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THE POTENTIAL ECONOMIC GROWTH IN THE UNITED STATES

BY

JAMES W. KNOWLES

WITH THE ASSISTANCE OF

CHARLES B. WARDEN, Jr.

MATERIALS PREPARED IN CONNECTION WITH THE

STUDY OF EMPLOYMENT, GROWTH, AND PRICE LEVELS

FOR CONSIDERATION BY THE

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STUDY OF EMPLOYMENT, GROWTH, AND PRICE LEVELS

(Pursuant to S. Con. Res. 13, 86th Cong., 1st sess.)

OTTO ECKSTEIN, *Technical Director*
JOHN W. LEHMAN, *Administrative Officer*
JAMES W. KNOWLES, *Special Economic Counsel*

LETTERS OF TRANSMITTAL

JANUARY 12, 1960.

To Members of the Joint Economic Committee:

Submitted herewith for the consideration of the members of the Joint Economic Committee and others is a paper on "The Potential Economic Growth in the United States."

This is one of a number of subjects which the Joint Economic Committee requested individual scholars to examine and report on in connection with the committee's study of "Employment, Growth, and Price Levels."

The findings are entirely those of the author, and the committee and the committee staff indicate neither approval nor disapproval of this publication.

PAUL H. DOUGLAS,
Chairman, Joint Economic Committee.

JANUARY 10, 1960.

Hon. PAUL H. DOUGLAS,
Chairman, Joint Economic Committee,
U.S. Senate, Washington, D.C.

DEAR SENATOR DOUGLAS: Transmitted herewith is one of a series of papers prepared for the study of "Employment, Growth, and Price Levels" by outside consultants and members of the staff. The author of this paper is James W. Knowles, Special Economic Counsel of the Study.

All papers are presented as prepared by the authors.

OTTO ECKSTEIN,
Technical Director,
Study of Employment, Growth, and Price Levels.

STUDY PAPER NO. 20

THE POTENTIAL ECONOMIC GROWTH IN THE UNITED STATES [1]

PART I

CHAPTER I. THE NATURE AND SIGNIFICANCE OF POTENTIAL ECONOMIC GROWTH [2]

Confidence in the Nation's potential for future economic growth has been the fundamental assumption upon which public and private economic policies have been based in the United States since its founding. Though occasionally challenged during unexpected reverses, as during the 1930's when concepts of economic maturity and stagnation were brought into the debates over economic policies for a time, this basic belief in the possibilities or opportunities for future increases in employment, output, and in per capita, real purchasing power for a rising population, has survived all vicissitudes of public debate to provide the foundation for public and private economic policies.

Hamilton's "Report on the Subject of Manufactures," 1791; encouragement to canal building; public lands policies; land grants to encourage railroad building beyond the limits of settlement; "Manifest Destiny;" aid to agricultural and mechanical education, including colleges; the "New Era;" the patent system—any student of American economic history could compile a long list of examples of growth-oriented policies and programs in both the public and private sectors of the economy. In 1812, when the population was less than 10 million, a sketch of the Nation's destiny pointed to an economy of 100 million, stretching from Atlantic to Pacific, possessed of large cities, magnificent canals and roads, seminaries of learning, vast domestic manufacturing industries, and other advantages of division of labor. (1) In 1872, when the population was hardly 40 million, another writer foresaw a population of 300 million, mail delivery from coast to coast in 24 hours, artificial fibers, and expansion of steel production by over 50 times (incidentally a drastic underestimation) (2).

[1] I wish to express my deep appreciation to my research associate in this study, Mr. Charles B. Warden, Jr., who carried the burden of preparing the various time series for use in the study and brought together the material on potential labor force and hours of work. Without his careful and unstinting efforts, the study could not have been brought to completion.

Mr. Thomas Wilson of the special study staff gave invaluable assistance in carrying out the complex computations on the IBM 650 computer. We are especially grateful to the Bureau of Labor Statistics and the Board of Governors of the Federal Reserve System, who made time available on their IBM 650 computers so that we could carry out these computations.

[2] Numbered references in parentheses in text are to numbered sections of "Technical Materials," beginning on p. 45.

The Employment Act goals

When the Employment Act of 1946 incorporated economic growth as an objective of national economic policy, therefore, the action was in line with a long American tradition. The emphasis on maximum or full employment in the early history of the act, both before and after enactment into law, occasionally has led to the comment that recent stress on economic growth and price stability as objectives of policy constitutes a change in interpretation of the act's stated goals of "maximum employment, production, and purchasing power" (3).

The act's language and history yield a different view. Section 2 declared it is to be "* * * the continuing policy and responsibility of the Federal Government to use all practicable means * * * to promote maximum employment, production, and purchasing power," with maximum employment clearly stated to involve "* * * creating and maintaining * * * conditions under which there will be afforded useful employment opportunities, including self-employment, for those able, willing, and seeking to work," and, further, these objectives should be accomplished through programs which would "* * * foster and promote free competitive enterprise and the general welfare" (4).

The Employment Act, it should be noted, does not purport to guarantee or assure full employment, an adequate rate of growth, and a stable level of prices. It does commit the Federal Government, in cooperation with other public and private agencies, to "* * * utilize all its plans, functions, and resources" to promote the accomplishment of these objectives.

The Employment Act, as basic enduring statutory law, is general in its statement of these goals or objectives, but it seems clear from the legislative history that supporters of the act did not intend its generalized expression of ultimate or ideal aspirations of a free people to be empty phrases or mere timeless expressions of vague hopes. In fact, under the act, the President is required to submit to the Congress at the beginning of each of its regular sessions an Economic Report which shall set forth "* * * the levels of employment, production, and purchasing power obtaining in the United States and such levels needed to carry out the policy [sec. 2] * * *." Prediction of the future course of the economy in specific quantitative terms was not required, according to one interpretation of section 3(a), though the act does direct that the Economic Report contain a statement of "* * * current and foreseeable trends in the levels of employment, production, and purchasing power * * *." There is an unmistakable mandate, however, for the regular, annual administrative determination of the levels of activity which will give definite and timely meaning to the ideals expressed in section 2 of the act (5).

This annual determination of the specific employment, output, and price levels which would constitute, in the judgment of the President and his advisers, the optimum achievement of the economy for the particular year requires the development of estimates of the economy's potentials for employment, growth, and price performance. Such quantitative economic potentials provide guidelines with which the actual performance of the economy can be compared, revealing directions and magnitudes of improvements needed if national economic objectives are to be achieved.

