal government have been added, with a correction to prevent duplication (see Note 1 at the end of this paper). This modification gives us measures corresponding to Kuznets' wartime concept of gross national product, except that the present totals include all defense expenditures in years of peace, as well as in wartime. I am indebted to Dr. Kuznets also for the classification of elements of the national product used in later sections.

In deriving estimates of labor input I have used continuing series of the Bureau of the Census and the Bureau of Labor Statistics, and employment and hours of work estimates of Clarence Long, Leo Wolman, and others.

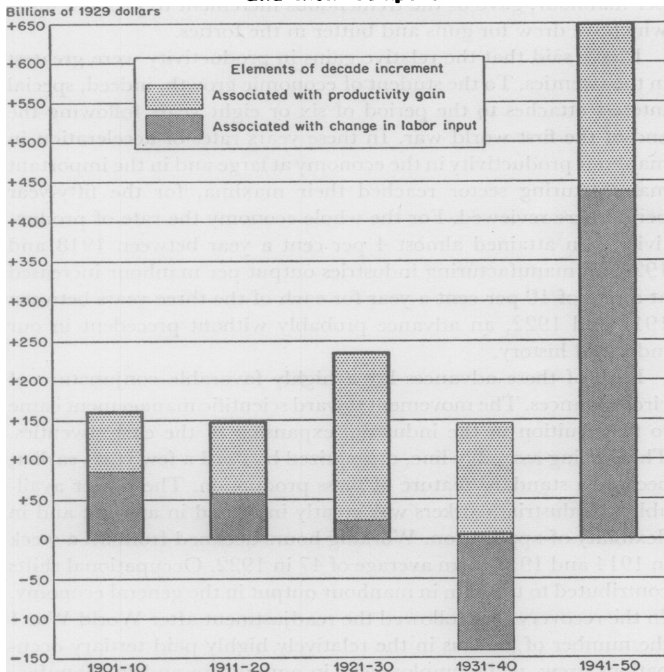
<i>Decade</i>	<i>Gross national product increment (billions of 1929 dollars)</i>	<i>Labor input increment</i>	<i>Productivity increment</i>
1901-10 (change from 1891-1900)	+161	+85	+76
1911-20 (change from 1901-10)	+148	+57	+91
1921-30 (change from 1911-20)	+235	+23	+212
1931-40 (change from 1921-30)	+5	-141	+146
1941-50 (change from 1931-40)	+650	+437	+213

The accelerations in economic expansion, as measured by increments to real gross product, came in the first, third, and fifth decades of the century. The second decade brought modest retardation; the fourth brought a major check, with actual retrogression during the first five years. The advance of the twenties was notable, that of the forties phenomenal.

There is a sharp and revealing contrast in behavior between the two components of national product increases. One, reflecting additions or subtractions of sheer manpower, shows progressively declining increments through four decades, culminating in a decrement of major proportions in the thirties. The absolute contribution of added labor in the twenties was only about one-fourth that recorded for the decade 1901-10. Hours of work were being steadily shortened in these earlier decades, and those in the lower age groups were being withdrawn from the work force. After the first decade it was only in the forties, under the stimulus of war and defense, that we resorted primarily to the instrument of added manpower to augment production. (One reason for the very large labor input increment in the forties was, of course, the subnormal level of employment in the thirties, which provide the base of comparison for the following decade.)

The chief lifting force between the first and the fifth decades was steadily growing productivity. This increment grew from 76 billions (of 1929 dollars) in 1901-10 to 212 billions in 1921-30. Relatively, this last was the greatest productivity gain of the half century. There was a drop in the depressed thirties, but even in that decade the productivity increment was more than large enough to offset the loss of 141 billions resulting from a great decline in the

Figure 1
Decade Gains in Real Gross National Product
and their Components



Each bar measures the amount by which the national product of a given decade exceeded the national product of the preceding decade.

volume of labor input. The most recent decade brought a productivity increment of 213 billion dollars, a figure approximately equal to the gain of the twenties. The employed labor force in the latest decade was the largest in our history and this, of course, served to enhance the gain resulting from the actual advance in manhour productivity. Great as it was, the productivity increment

in this decade was materially exceeded by the labor input increment. Additions to manpower, supplemented by increases in output per manhour, gave us the tremendous increment to product upon which we drew for guns and butter in the forties.

I have said that the relative gains in productivity were greatest in the twenties. To the student of economic growth, indeed, special interest attaches to the period of six or eight years following the end of the first world war. In these years rates of acceleration in manhour productivity in the economy at large and in the important manufacturing sector reached their maxima, for the fifty-year period here reviewed. For the whole economy the rate of productivity gain attained almost 4 per cent a year between 1918 and 1924. In manufacturing industries output per manhour increased at a rate of 10 per cent a year for each of the three years between 1919 and 1922, an advance probably without precedent in our industrial history.