When estimates of the economy's potential employment and output are computed, however, the result necessarily constitutes measures of potential growth of the United States. In a country with an increasing population, sufficient savings, and a significant rate of technological advance, maximum employment and output, if achieved year after year, will be accompanied by growth—the increase in population makes possible a rising supply of labor; saving makes possible a rising stock of capital; and technological progress results in labor and capital becoming more efficient so output rises even faster than population. Obviously this is not an inevitable set of relations at all times in all countries but the combination has been true in this country.

The connection between maximum employment and production, on the one hand, and potential growth on the other, was recognized even during the debates preceding passage of the Employment Act. A number of projections were prepared providing estimates of the growth of employment and output which might reasonably be expected in the immediate postwar years in view of past trends and then known conditions (6). The early Economic Reports contained similar estimates of the possible employment and output which could be achieved if recession were avoided (7). Beginning in 1950, its staff has prepared similar estimates for the use of the Joint Economic Committee, estimates to which the label "potential" growth has been applied since publication of a staff study in 1954, entitled "Potential Economic Growth of the United States During the Next Decade" (8).

In the same way that economic growth possibilities have been an inseparable part of the Employment Act's history and of the goals set forth in section 2, the ideal of a stable level of prices has always been a basic part of the act. It is easy to understand why this point should be the subject of controversy since the act treats of price stability solely through its reference to maximum purchasing power. This term has generally been taken to imply a stable level of prices since advancing prices clearly erode the purchasing power of both current incomes and past savings (9). But the failure of Congress to delineate clearly the kind of price behavior to be sought under the act provided a basis for controversy.

From the beginning, the President's Economic Reports, statements of his Council of Economic Advisers, and the activities and reports of the Joint Economic Committee have reflected deep concern about the inflationary tendencies of the postwar period. President Truman's first Economic Report under the act (January 1947) pointed to the rise in prices in the latter half of 1946 as an impediment to the maximum purchasing power goal of the act. The Joint Economic Committee in June and July 1947 devoted its first major inquiry to price developments. Whatever may be one's view as to the desirability of changes in the language of the act, one point is indisputable—those in the Federal Government charged with the responsibility for policy under the act have always operated on the belief that reasonable price stability is one of the objectives it sets for national economic policies (10).

This study of the potential economic growth of the United States, therefore, is the latest in a series of quantitative analyses of economic growth possibilities which have originated in connection with the Employment Act. It differs in some respects from its predecessors, however, and succeeding chapters can be more easily followed if the concept of economic growth, its relationship to policy analysis under the Employment Act, and the analytical framework used in developing the estimates of potential growth are sketched briefly at the outset.

In line with the preceding discussion, this study looks at the goals of maximum employment, production, and purchasing power as directing attention of public and private policymakers to the ideal of a dynamic, growing economy, exhibiting a minimum of fluctuation in actual rates of use of labor and capital around the maximum average rate of utilization feasible under existing institutional conditions, which, at the same time, is consistent with reasonable stability of the general average level of prices of goods and services.

A dynamic economy

The "dynamic" aspect of this ideal seems to have been reflected in the act, though not perhaps in the exact language an economist might suggest if it were being drafted today. The goal of a free, private, competitive economy, listed in section 2, calls for a dynamic economy, i.e., one free from those public and private restraints which would impede adjustment to changes—

(*a*) in individual tastes and preferences;

(*b*) in effective demand for different goods and services as a result of (*a*) above combined with changes in the level and distribution of purchasing power, and changes in relative prices;

(*c*) in techniques for combining resources in production;

(*d*) in characteristics of products and services;

(*e*) in the geographic distribution of population and industries; and

(*f*) in international economic relationships.

"Dynamic" thus describes the more outstanding characteristics of American economic life. The frequency and magnitude of these changes have a profound effect on the potential rate of economic growth, on the magnitude of the frictions in the economy and hence on the proportion of resources which are unavoidably idle at any given time, and on the ease or difficulty faced in minimizing economic fluctuations.

Economic growth

Economic growth is an increase in the Nation's capacity to produce goods, services, and leisure (11). It is not, therefore, synonymous with the idea of progress or with the more conventional concept of economic growth as an expansion of real per capita gross national product, or with other definitions of growth that have been used from time to time. The distinction between progress and economic growth is the familiar distinction economists make between means and ends. Progress relates to an increase in the welfare of the people of the Nation while economic growth is an increase in the economy's productive capacity, i.e., an increase in the Nation's ability to provide the material means to satisfy individual or collective desires for different kinds of goods and services, and thus, in the end, contribute to an increase in welfare. Much of the increase in well-being—progress—comes about in ways unrelated, or only indirectly related, to economic growth, per se, such as: a decline in the death rate; a rise in the percentage of children of school age in school and of youths going on to higher education; the growth of leisure; the growth of the creative arts; the circulation of books; a rise in political and religious freedom for the individual; improvements in moral standards and behavior.

Economic growth as an objective of national economic policy, therefore, is an intermediate objective—it is a goal which the Nation can seek in order to provide a material basis for progress or an increase in welfare. If the output of goods and services that results from the increased productive capacity of the economy is used wisely, and in accordance with the desires of individuals and of the community as expressed through community and political channels, it can contribute to welfare and progress. Professor Galbraith has produced perhaps the most familiar recent example of an economic analysis resting on the distinction between progress and growth in capacity to provide material goods and services (12).

Distinction between economic growth and a mere increase in output, either in the aggregate or per capita, is of both practical and theoretical significance. The distinction is between the performance of the economy in any given period of time (output, or increase in output, for example) and its capability. Economic growth refers, of course, to an increase in the capability or productive capacity of the economy while the current performance of the economy is measured by output, employment, the increase in output, output per capita, real income per capita, the amount of leisure (individual), and the stability or instability of output, employment, and prices.

Current economic performance

Performance of the economy is reflected in the Employment Act's description of the other aspects of its ideal of how the economy should operate. As stated above, this means at least the following: (1) a minimum of fluctuations in actual rates of use of labor and capital around the maximum average rate of utilization feasible under existing institutional conditions, managerial skill, and economic knowledge; and (2) reasonable stability of the general level of prices of goods and services.

The first part of this definition of economic performance is generally called economic stability for it means that there is a limited range of fluctuations in the rate at which the Nation uses its economic capacity, human and material. It therefore implies a constantly rising level of employment and of total production of goods and services as the Nation's supply of labor and capital goods increases. In the Employment Act this stability objective, in part, is described as maximum employment and production, referring to that aspect of economic stability which I have just described.