Back of these advances lay a highly favorable conjuncture of circumstances. The movement toward scientific management came to first fruition in the industrial expansion of the early twenties. The moving assembly line, dramatized by Ford a few years earlier, became a standard feature of mass production. The power available to industrial workers was greatly increased in amount and in flexibility of application. Working hours declined from 53 a week in 1914 and 1917 to an average of 47 in 1922. Occupational shifts contributed to the gain in manhour output in the general economy. In the recovery that followed the readjustment after World War I the number of persons in the relatively highly paid tertiary occupations grew, while employment in agriculture and in manufacturing lagged, or declined. The stock of real capital per worker, in the form of producers' durable equipment and industrial and commercial structures, stood at a relatively high level in the early twenties, having increased by some 40 per cent in two decades.⁵ No comparable rise occurred until the notable increase that fol-

⁵ I have here made use of Dr. Raymond Goldsmith's data on elements of estimated national wealth, in 1929 prices. See "A Perpetual Inventory of National Wealth", *Studies in Income and Wealth, Volume Fourteen* (National Bureau of Economic Research, 1951), pp. 5-73.

lowed the end of World War II. Perhaps of greater importance than the increase in the stock of capital goods was the advance in the *quality* of capital instruments. Technological improvements as well as the innovations of scientific management were widely adopted in the early twenties; such improvements were chiefly manifest in the tools of production. These diverse factors combined with others in the complex of working conditions that determine productive effectiveness to yield a remarkable productivity gain.

III

USES OF PRODUCTIVE RESOURCES

The characteristics of an economic system are defined not alone by the magnitude and sources of its productive power. The purposes for which productive resources are used are the most significant indicators of its pattern of life. These purposes reflect the collective desires and needs of the individuals who make up the system. Basic wants for food, clothing and shelter, desires for satisfactions above subsistence levels, the role of instrumental goods in the productive process, and compulsions imposed by necessities of war or defense are all manifest in the patterns of use that prevail at given times. Such uses, in the aggregate, are shown by the familiar national income and national product classifications that have been developed within recent decades for this and other countries.

Maintenance, defense, and progress

A somewhat different classification of uses has been employed in this study. Here we think of economic resources as being used for three broad purposes — maintenance, defense, and progress. The population must be supported at an established consumption level; the existing stock of capital equipment must be maintained if there is not to be retrogression through depreciation and obsolescence; means must be provided for defense against attack from abroad. Only after these needs have been met is economic progress possible.

Such progress may take the form of an advance in consumption levels (i.e., an increase in average per capita expenditures for consumption goods and services) or a net increase in the stock of capital.⁶

If the "progress" made in any period is to be determined, the requirements for maintenance must first be established. For capital stock, maintenance needs can be equated to "capital consumption" — the wearing out of plant, equipment, and residential housing — during a stated period. The criterion is definite here, although one must be content with estimates of the magnitudes involved. Less precise criteria are available when we consider population maintenance. There can be no absolute and fixed definition of consumption standards. Each generation, indeed each decade and each year, brings changes in the content of living and in the subjective scales by which people judge the adequacy or inadequacy of the real incomes provided by their monetary receipts. I here assume that the consumption level attained in a given decade (as measured, in constant dollars, by average per capita expenditures for consumption goods and services) establishes a criterion of consumption needs that carries over into the decade following. This is not to say that basic requirements for the maintenance of consumption levels are always met. Claims growing out of such needs may be relinquished in periods of national emergency; in deep depression

⁶ Economic growth has elsewhere been defined as an advance in the net product of goods and services per capita of the population. (Cf. J. J. Spengler, "Theories of Socio-Economic Growth", in *Problems in the Study of Economic Growth*, Universities-National Bureau Committee on Economic Research, 1949). The present definition of economic progress is similar to this in respect of consumption gains; it differs, however, in two important ways: 1) Expenditures for defense are not considered to contribute to progress. (They are, of course, an essential form of maintenance.) 2) Any formation of net capital is considered to be a component of progress, whether there is a gain per capita of the population or not. Technological improvements contributing to major advances in *quality* of capital goods could quite conceivably make possible rising per capita consumption with no accompanying increase in total capital stock. This is not likely to be the case with a growing population — certainly we stand far short of such a condition now — but in an industrial economy marked by rapid technical advance it is not essential to progress that quantitative additions to the stock of capital grow at a faster rate than population.

Under the present definition there may, of course, be progress in a net sense if there is an advance in only one of the two forms of progress, provided that this advance exceeds the decline in the other form.

output may be inadequate to meet even fundamental needs. But the historical record provides ample justification for the view that consumption levels are persistent, that they change slowly, and that gains in such levels, once realized, are defended with tenacity.⁷

⁷ I have used the term "consumption level" in the sense of J. S. Davis' illuminating discussion, in his presidential address (*American Economic Review*, March 1945). In some respects the "standard of consumption", which means the scale desired and striven for, whether realized or not, would be an appropriate criterion, but available measures are restricted to levels of consumption actually realized. There is, moreover, justification for using the *attained* level and for viewing this as including the more vigorously defended elements of the consumption standard.

A case could be made for using as criterion not the consumption level of the year or decade immediately preceding, but the highest consumption level previously attained. Duesenberry and Modigliani have suggested that consumption propensities are influenced by previous peak incomes as well as by current income levels. Tom E. Davis of Johns Hopkins has shown that the Duesenberry-Modigliani models can be further improved by substituting previous peak consumption for previous peak income ("The Consumption Function as a Tool for Prediction", *Review of Economics and Statistics*, Vol. XXXIV, No. 3, August 1952). This procedure would be particularly appropriate in dealing with the postwar forties.

The criterion here employed, it is to be noted, gives a consumption standard which changes over time. This would be true in a secular sense, of course, in an economy marked by rising living standards. It would be true, also, with reference to periodic movements. Thus a consumption level carried over from a prolonged depression would not be the same as a consumption level carried over from a period of prosperity. These differences would have a bearing upon the choices entering into the use of disposable resources at different times. Thus in a period following prolonged depression some resources would be used to restore the consumption levels of a still earlier period.

Our procedure, in which each decade average provides a consumption standard for the following decade, implies that consumption levels advance or decline in jumps. This probably approximates the truth, for advances in such standards appear to come in uneven spurts. However, the reader should recognize that the discontinuities imposed by the use of fixed ten-year intervals are arbitrary in their timing and, to some extent, in their relative magnitudes.

With reference to consumption standards I would emphasize that this study relates to a particular historical period. The consumption levels that are taken to have been marked by strong tendencies to persist are those of the five decades 1891-1900 to 1931-40. It is possible that as durable goods and luxury elements become more important in consumer standards, persistence of consumption levels will be less marked. Thus the high postwar standards may be less tenaciously defended than were the lower standards of a decade or two ago. However, it is far from certain that even high standards, entrenched by ten years of habituation, would be lightly sacrificed if per capita output should continue to increase. (Standards of *use* will, of course, be more stable than levels of *purchase*. But the distinction between use and purchase has less significance for decade intervals than it would have for shorter periods.)

Maintenance needs are relatively stable in their changes from period to period. Expenditures for defense and for progress are far more variable. In tracing changes over the last half century it will be useful to treat maintenance expenditures as a first deduction from gross national product. The margin above maintenance requirements⁸ is a quantity to which special interest attaches in a study of economic development.

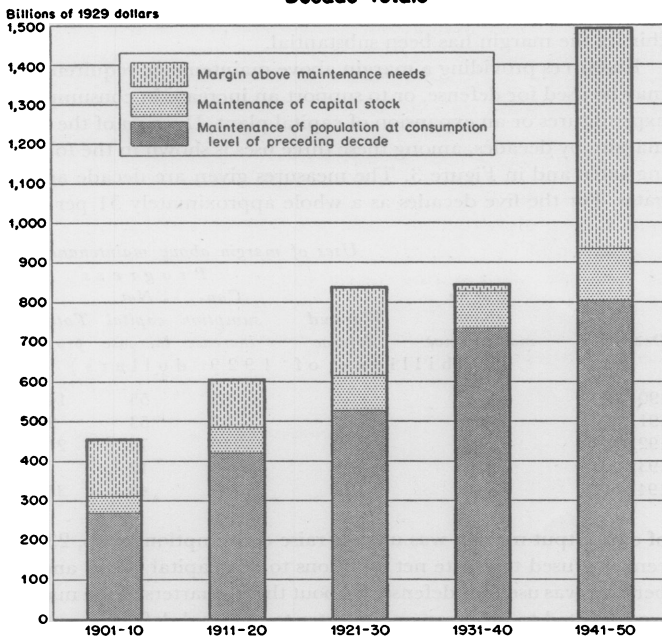
The margin above maintenance needs

The deductions from gross national product to care for maintenance in a given decade must provide for the support of the population of that decade at per capita consumption levels equal to those prevailing during the decade preceding and for the production of capital goods sufficient to offset in full depreciation of the preceding decade's stock of capital. The procedure, using decade aggregates, is shown in the following table. A graphic representation of the division of decade totals is given in Figure 2.

Decade	Gross national product	Maintenance charges			Margin above maintenance Col. 2 — 5
		Support of population	Capital stock	Total Col. 3 + 4	
		(b i l l i o n s o f 1 9 2 9 d o l l a r s)			
(1)	(2)	(3)	(4)	(5)	(6)
1901-10	455	268	43	311	144
1911-20	603	420	65	485	118
1921-30	838	527	88	615	223
1931-40	843	734	95	829	14
1941-50	1,493	803	132	935	558

* I have elsewhere called a variant of this concept the "disposable margin". There is justification for this term, I think, in that there is a larger element of conscious choice, individual or collective, in the allocation of resources above those required for maintenance than there is in the disposition of resources that serve established needs for consumption or capital replacement. But the term is not altogether apt, since the margin must perforce be measured retrospectively. The resources entering into it, whether used for defense or for progress, have already been committed by the time measurement is possible. It seems advisable, therefore, to use the neutral term "margin above maintenance needs" or, in short, "output margin", in preference to "disposable margin".

Figure 2
Uses of Real Gross National Product
Decade Totals



The entries in column 6, which define amounts by which the gross national product exceeds maintenance needs, represent margins available for new uses. Without the product represented by each of these quantities we could, in any decade, maintain the existing stock of capital equipment and support the full population at the consumption levels of the preceding decade.⁹ The margins above

⁹ In the thirties we did not, in fact, achieve full maintenance, for actual consumption standards in that decade were slightly below those of the twenties. We devoted to population maintenance 725 billions of 1929 dollars, not the 734 billions required for full maintenance. We did, however, increase capital stock by a small amount.

maintenance requirements have ranged from a very small fraction of gross product, in the thirties, to almost 40 per cent of gross product, in the forties. Over the five decades they have averaged 25 per cent of gross product. In every decade except the depressed thirties the margin has been substantial.