It also includes, of course, the second aspect already noted, stability in the general level of prices of goods and services. In respect to this goal, it is necessary to refer to the fact that the economy should be dynamic, adjusting readily, rapidly, to changing conditions. In such an economy, relative prices must remain free to change, that is each individual price, or the prices of individual goods and services, must be free to change rapidly and in such magnitude as will call forth those changes in outputs, demands, and resource allocations required by changing preferences, incomes, and technological feasibilities. Price stability implies that while the general average of prices is reasonably stable, with no upward or downward drift, each individual price remains free to change relative to the general level so long as the various changes offset each other and leave the general average unchanged.

Potential output versus capacity

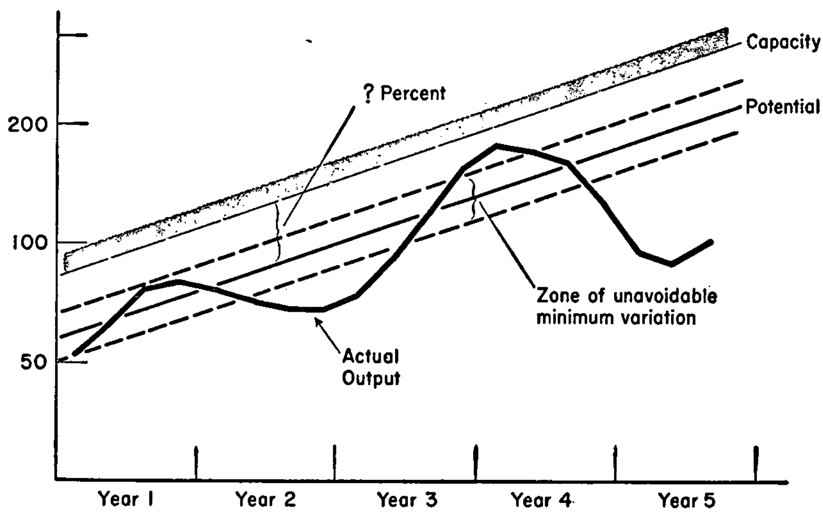
At the outset of this chapter, the term "potential" was used and reference was made to the Nation's potential for economic growth. Now we refer to economic growth in terms of an increase in the Nation's capacity to produce goods and services as well as leisure.

In the analysis that follows, the distinction between capacity and the output potential for which a measure is developed, is of critical importance. To make the relationship clear, chart I was developed.

CHART I

CAPACITY, OUTPUT, AND POTENTIAL

an EXPLANATORY SKETCH



It will be noted that the topmost line, labeled "capacity," is above the "potential" by some unspecified percentage, though the two lines are shown parallel. The potential is a measure of the optimum or best practice which it is believed the economy is capable of sustaining on the average, year after year, without running into serious instability of employment, output, or prices. It is, in a word, a measure of what would be reasonably good performance of the economy, maintaining a stable relationship between output and capacity. Around this line of potential, lines have been dotted which represent what may be termed tolerance zones. Within these limits, the economy is fluctuating by so little that it cannot be regarded as being a serious challenge to the objectives of the Employment Act though certainly a matter of concern. Over time, it might be possible to reduce this type of variation. In fact, one of the objectives of economic research, both pure and applied, should be to determine what these limits of variation are and how much they can be narrowed in practice.

No attempt to determine them quantitatively has been made in this study.

Actual output is shown varying part of the time within this acceptable zone on either side of the potential, sometimes above and sometimes below. Occasionally, output may move completely outside of this tolerance zone. Either it rises too close to capacity, hence, into a seriously inflationary and probably unstable position, or, on the other hand, falls far below the potential as recession and widespread unemployment develop. In terms of the objectives of the Employment Act, the stability goal would be achieved if the economy could remain inside the zone of acceptable variations, as close as practical to the potential line. Over time, to the extent possible, an increase in the ratio of potential output to capacity would be desirable so long as this does not involve either inflation or drastic instability of output and employment. As a practical matter, therefore, the measurement of the potential output of the economy can be an important instrument for analyzing the relation of current economic performance to the objectives of the Employment Act, that is, as to whether or not output and employment are staying as close as reasonable men might require to the standard set up by the Employment Act. It also may be used as a convenient technique for analyzing the current situation of the economy a use to which, in fact, the staff of the Joint Economic Committee has been putting earlier versions.

If an index of capacity for the total economy was available, the problem would reduce to two steps: (1) Analysis of causes of growth of capacity; and (2) analysis of operating characteristics of the economy to discover the optimum operating rates, or ratic of output to capacity. But, economic analysts have debated at length whether or not it is possible to develop an unambiguous concept of capacity for the economy (or even a single industry), much less measure it. To illustrate the point, it may be possible to operate a given plant 24 hours a day, yet under ordinary circumstances the usual practice may be to operate only one or two 8-hour shifts a day. Suppose the plant ordinarily operates on one 8-hour shift per day, what is the practical capacity of the plant? By this standard, capacity would be the amount produced in one 8-hour shift. Obviously, if demands were strong enough it would be possible to operate the plant three shifts, or 24 hours a day—tripling its capacity. Many plants that normally operated one shift or two shifts added shifts during World War II, and plants that normally operated on an around-the-clock, continuous-process basis were run during these war emergency years at increased rates of output through such devices as lengthening the period between maintenance or repair, thus reducing downtime.

In a host of ways, therefore, the maximum output of the economy is flexible over a considerable range, even when each industry or trade is operating at what managements ordinarily would call full capacity rates. No attempt was made, therefore, to measure the ultimate capacity of the economy. It is clear only that it must be much higher than the measure of potential output arrived at in this study. *For each year, the potential output level represents the amount the economy could produce at some stipulated rate of use of the labor force and of capital, and under the assumption that productive resources are used at something approaching the economy's notion of a least-cost combination of inputs.* That is, capacity, however conceived, is being operated so as to produce output at the least cost per unit of output, in accordance with the best practices possible with existing management, capital, and training and knowledge of the labor force. It is, in a word, a measure of what practical man can do under the usual operating conditions maintainable over long periods of time without excess strain or breakdown, on the one hand, or, on the other, excessive, wasteful slack in the system, particularly prolonged, involuntary unemployment of labor.

The rate of employment

A key element in the measurement of the potential output is the ratio of employment to the labor force, or, in more familiar form, the percentage of the labor force unemployed. This ratio, the key to debate about Employment Act policies, never has been defined officially, either by the executive branch, the Congress, or any of its committees. Indeed, no such definition could be stated which would be valid for all time, because of two basic facts.