Resources providing a margin above maintenance requirements may be used for defense, or to support an increase in consumption expenditures or an expansion of capital plant. Division of the total margin, by decades, among these three uses is shown in the following table and in Figure 3. The measures given are decade aggregates. For the five decades as a whole approximately 51 per cent

Decade	<i>Uses of margin above maintenance</i>				
	<i>Margin above maintenance</i>	<i>War and defense</i>	<i>P r o g r e s s</i>		
			<i>Con-</i>	<i>Net</i>	<i>Total for</i>
			<i>sumption</i>	<i>capital</i>	
			<i>increase</i>	<i>increase</i>	<i>progress</i>
	<i>(b i l l i o n s o f 1 9 2 9 d o l l a r s)</i>				
1901-10	144	4	85	55	140
1911-20	118	28	37	53	90
1921-30	223	8	140	75	215
1931-40	14	11	—9	12	3
1941-50	558	228	285	45	330

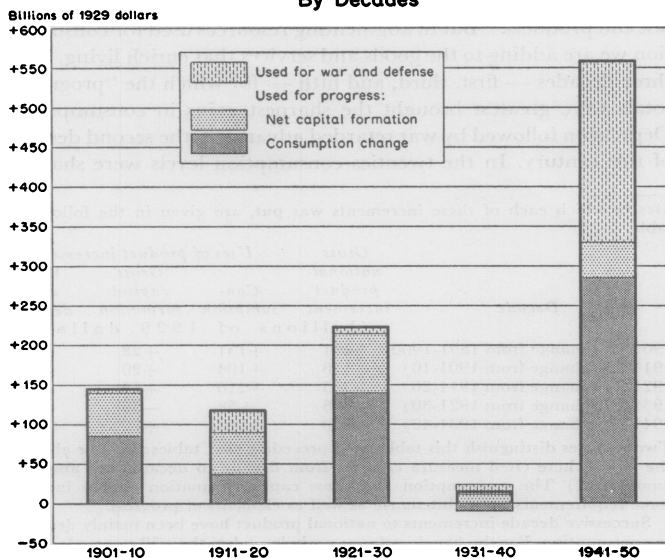
of our output margin was used to raise consumption levels, 23 per cent was used to create net additions to our capital plant, and 26 per cent was used for defense.¹⁰ About three-quarters of the margin was devoted to progress, one-quarter to national defense.

Behind these over-all proportions there have been wide decade-to-decade shifts in the uses to which the output margin has been put. Amounts spent for war and defense have varied from 4 to 228

¹⁰ Each consumption increase in the above table is measured with reference to the preceding decade as standard, whereas the defense and capital formation figures are the total absolute amounts used for these purposes. If we use the consumption level of 1891-1900 as a fixed consumption standard for the fifty years from 1901-50, we may compare consumption changes for the whole half century with the absolute amounts used for other non-maintenance purposes. Using 1891-1900 as a base, we find that 74 per cent of the margin above maintenance needs was used to raise consumption levels, 12 per cent for net capital formation, 14 per cent for defense.

billions of 1929 dollars. Net capital formation has varied from 12 to 75 billions. Amounts devoted to consumption gains have ranged from -9 to 285 billions. Progress, as measured by the sum of the

Figure 3
Uses of National Product Margin above Maintenance Needs
By Decades



amounts going to raise consumption levels and to expand capital plant, was most rapid in the first, third, and fifth decades. We have moved forward in three great surges, each taking the economy to a new peak.¹¹

The entries measuring decade-to-decade changes in the resources

¹¹ What I have called margins above maintenance needs are, of course, not the same as increments to gross national product. Yet the two are not far apart in magnitude. Decade increments to national product, and the three major

devoted to raising per capita consumption levels are perhaps of greatest interest. These are the immediate indexes of changes in the material well-being of members of the population at large. In maintaining capital stock we are resisting the processes of erosion. In spending for war and defense we are diverting resources to necessary protection, but these uses do not represent social or individual advances. In adding to capital we are building instruments, not end products.¹² But in augmenting resources used for consumption we are adding to the goods and services that enrich living. The three decades — first, third, and fifth — for which the “progress” totals were greatest brought the sharpest gains in consumption. Depression followed by war retarded advance in the second decade of this century. In the twenties consumption levels were sharply

uses to which each of these increments was put, are given in the following table.

<i>Decade</i>	<i>Gross national product increment</i>	<i>Uses of product increment</i>		
		<i>Con- sumption</i>	<i>Gross capital formation</i>	<i>War and defense</i>
		(billions of 1929 dollars)		
1901-10 (change from 1891-1900)	+161	+131	+28	+2
1911-20 (change from 1901-10)	+148	+104	+20	+24
1921-30 (change from 1911-20)	+235	+210	+45	-20
1931-40 (change from 1921-30)	+5	+58	-56	+3
1941-50 (change from 1931-40)	+650	+363	+70	+217

Two features distinguish this table from preceding text tables: 1) For all uses the figures here cited measure *changes* from decade to decade, not absolute amounts. 2) The consumption and gross capital formation entries include some requirements for maintenance as well as elements of progress.