First, measures of employment, labor force, and unemployment, undergo improvements from time to time, with a consequent change in the level of unemployment revealed by the surveys and in the ratio to the labor force. The same degree of tightness in labor markets, for example, might be measured at one time by, let us say, 3½ percent of unemployment, whereas later under a different system of measurement, perhaps using an improved interviewing technique, an enlargement of sample, or other change in the statistical program, the same degree of tightness might be measured by a figure which averaged 4 percent. Does this mean the percentage of unemployment has increased or our objectives have changed? Obviously not. The same degree of tightness or slack in the labor force is revealed each time. It is simply that the measuring device has changed and, presumably, is more efficient than formerly. There is need to be aware constantly of changes or improvements in the system of economic measurement, and, from time to time, redefine, in terms of the changing system of measurements, maximum employment, production, and purchasing power within the meaning of the Employment Act (13).

The second point is that the Nation ought to, and does, strive continually to make improvements in the efficiency with which labor markets operate and in the efficiency with which labor is used. If the efficiency with which shifts of labor from job to job and from industry to industry, is raised and the stability of the economy increased, then we should be able to operate with, let us say, only 3 percent unemployment on the average compared to about 4 to 5 percent unemployment, which seemed to have been achieved, in fact, on the average of the better years, simply because policies could not be designed to do better consistently (14). One path of progress is through learning how to operate with less slack in the labor force—less time spent between jobs, unemployed because labor markets do not operate smoothly in transferring labor from places and industries experiencing declining demand to places and industries with increasing demand.

Even if the efficiency of the economy increases, and the flexibility and speed of operation of labor markets improves, the Nation may be willing to tolerate or even seek a higher level of unemployment than the minimum technically possible. This might happen if the unemployment was exceedingly short-range—that is, only a few days or a week or two at a time for each person affected—and constituted a necessary condition for achieving a desired speed of movement of labor between industries, occupations, and jobs; in the process, producing a much-enlarged scope of opportunity for each individual to improve himself, and a wider range of choice. In a word, although there could be a net gain in welfare or progress from a higher rate turnover of the labor force, this higher turnover itself—though desirable—would generate a higher level of unemployment on the average (15).

While there has been no official statement or determination of the percentage of the labor force unemployed which shall be regarded as consistent with the objectives of the Employment Act, nevertheless, various figures have been widely used in discussions of policy under the act. These figures range between 2 percent on the low side to 5 or 6 percent unemployed in the upper end of the range. The staff of the Joint Economic Committee has from time to time computed the output of the economy at an assumed rate of maximum employment, or a potential growth trend, basing this computation on the assumption that unemployment would average about 4 percent of the civilian labor force (16). In periods of high prosperity, with modest fluctuations in output and employment, unemployment has averaged about 4 percent of the labor force.

In view of the historical record, and the past use of the 4 percent figure by the staff, it is again used in this current study. In the discussion below, chapter IV, it will be shown that the choice of an assumed rate of unemployment does have implications both for public and private policies, and for the rate of growth. For the historical analysis in chapter III, however, the choice of any average that would seem reasonable for the past probably would result in a potential output close to that calculated on the assumption of 4 percent actually used. While a lower rate than this could be achieved in the future if private and public policies were designed to do the job, in the past the economy has not achieved a lower unemployment on the average. It seems useless to measure past performance against a standard the economy seems to have been unable to achieve in view of its institutions and technical possibilities.

The measurement of potential growth

How can economic growth, in terms of the potential output as described above, be measured?

In the first place, the output measure to be used is the total of goods and services in constant prices, that is, real gross national product. Potential output, then, is the real GNP that the economy would be capable of producing under stipulated assumptions, the principal one being that 96 percent of the labor force is employed. This is merely the indicator or measure.

How can the level of this indicator and its rate of growth be calculated? The potential output and growth of the economy depends on the amount and rate of growth of available resources and their productivities; in short, upon the size of the labor force, its skills and know-how, on the accumulated stock of capital, on the availability of natural resources, and upon the current technology and the rate at which new techniques are introduced.

These factors are familiar. Output and growth also are influenced by the rate and character of scientific research; the proportion of output which is plowed back into intangible capital assets; the extent to which the current capital stock embodies the most up-to-date technology or still reflects that of some past period; rising levels of educational attainment and health; the ratio of the labor force to population; changes in the average number of hours worked per year per person employed; changes in the average degree of managerial skill; the degree of stimulation of advancement of efficiency from competition at home and abroad; and a wide variety of influences arising out of the social and political environment in which the economy operates. Some of these factors cannot be measured directly at the present time, some of them are not measured though perhaps they could be, and some may not be measurable at all.

Economists, however, cannot put off attempts at the solution of practical problems until final, perfect solutions to the problems of concept and measurement can be found. Progress comes from the continual interplay of theory, measurement, and empirical analysis so that theorists develop better analytical tools out of the challenge of practical research attempts, while measurement and empirical analysis progress by using to the utmost whatever tools are available to do the best job possible at the moment, recognizing always that eventually some better solution will be possible when improved tools and improved measurements are developed out of experience.

In this spirit, the present study is an attempt at development of a simple model or description of the economic process of production, using available measurements of the various inputs and outputs, and at development of a way of determining from these data the quantitative relationships between the various inputs and outputs.

In chapter II, the technical argument is outlined, including the measures of the various factors and the aggregate function, expressing the relation between inputs of productive factors and outputs of goods and services. Further, the structure of the model of the growth of the economy will be related to preceding work.

In chapter III, the actual fit of the model to the historical data is given, showing the way in which the actual relationships were developed by processing various measures of inputs and outputs. Some of the implications of this analysis for interpreting past economic growth are developed.

In chapter IV, the measures of potential economic growth developed in chapter III are utilized to develop a picture of the possibilities for future potential economic growth of the United States to the year 1975, with some discussion of their implications for public policy.

Notes referring to sources or expanding on particular technical points in the analysis are given in part II of this paper, entitled "Technical Materials." Numbered references throughout part I are to these numbered "Technical Materials."

Chapter II. The Determinants of Potential Economic Growth

The calculated growth potentials of the American economy presented in chapters III and IV rest upon an analysis of the historical record of the performance of the economy and of the major output-determining factors. Fortunately today the analysis of the factors which determine the output of the economy at any particular time and which determine the rate at which the economy's capabilities for producing goods and services increases over time, can draw upon a much larger and richer body of theoretical and empirical research than formerly.

Almost two decades ago, when, during World War II, analysts in and out of Government developed models of the economic growth of the economy as a basis for making projections of a postwar full employment economy, the data available and the analytical tools were more primitive than at present. These models, or projections were used to study the problems of reconversion and unemployment which would arise when World War II came to an end, and a return to more peaceful conditions was possible. In the intervening years, both economic theory and empirical research have turned increasingly to the study of economic growth and progress under various pressures of practical problems, on the one hand, and of increased theoretical interest on the other. This increased interest in, and devotion of intellectual and research resources to, the study of economic growth is all to the good.