Successive decade increments to national product have been mainly devoted to consumption. For the five decades as a whole no less than 72 per cent of the total of the increments to national product was devoted to consumer needs. Nine per cent was devoted to additions to gross capital, and 19 per cent to war and defense. There were, of course, variations from decade to decade, corresponding in general to decade shifts in margins above maintenance needs. The first, third, and fifth decades brought the greatest advances in both consumption expenditures and gross capital formation.

¹² The residential housing component of capital formation is an exception. Housing is an end product the use of which is spread over a number of years. For some purposes it would be useful to include residential housing among consumption goods. However, estimates of consumption including residential housing would not differ greatly from those given. Expenditures on residential construction during the last five decades have amounted to less than 5 per cent of all consumer expenditures.

advanced in a productivity spurt of exceptional intensity. Protracted depression brought retrogression in the thirties. The forties witnessed an extraordinary outburst of productive power. Drawing upon great additional resources of manpower and using improved equipment and new productive techniques, we provided war materials in massive proportions; in the same decade we lifted consumption levels to heights never before attained.¹³

We obtain a clearer view of the historical course of consumption levels by reducing the consumption increments to per capita terms, and showing each decade gain against the pre-existing level of per capita consumption. This is done in the following table; the expenditure figures are decade totals, per capita.

<i>Decade</i>	<i>Per capita consumer expenditures</i>	<i>Change from preceding decade</i>	
	(1929 dollars)	<i>Absolute</i> (1929 dollars)	<i>Relative</i> (per cent)
1891-1900	3,157		
1901-10	4,166	1,009	+32
1911-20	4,537	371	+9
1921-30	5,741	1,204	+27
1931-40	5,670	-71	-1
1941-50	7,692	2,022	+36

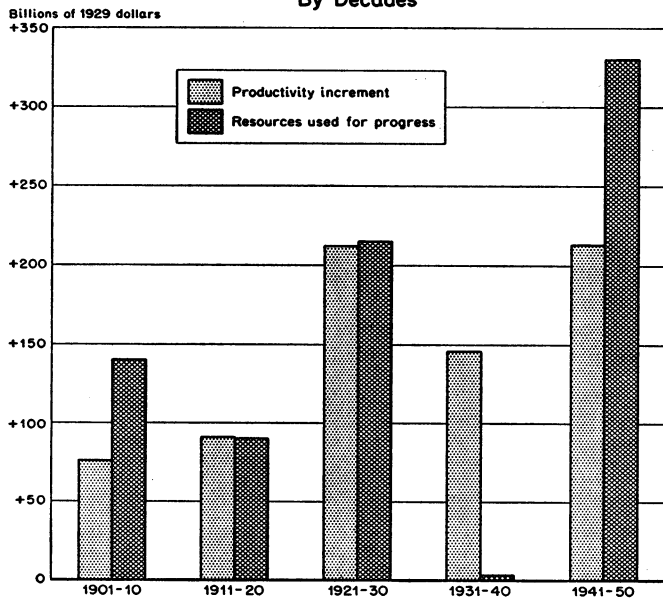
From an average per capita expenditure of \$3,157 in the decade 1891-1900, there was an advance of over one thousand dollars to \$4,166 in the decade 1901-10. (These are, of course, decade totals, in dollars of 1929 purchasing power. A figure for per capita expenditure per decade may be divided by ten to give the more familiar

¹³ The major advance in consumption levels came, of course, in the second half of the latest decade, but even during the years of fighting there was a substantial net gain in the output of consumption goods. We may, roughly, break the total consumption increase of 285 billions of 1929 dollars recorded for the decade as a whole into a 93 billion dollar gain from 1941 to 1945 and a gain of 192 billions from 1946 to 1950. The base of comparison for each of the five-year periods is the decade 1931-40.

One factor contributing to the notable consumption gain in the forties was the relatively low level of consumption in the thirties, which fell slightly below the preceding decade. The thirties provide the base of comparison for the forties.

average annual per capita expenditure on consumption goods and services.) This was a gain of 32 per cent over the ten-year period. The next great advance came in 1921-30, with a jump of 27 per cent over the preceding decade. The final decade brought a gain of 36 per cent in per capita consumption expenditures, to a level of \$7,692. This amounts to \$769 per capita of the population per year, a notable advance over the average of \$316 prevailing fifty years before. (The yardstick is, of course, a dollar of constant purchasing power.) The thesis that industrial development is necessarily marked by increasing misery would be hard to defend in the light of this record.

Figure 4
Productivity Increments and Resources Used for Progress
By Decades



On the role of the productivity increment in progress

Decade after decade the major portion of the resources making up the margin above maintenance needs has been used for progress — to elevate consumption levels and to expand our capital plant. The resources so used are not sharply defined. We do not earmark for particular uses certain additions to labor input, certain new plants, or specified productivity gains. Nevertheless, we may ask what part has been played in the economic advances of the last fifty years by the increments to product attributable to gains in productivity. We cannot trace particular gains to particular results, but it is suggestive to compare the magnitudes of productivity gains, margins above maintenance needs, and resources used for progress. The several series, in the form of decade aggregates, are repeated in the following table. The measures relating to productivity and progress are shown graphically in Figure 4.

Decade	Productivity increment	Margin above maintenance (billions of 1929 dollars)	Resources used for progress	Productivity increment as percentage of	
				margin above maintenance	resources used for progress
				(per cent)	(per cent)
1901-10	76	144	140	53	54
1911-20	91	118	90	77	101
1921-30	212	223	215	95	99
1931-40	146	14	3		
1941-50	213	558	330	38	65

In the thirties substantially all the productivity increment was used for maintenance purposes. Omitting this decade, the sum of the productivity increments was equal to 57 per cent of the sum of the margins above maintenance needs, to 76 per cent of the sum of the resources used for progress over the half century. These percentages varied from decade to decade, but only in the forties did the productivity increment amount to less than one-half of the margin above maintenance needs. (A great increase in the volume of labor input was the chief factor in the expansion of this margin in that period.) The productivity increment equaled the full amount of the resources utilized for progress in the second

and third decades; in the first decade it was more than one-half, in the fifth decade almost two-thirds, of the total amounts available for progress.

In considering productivity gains as a factor in economic and social progress, we must not regard productivity as an independent first cause, nor overlook the reverse influence of progress on productivity. We may not say that there would have been no progress in the second and third decades had there been no productivity gains, or that the increment to product available for progress would have been reduced by fifty to sixty per cent in the first and fifth decades if manhour output had not increased. For if productivity had not increased, complex related processes would have been modified. Hours of work would not have been reduced as they were in the twenties and thirties if manhour output had not gone up; the size and degree of use of the labor force would have been altered somewhat; the capital plant would not have grown as it did, and capital maintenance requirements would have been less. In the interactions of the factors in economic change, productivity gains were at once cause and effect of these associated movements in capital supply, in the labor force, and in working conditions. Yet there can be no doubt, from the relative magnitudes involved, that the productivity factor, as a closely correlated variable, has played a major part in the advances in consumption levels and the expansion of capital plant that constitute economic progress.¹⁴ The form of progress most richly and consistently aided by

¹⁴ Additions to output attributable to the input of new labor played a major role in meeting defense needs in the forties, and contributed materially to progress in that decade. In the thirties the labor input increment was negative. It was small in the twenties — equal to less than one-ninth of the output of resources used for progress. In the decade spanning the first world war the labor input increment, while not inconsiderable, was much smaller than the productivity increment. Only in the first and fifth decades was the input of new labor large enough to play an active role in progress.

There can be no doubt that some part of the labor input increment (a part including the labor of immigrants and of new members of the labor force with young families) is utilized for population maintenance, rather than for the lifting of consumption levels or for net capital formation. — the two forms of economic progress. In periods of war a major portion of the labor input increment is allocated to defense. These considerations support the evidence provided by the statistical record that the productivity increment has been a far more potent factor than the labor input increment in economic progress in the United States over the last half century.

productivity gains has been progress in living standards. Such gains have also given steady support to the expansion of capital plant. They have helped to maintain established consumption standards when other instruments failed. The steadily re-created productivity increment has been, at once, the spearhead of progress and a reserve against emergency.

IV

In the preceding pages we have discussed the pattern of economic growth of the United States over the last half century. The materials presented bear on questions central to the appraisal of an economic system. Has it produced? Has it grown in effectiveness as a producing mechanism? It was Ernest Bevin's view that the central test of an economy is "Has it delivered the goods?". But this cannot be the sole criterion of judgment. We must ask "How has productive power been used?" This question raises issues beyond the economic. Arnold Toynbee has said that the new power found through the simplification of process that generates the growth of civilizations always presents a moral challenge. Disposable resources may be used to promote welfare or illfare. In a progressive economy, marked by steadily recurring productivity increments and expanding margins above maintenance needs, each generation faces this challenge anew.

Our economy, in its performance over the first half of the twentieth century, has clearly met Bevin's test. We have used our natural resources to produce a great and growing volume of goods and services. Apart from the protracted check that came in the thirties, the advance has been virtually unbroken. By far the greatest factor in this gain has been rising productivity. Machines, plants, administrative methods, and men have improved in productive quality; equipment has grown in quantity; flexible power has been carried to assembly line and bench. These improvements, embodied in innumerable major and minor working methods, have brought an increase in output per unit of productive effort that is probably without precedent in our history.

Appraisal of the uses to which these tremendous productive

powers have been put is not so simple. Non-economic standards of judgment must enter if the moral issues suggested by Toynbee are to be faced. We have used some of these powers for destruction, a fact that may be charged to the ill-fortune of our generation rather than to design and deliberate choice. Thanks to modern technology we have had to employ only a relatively small part of our resources to maintain and enlarge our productive plant. We have used most of our vast new powers to ease the lot of citizens at large through gains in leisure, and to improve it through diversified consumption patterns. Not all the standards expressed in this diversification might win a moralist's highest sanction. There are doubtless faults to amend. But the record leaves no doubt that much of our new productive power has gone, over this half century, to advance human welfare. In major degree, the benefits of industrial progress in the United States in this half century have served to lighten toil for producers and elevate living standards for consumers.