Professor Domar has stated the past position of growth in economic theory quite aptly:

> In economic theory, growth has occupied an odd place: always seen around but seldom invited in. It has been either taken for granted or treated as an afterthought (17).

The turn of economic research toward mathematical and empirical studies, finding its ultimate expression in rationally designed econometric studies and input and output tables, has produced a whole new body of analytical tools for tackling the problems of analyzing and measuring the potential growth of the economy. The pioneering work is found in the studies of the production function and its empirical measurement, by Prof. Paul H. Douglas and his colleagues, first at Amherst and later at the University of Chicago, which found expression in the Cobb-Douglas production function (18).

This work has been carried forward in a number of studies including those by Tintner, Hildreth, Nichols, Verhaulst, Heady, Solow, and Leontief (19). Closely related developments have occurred in linear programing (20) and the development of input-output models associated principally with the work of Leontief (21). The critical literature on the statistical derivation of production functions is extensive, especially on the economic interpretation of the results (22).

Supply, demand, growth, and output

The previous chapter stated that the growth in the economy's capabilities for producing goods and services, that is, its capacity, and, hence, by implication its potential output, is a function of a large variety of factors affecting the supply of productive resources—labor, capital, natural resources—as well as the efficiency with which those resources can be used in production. Actual output is a result of a wide variety of factors affecting both demand and supply. The rate of increase in output will be determined by the growth of demand, on the one hand, or the growth of supply, or potential output, on the other, according to which is the smaller, and hence the limiting factor in each period of time. If the potential growth is growing at 4 percent per year, and aggregate demand is growing at 3 percent, then, output obviously will tend to be limited to a rate of rise of 3 percent rather than rising in line with the potential supply at 4 percent per year.

The reverse situation, of course, will be true if aggregate demand is growing at, say 5 percent, while the growth of potential output is only 3 percent. In this case an inflationary excess of demand will develop and the excess of aggregate money demand over potential output will find expression in inflation—a familiar development during war periods or periods of monetary inflation.

In making an analysis of the historical record in search of a measure of potential output and growth, allowance must be made for the fact that two sets of forces have been operating—a set of demand factors and a set of supply factors that tend to make available output in line with demand. In the analysis, therefore, measures of cyclical variations in demand and other short-term influences have been introduced and by taking account of these, the output of the economy at some rate of operation, which we shall specify as the potential, was determined for each year, defining this potential in terms of a rate of use of resources. The historical data analyzed below cover the years 1909 to 1958 in detail.

Capacity and growth

The preliminary sketch presented in chapter I (p. 6) indicated one possible approach to analyzing and measuring the potential output of the American economy and its rate of growth. If, in addition to the series on GNP in constant prices, a measure of capacity was available, it would be possible to calculate the ratio between actual output and capacity for each year, or month, or quarter, over a series of years. Then the performance of the economy in each of these time periods could be studied and compared with the ratio of output to capacity. From this process, it would be possible to arrive at an average ratio of output to capacity corresponding to criteria for desirable performance, including perhaps ratio of employment to the available labor supply, use of capital to availability of capital, stability of prices, and rate of growth of capacity. This average ratio applied to the measure of capacity each year would give a time series representing the desired potential output of the economy.

This would be a suitable process if a reasonably unambiguous measure of the capacity of the economy was available. As noted above, no such measure for the capacity of the economy as a whole is available and, indeed, there is much dispute over whether or not one can be produced, or even designed in theory (23). The problem of computing the measure of potential economic growth arises in part because the development of a concept and measure of the capacity of the economy has proved impossible up to the present.

The production function

If the problem cannot be approached via a measure of capacity, how can the definition and measurement of the potential output be arrived at more directly from an analysis of the historical record of the performance of the economy?

The technique used involves a variation on the economists' device of "the production function." By this is meant a set of functional relationships between each of the productive factors and the output of the economy. As noted above, output is the aggregate of the economy—including government, agriculture, all of the various other private industries, nonprofit organizations, individual households, distribution, finance, and services—in a word, all that is covered in the now conventional measure of output, the gross national product. This measure is used here in real terms adjusted to constant 1954 dollars.

In the past, production functions have been developed covering manufacturing (24), agriculture (25), and for somewhat larger aggregates (26). An extensive literature has developed on the theory of production functions and the interpretation of the results of fitting them to statistical data for individual industries, sectors or the economy as a whole (27). Since the economy is made up of literally hundreds, if not thousands, of industries or separate economic sectors, of several million business firms, at least a minimum of 100,000 governmental units, and somewhere in the neighborhood of 55 to 60 million household units, as well as numerous foreign entities having an impact on our economy, the process of deriving a meaningful aggregate production function involves heroic simplifications. Any attempt at aggregate or national economic analysis inevitably faces this problem, which, in the literature, has led to elaborate investigations of theories of aggregation and the construction of index numbers.

While these problems in aggregation and index number construction are not discussed here at length, it must be recognized at the outset that existing measures of total output and inputs are compromises arrived at in the search for the best measures possible at the present time. The question to be answered is whether or not the utility of such devices of aggregate analysis is sufficiently great to offset any lack of precision such compromises entail. This study is founded on the conviction that the price is not too great—that useful analyses of the economy as a whole can be made if the qualifications arising from aggregation are kept constantly in mind.

Production in the individual plant versus the total economy

The characteristics of the aggregate production function for the economy developed below will be clearer if its relationship to the productive process in an individual plant is outlined briefly. In such a small unit—small compared to the total economy—production consists of a series of processes of combining and coordinating materials, forces, services in the creation of valuable goods or services. These valuable goods or services are called output, while the materials, forces, and services used up in their creation are called inputs. These terms have different meaning in the case of the individual establishment than when used with reference to the economy as a whole. In the individual case, a good or service can be an output of one establishment but an input to another. In aggregate output, measured by

GNP, only the value added in each establishment or firm is counted, costs of purchased materials being deducted, so that total output is as free as possible of double counting. The total of the incomes paid to productive factors will equal total output for the economy as a whole but will fall short for the individual productive unit by the value of purchased materials and components.

A second distinction exists between the flows per unit of time—year, month, etc.—of inputs and outputs, on the one hand, and stocks of goods or productive resources on the other. Generally, inputs and outputs are time flows, such as hours of labor or of machine time on the input side of the productive process, and tons of steel per year or months of rent of dwellings on the output side. Stocks are sources of flows of productive services—capital and labor—and are results of past output flows, being the sums (integrals) of those parts of past output flows which were not used up, consumed, in the time period in which they were produced.

The production function relates the flow of outputs per unit of time to the various flows of inputs per unit of time in such fashion that if the coefficients of the function are known, and the volumes of the various inputs are known, the resulting volume of output can be predicted from the function.

The third important distinction is between production under stationary or static and under dynamic conditions. A static situation may be thought of as one in which productive capacity is unchanging and technical knowledge always remains the same. Under these conditions, met with occasionally in an individual unit, but rarely, if ever, in an entire economy, the volume of production can vary only between zero and the fixed capacity volume, and the constant knowledge of technical possibilities readily yield the best combination of productive resources to yield any required output volume between these limits.

In a dynamic situation, capacity can be expanded to meet demands as they push beyond present capabilities, present inputs may increase either current output, as in the static case or future outputs, and technical knowledge can change, making possible combinations of productive services or types of outputs not previously feasible. In a dynamic world, current output possibilities and the spectrum of input combinations reflect the cumulative effects of an endless stream of past decisions allocating resources between consumption and investment, and between investment in tangible productive resources and in intangibles such as education, research, health, institutional arrangements (protection of competition, economic and political rights at law, etc.) and promotion of moral standards.

To bring out the implications of these distinctions for the later analysis, let us assume a productive unit with a fixed stock of plant and equipment, operating in competitive markets for both inputs and outputs, and during a time period in which technical knowledge is unchanged. At low rates of production, output will tend to rise faster than inputs, productivity will rise as volume rises and the firm will experience increasing returns. At higher operating ranges, output and inputs will rise together, the rise in productivity will slow down and finally halt so that constant returns appear. If very high rates of production are attempted, productivity may fall and decreasing returns set in as inputs rise faster than output.

What happens if dynamic conditions replace the static assumptions used above? First, capacity can now change as a result of investment in new plant and equipment called forth by high rates of production and high profits. The same type of relationship between inputs and outputs will prevail as in the static case at each point of time but at the larger volumes corresponding to rates of utilization of productive resources experienced at the former lower capacity.

Changes in techniques are also possible and these have a somewhat different range of possible effects. One possibility is that changes will be neutral as between inputs so that production relations retain the same shapes but the efficiency of each combination of inputs is increased—that is, a doubling of capital and labor inputs which would double output under one set of production relations, might, through simultaneous changes in techniques, be accompanied by a tripling of output.

It will be noted that under both static and dynamic conditions some combination of inputs is feasible which, given existing techniques, relative prices and stocks of productive resources, yields a minimum total cost per unit—that is, a least-cost combination. A rational entrepreneur would prefer to maintain this rate of output at all times if this were possible. Little is known about the rates of production corresponding to these least cost combinations, but such information as is available suggests that this rate is below what management generally regards as the practical capacity of their firms, particularly in manufacturing.

The McGraw-Hill surveys of business plans for investment in new plant and equipment provide estimates of actual operating rates and of preferred operating rates in various manufacturing industries. This survey measures capacity in terms of plant and equipment without adjustment for availability of manpower or materials. Each company reports changes in capacity and rates of operation in accordance with their own definition though most companies in each industry appear to follow similar practices in defining capacity. In two surveys (1955 and 1957) companies reported their preferred operating rates. For all manufacturing, the preferred rate is reported to be about 90 percent of capacity and the rates for individual industries range from 85 percent in transportation equipment to 95 percent in paper and 96 percent in steel.

If, in general, managements tend to report as preferred operating rates, those corresponding to their least-cost combination of resources, as seems reasonable, then it could be concluded that the optimum operating rate, at least in manufacturing, is significantly below management's estimate of practical capacity and even further below any conceivable measure of absolute capacity since this must be well above rated capacity. Higher rates of operation for prolonged periods (as during and immediately after World War II) amply sustain this point.

When attention turns from the individual plant, firm, or industry to an aggregate production process for the total economy these points become clear:

(1) The optimum or best operating rate for the economy may not be a simple average of the preferred or optimum rates of the individual production units—firms, plants, etc., weighted by their individual capacities. The optimum rate for the total economy will reflect both the individual preferred rates and the composition or mix of demand

which may not call for operations to be at the optimum or preferred rates in each individual producing unit. Under dynamic conditions, some misjudgment of markets by firms is unavoidable and cannot quickly be corrected by shifting resources to other outputs.

(2) The optimum rate of operation for a dynamic economy such as ours will be affected also by the proportion of labor and capital which must be shifted annually to new uses or retired in order to adjust to changing demands and techniques. The higher the rate of turnover or shifting of resources in response to dynamic changes in the economy the lower the optimum rate of use productive resources which it is practical to aim for and vice versa.

(3) As a corollary to point (2), the more mobile resources are, the more rapidly and efficiently they respond to changes, the higher the preferred operating rate for the economy can be; while slow adjustments or shifts will lower the operating rate which can be on a sustained basis without inflation.

(4) For the total economy, it will be difficult to detect statistically valid evidence of increasing or decreasing returns under dynamic conditions, except those associated with wide cyclical swings in the rates of operation—recession or deep contraction and subsequent recovery, on the one hand, and periods of over-full demand, such as World War II, on the other. During other periods, the influence of technological progress on productivity of resources, and inevitable errors in estimating inputs and outputs, seem likely to conceal or gloss over any tendencies to increasing or decreasing returns between periods of similar rates of operation but different all-out output capabilities. This tendency will be reinforced by the offsetting occurring in putting together the aggregates from data on a myriad of individual units except in the unlikely event that all, or almost all units, experienced simultaneously either strongly increasing or decreasing returns.

(5) Measures of total inputs and output for a dynamic growing economy like ours are likely to exhibit, as a common characteristic, highly correlated growth trends. These correlated growth trends in output and inputs will be accompanied by a persistent, rapid time trend in total productivity of all inputs combined reflecting changes in the intangible contributions to production already mentioned including research, education, technological change, improved health, etc. These common time trends complicate the statistical problem of determining quantitatively the functional relationships between inputs and output that constitute the desired aggregate production function.

The design of an aggregate production function

In light of the preceding sketch, the required design of a production function incorporating relationships between inputs and outputs can be laid out in a way that make possible a statistical determination of the production coefficients relating each input to aggregate output for the economy. At this point, and in the following chapter, the overriding objective of this study must be kept constantly in view since it vitally affects the design and its implementation in chapter III.

The production function is sought as a means of estimating the economy's potential output under conditions of sustainable "maximum employment, production, and purchasing power," and, hence, estimating the rate at which this potential has grown in the past, is growing now, and could grow in the future. This means that our interest centers on long-run or secular relationships more than on short-run, cyclical movements.