Note 1

ON THE PRESENT ESTIMATES OF GROSS NATIONAL PRODUCT

The estimates of gross national product used in this paper are a modification of Kuznets' basic concepts. Kuznets' peacetime concept of national product omits all war output of a nondurable character and "all nonwar expenditures of governments except those representing final products . . . or gross additions to government construction." (*National Product since 1869*, p. 23). For comparison with total labor input we wish to include the full defense output in national product; we therefore add to Kuznets' figures estimates of total war and defense expenditures. (These are unpublished estimates of M. Slade Kendrick for the period 1891-1938, estimates of the Department of Commerce for the years 1939-1950.) This addition would lead to a duplicate count of war durables, which do enter into Kuznets' estimates (peacetime concept) as elements of gross capital formation. To correct for this we deduct the equivalent of the war durables in Kuznets' series for the years 1917-21 and 1939-50, when such duplication would be considerable. We thus derive a series which differs somewhat from those of both Kuznets and Commerce — from Kuznets in that nondurable defense goods are included in our national product estimates in years of war and of peace, from Commerce in that the contribution of government to our estimates is more restricted. Kuznets' concept, which we employ except in respect to nondurable war goods, is narrower than that of Commerce in treating the contribution of government. Kuznets' present estimates extend only to 1949. We have projected his series to 1950 on the basis of a splice with the Department of Commerce series.

We have built up estimates of gross national product in constant dollars as the sum of its three deflated components. The deflators

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.¹ 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;

¹ 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.² We may do something by judi-

² 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

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.⁸ 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.

⁸ 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.⁴

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.⁵ 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.

⁴ 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).

⁵ 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.

Note 3

ESTIMATION OF THE LABOR INPUT INCREMENT AND THE PRODUCTIVITY INCREMENT

The problem is that of separating an increment to output into a portion associated with an increase in labor input, and a portion associated with a productivity gain. (There are three other cases, representing other combinations of plus and minus changes in the labor input and productivity factors, but the principle involved is the same.) Since there is interaction between the two factors, which are related in a multiplicative way, there can be no definitive solution, but useful approximations to the two components of the increment may be obtained.

In brief, the procedure is as follows:

- a) Estimate the increase that would have occurred in total output as a result of the given increase in labor input, but with no change in productivity. This gives what we may call Component *A* of the increment to gross national product.
- b) Estimate the increase that would have occurred in total output as a result of the given increase in productivity, but with no change in labor input. This gives what we may call Component *B*.
- c) Estimate the interaction component, the portion of the gain in gross national product that represents the combined result of an increment to labor input and an increment to manhour output. This gives what we may call Component *C*.

It is justifiable to assign Component *A* to the labor input factor, Component *B* to the productivity factor. *A* will vary directly with labor input, *B* with productivity. *C*, however, will vary with both factors. *C* is therefore arbitrarily divided, half being assigned to the labor input increment, half to the productivity increment.

This method may be illustrated with reference to decade aggregates for 1901-10 and 1911-20.

<i>Decade</i>	<i>Gross national product (billions of 1929 dollars)</i>	<i>Labor input in total manhours (relative)</i>	<i>Output per manhour (relative)</i>
1901-10	455	100.0	100.0
1911-20	603	111.4	118.9

The increment to gross national product (148 billions of dollars) is the sum of:

Component *A* ($455 \times .114$): 52 billions

Component *B* ($455 \times .189$): 86 billions

Component *C* ($148 - 52 - 86$): 10 billions

The final estimate of the labor input increment for 1911-20 is 57 billions ($A + \frac{C}{2}$, or $52 + 5$); the final estimate of the productivity increment is 91 billions ($B + \frac{C}{2}$, or $86 + 5$).

As I have suggested at an earlier point, neither of these increments is to be regarded as the specific product or the marginal product of any of the conventional factors of production. Changes in the productivity ratio $\frac{Q}{MH}$, from which estimates of the productivity increment are derived, are the net result of a complex of movements, all involving relations between output and factor input that are defined conceptually by the traditional laws of return (operating over time). Thus if a change in labor input alters the ratio of effort input to natural resources or to instruments used and, through the play of diminishing returns, reduces average output per manhour of work done, these related changes will be reflected in both the labor input increment and the productivity increment (how their results will be divided between the two increments will depend on the relative magnitudes of the changes in labor input and in average return per manhour of labor input).

The method described is the mathematical equivalent of the following:

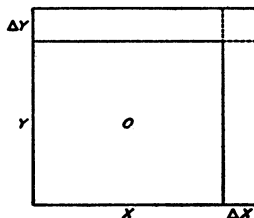
The labor input component of the increment to product between two periods is the increase in output that would have resulted from the given

increase in labor input, had the employed labor force been working at a productivity level equal to the average of manhour output in the two periods compared.

The productivity component of the increment to product is the increase in output that would have resulted from the given gain in output per manhour, had labor input been equal to its average during the two periods compared.

It may be demonstrated that the sum of the two components, as thus established, is equal to the total increment to product.