With this objective in view, characteristics of the desired function, describing production relationships in the economy can be reduced to these:

(1) It should incorporate measures of as many of the identifiable productive resources as is possible in light of availability of data, especially—

- (*a*) labor;
- (*b*) tangible capital: plant, equipment, etc.;
- (*c*) the state of technology and its changes; and
- (*d*) other intangibles such as research, health, education, etc.

(2) It should incorporate a procedure for separating changes associated with cyclical and other short-run fluctuations from changes reflecting secular influences.

(3) Provision should be made to separate changes in output due to shifts in the production function itself in response to changes in techniques, etc., from changes in output reflecting increases in the supply of the productive services of labor and capital.

(4) A procedure is needed for allowing for influences on aggregate output and on the productivity of inputs arising solely out of shifts in demand between goods and services with varying requirements for productive resources—i.e., between those with higher or lower requirements for capital, and higher or lower requirements for labor.

(5) If possible, specific provision should be made to measure the influence of changes in quality of inputs and outputs on the production function.

(6) Since the absolute magnitudes of the measures of inputs and outputs for the economy as a whole will depend on the particular price structure used to price inputs and outputs and on various conventions of mensuration, these absolute levels will be of little significance. Primary attention must center on changes between time periods—year to year— and on relative proportions between measures in each period. Therefore the form of the function should be chosen so as to operate in terms of rates of change.

(7) If possible, the functional form chosen should be linear or involve only linear transformation so as to take advantage of the high speed computing possibilities of electronic data processing equipment. This is of special importance in view of the high intercorrelations between the inputs which made it necessary, as will be seen below, to run successive approximations to locate the preferred fit of the formula to the statistical record of past economic performance.

(8) Last, but not least, the formula should be framed to reduce the high intercorrelations as far as feasible, especially between the inputs, or in statistical terms, the independent variables in the function.

In light of these criteria, the search for an aggregate production function, started with a theoretical form that was a variation of, and elaboration upon, the now classic Cobb-Douglas function which is linear in the logarithms. In its original form it was applied to manufacturing, first to U.S. data, covering various series of years and regions, then to time series for other countries, and then to cross-section data for large numbers of manufacturing industries for each of several years, here and abroad. In form, the function was:

$$P=bL^{k}C^{1-k}$$

Where P was an index of manufacturing production, L was labor input (index of average number of wage earners in manufacturing), C was the capital input (index of fixed capital in manufacturing) and b and k were constants to be found by the classical least squares regression method.

In this form the function assumes that the sum of the exponents is unity, and hence that there existed constant returns to scale. In later studies this restriction was removed and more refined variations on data used, with the function assuming the form

$$P=bL^kC^j$$

so that $k+j$ could be equal to, less than, or greater than unity. The studies of Professor Douglas and his associates, as well as others, tended to arrive at estimates of $k+j$ close to or equal to unity, though with some tendency toward diminishing returns. (28)

This later form of the Cobb-Douglas function was chosen as a starting point and modified in light of subsequent research results and of the changes in availability of data. Five modifications were made:

(1) Labor input, expressed in man-hours, was split into two components, first, a secular component (Lp) based on longrun or secular changes in the rates of participation of the population in the labor force and secular trends in hours of work and second, a cyclical component, the ratio of actual labor input to the potential labor input $\left(\frac{La}{Lp}\right)$.

(2) Capital (measured as a gross stock in constant prices) was used in the form of a ratio of the stock of capital to the potential labor input (K/Lp).

(3) The influence of changes in technology on productive efficiency was captured in part by inserting a new variable, the average age of the capital assets surviving in the capital stock in each year (k). The lower the average age of the capital stock, the closer the productive process was assumed to approximate the latest, most efficient techniques; the older the average age, the less the stock incorporates the most efficient known techniques. This is a measure of qualitative changes in the capital stock (K).

(4) A time trend (t) was introduced to measure the influence of all those intangibles which could not be measured directly. This is a proxy variable, accounting in this case for technical and other changes, or in technical terms for any kind of shift in the production function.

(5) An index (X) was introduced, so constructed as to measure the influence of change in demand on the total productivity of the inputs. This index (X) reflects changes in the composition of demand between products and services requiring varying amounts of labor and capital per unit.

Inserting these changes in the classic Cobb-Douglas production function, a formula was obtained in the following form, where O_a represents output:

$$O_a=A.Lp.\left[\frac{La}{Lp}\right]^a.\left[\frac{K}{Lp}\right]^b.k^c.x.d^t$$

The formula was tested against statistical data by least squares, by procedures outlined along with the results in chapter III. The formula had to be modified further during the fitting process.

Chapter III. The Statistical Analysis of Output

The statistical analysis of the historical record of the output of the U.S. economy and of the major output-determining factors proceeded in five stages:

(1) Assembling of historical data on an annual basis for output and each of the related variables needed for the equation developed in chapter II.

(2) Transforming of the basic variables, where necessary, into the form required in order to fit the equation to the data.

(3) Fitting the equation to the data, using the classic least-squares regression procedure, making modifications of the equation as tests with the data progressed, and obtaining a final fit by successive approximations.

(4) Interpreting the function obtained in economic terms to test its reasonableness in light of economic analysis and other previous related studies.

(5) Computing the potential output of the economy for 1909–60, using the derived production function.

The variables and their measurement

As indicated previously, output of the economy is a result of a wide variety of forces. The growth in the economy's potential output is therefore similarly effected by a range of factors far too large to be incorporated directly in the computations at this time. Fortunately, it is possible to measure output for the economy as a whole, and the two major productive factors, labor and capital. As will be seen later, these dominate the rate of growth and cyclical fluctuations to such an extent that the variables that are not measured directly can be represented indirectly by a proxy or stand-in. In the historical analysis covering the years 1909–58, the influences on our potential economic growth were subjected to statistical analysis making use of the following measurements of output and inputs.

(1) *Output.*—The measure of output is the GNP deflated (adjusted for changes in prices) to prices prevailing for each of the component goods and services in the year 1954. This series is constructed by the National Income Division, Office of Business Economics, Department of Commerce, and published regularly on an annual and quarterly basis in the "Survey of Current Business" (29).

GNP measures the market value of the output of goods and services produced by the Nation's economy before deduction of depreciation charges and other allowances for business and institutional consumption of durable capital goods. The series in real terms, which was utilized in this study, reprices this output in terms of prices prevailing on the average during the year 1954. It, therefore, covers changes in constant dollars of the total purchases of goods and services by consumers and Government, net foreign investment, and gross private domestic investment, including the change in business inventory.

(2) *Labor.*—Labor input has been measured in terms of the total number of man-hours or the product of employment multiplied by the average hours worked per year per person engaged in production. Two measures of labor input were used. The first of these was a series on actual labor input in man-hours which represented the product of the total number of persons actually employed multiplied by actual average annual hours worked per person employed (30).