Let X = Manhours of work input,
 period 1
 $X + \Delta X$ = Manhours of work input,
 period 2
 Y = Output per manhour,
 period 1
 $Y + \Delta Y$ = Output per manhour,
 period 2
 $O = XY$ = Total output, period 1
 $O + \Delta O = (X + \Delta X)(Y + \Delta Y)$
 = Total output, period 2



If we assume that X and Y change linearly between periods 1 and 2, then:

$$\bar{X} = X + \frac{\Delta X}{2}$$

$$\bar{Y} = Y + \frac{\Delta Y}{2}$$

The increment associated with the change in X is given by $\Delta X \left(Y + \frac{\Delta Y}{2} \right)$.

The increment associated with a change in Y is given by $\Delta Y \left(X + \frac{\Delta X}{2} \right)$.

As the sum of these two increments we have:

$$\Delta X \left(Y + \frac{\Delta Y}{2} \right) + \Delta Y \left(X + \frac{\Delta X}{2} \right) = Y\Delta X + X\Delta Y + \Delta X\Delta Y = \Delta O$$

(I am indebted to my colleague Henry Scheffé for this mode of viewing the decomposition of the increment to product.)

Beyond the formal equality thus established, the procedure has logical justification. In the limiting case in which there is no change in productivity, the entire increment to product is assigned to the change in labor input; at the other limit in which there is no change in labor input, the entire increment to product is assigned to the change in productivity. In cases falling between these limits, as we have seen, half of the small rectangle corresponding to the product of ΔX and ΔY (this corresponds to C of the procedure first noted) is assigned to each of the two factors.

The actual values, by decades, of the several components of the increments to product are given below. Component *A*, it will be noted, is equivalent to $Y\Delta X$, Component *B* to $X\Delta Y$, and Component *C* to $\Delta X\Delta Y$.

<i>Decade</i>	<i>Increment to gross national product</i> (billions of 1929 dollars)	<i>Component A</i>	<i>Component B</i>	<i>Joint component C</i>
1901-10 (change from 1891-1900)	+161	+77	+67	+17
1911-20 (change from 1901-10)	+148	+52	+86	+10
1921-30 (change from 1911-20)	+235	+20	+209	+6
1931-40 (change from 1921-30)	+5	-129	+158	-24
1941-50 (change from 1931-40)	+650	968+	+173	+81

In deriving final estimates *C* was divided equally, for each decade, between the labor input component and the productivity component. In presenting these estimates it is recognized, of course, that labor input and productivity have changed together, and have interacted as they changed. Neither would have had the value actually recorded for a given decade had the other not been present as an active factor.

If the changes of the five decades are aggregated, we obtain from the above table the following summary of shifts between the decades 1891-1900 and 1941-1950:

<i>Total increment to gross national product 1891-1900 to 1941-1950</i>	<i>Component A</i>	<i>Component B</i>	<i>Joint component C</i>
1,199	416	693	90

Splitting the joint component *C* in half, and assigning half to each of the two factors, we have for the half century of growth a labor input increment of 461 billions (of 1929 dollars), a productivity increment of 738 billions. These are, respectively, 38.4 per cent and 61.6 per cent of the total increment of 1,199 billions.

Since the estimated magnitudes of the several components of an increment to national product are affected by the time unit employed, it is of interest to compare the preceding division of

the half-century increment to national product with the division we should obtain by treating the half-century increment as a single lump. Relevant measures are given below:

<i>Decade</i>	<i>Gross national product</i> (billions of 1929 dollars)	<i>Labor input</i> <i>in manhours</i> (relative)	<i>Output per</i> <i>manhour</i> (relative)
1891-1900	294	100.0	100.0
1941-1950	1,493	180.5	281.3

Applying to this half-century increment the method just described, we have:

<i>Increment to gross</i> <i>national product</i>	<i>Component</i> <i>A</i>	<i>Component</i> <i>B</i>	<i>Joint</i> <i>component</i> <i>C</i>
1,199	237	533	429

If we split the joint component, assigning half to each of the two factors, we have for the half century a labor input increment of 451.5 billions, a productivity increment of 747.5 billions. These are, respectively, 37.7 per cent and 62.3 per cent of the total increment of 1,199 billions.

Chief interest attaches to the difference between the two values of the joint component, 90 when we move by decade steps, 429 when we move by a single half-century jump. In the latter case a much larger quantity is allocated on the somewhat arbitrary half-and-half division. Yet this division gives final values for the two components that are very close to those obtained from the presumably more accurate decade intervals.

The close agreement is in part fortuitous. Results obtained in the one case are not a check upon the other. The method of division here employed, applied to a single time period and then to subdivisions of that time period, would give identical results only where:

- a) the relations between the two variables (labor input and output per manhour) are linear;
- b) the separate subperiod movements mark out equal areas

above and below the straight line defining the net movements of the two variables between terminal dates of the whole time interval.

(The line defining the relation between labor input and output per manhour for each subperiod — here a decade — connects the appropriate corners of a rectangle similar to that represented by $\Delta X \Delta Y$ in the diagram on page 33. The limiting case, for these conditions, is that in which the movements between subperiods and between terminal dates of the whole time interval are defined by the same straight line.) In the present instance the related movements of labor input and manhour output during the last two decades of the half century departed sharply from the direction of changes during the first three decades. For the half century as a whole there was virtual equality of the deviations above and below the line marking the net fifty-year movements of the two variables; close agreement of the derived measures results. Where there is failure to agree, estimates based upon the shorter intervals would be preferred.

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