The second measure of labor input was the total man-hours of labor available for productive activity in the economy, whether actually employed or not.

It was arrived at by a study of trends in rates of participation in the labor force of men and women in various age groups, and by a study of trends in the average annual hours worked per person engaged in production. It was assumed for the historical period (1909–58) that about 4 percent of the labor force was unemployed when the economy was operating at its potential output. Other percentages could have been assumed without changing the basic historical analysis except as to the relative level of the series (31).

(3) *The stock of capital.*—To measure the supply of capital services available for use in production an estimate of the gross capital stock of the private economy prepared by Dr. George Terborgh was utilized (32).

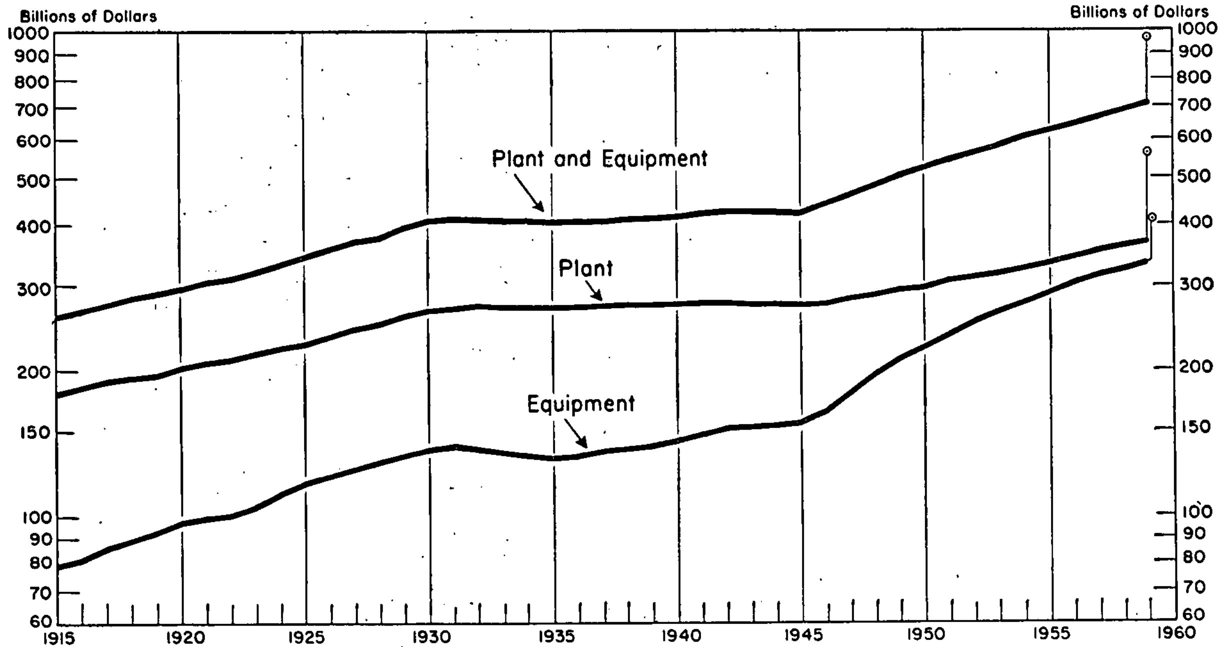
In this series the gross capital stock represents the value, in constant dollars, of all capital assets surviving from past installations at any particular point in time. It is, therefore, gross of depreciation. It includes private plant and equipment in agriculture, mining, manufacturing, commercial, and similar types of activities, but specifically excludes residential structures, inventories, and all Government assets. (See chart II, p. 21.)

These stocks were computed by the application of survival curves to data on prior installations in constant prices. (See chart III, p. 22.) Since these curves gave estimated percentages of original installations surviving after given intervals, it is possible to compute the survival at any point from or prior installations and to trace the movement of the survival over any given time (33).

(4) *The age of capital.*—To measure the degree to which the existing capital stock incorporates available technology, it was decided to use as one variable in the analysis a computation of the average age of surviving capital assets included in the above estimate of capital stock. This also was the work of Dr. Terborgh.

CHART II

Computed Gross Stocks of Business Plant and Equipment at Constant (1959) Prices[a] (Ratio Scale)

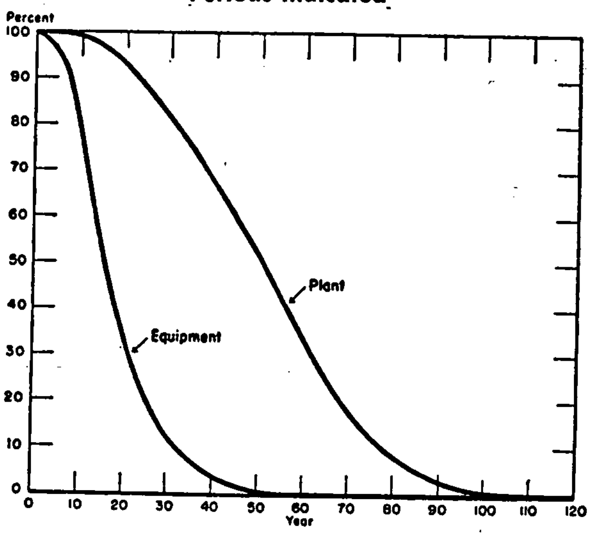


[a] The 1959 stock includes, of course, a partially estimated installation figure for that year. A mimeographed description of sources and methods for this and subsequent charts is available on request.

Source: Capital Goods Review, No. 39.

CHART III

Estimated Percentages of Original Installations of Plant and Equipment Surviving After the Periods Indicated[a]



[a] These survival curves imply *average* service lives of about 17 years for equipment and 50 years for plant.

Source: Capital Goods Review, No. 39.

The procedure used in computing the capital stock on the basis of survival curves made possible this computation of the age of capital. Since the survivals are dated by year of origin, it is possible from the computation to derive not only the total stock, but its age composition as well. From this, the weighted average age can be computed (34).

(5) *All other variables.*—Because there were a number of important influences which could not be measured directly, the analysis included a time trend having a constant rate of increase per year. This time trend is a proxy or stand-in for the many other variables mentioned at the outset, such as changes in managerial skill, technological progress, improvements in the health and education of the labor force, and so forth. It was found that there was no basis for varying this rate from period to period.

Three transformations

It was necessary to transform some of the basic information so as to place three of the terms in the form in which they appear in the equation of the production function. These three transformations produced a cyclical term, a transformation of the capital stock variable and a new variable used to measure the influence on productivity of changes in the composition of demand.

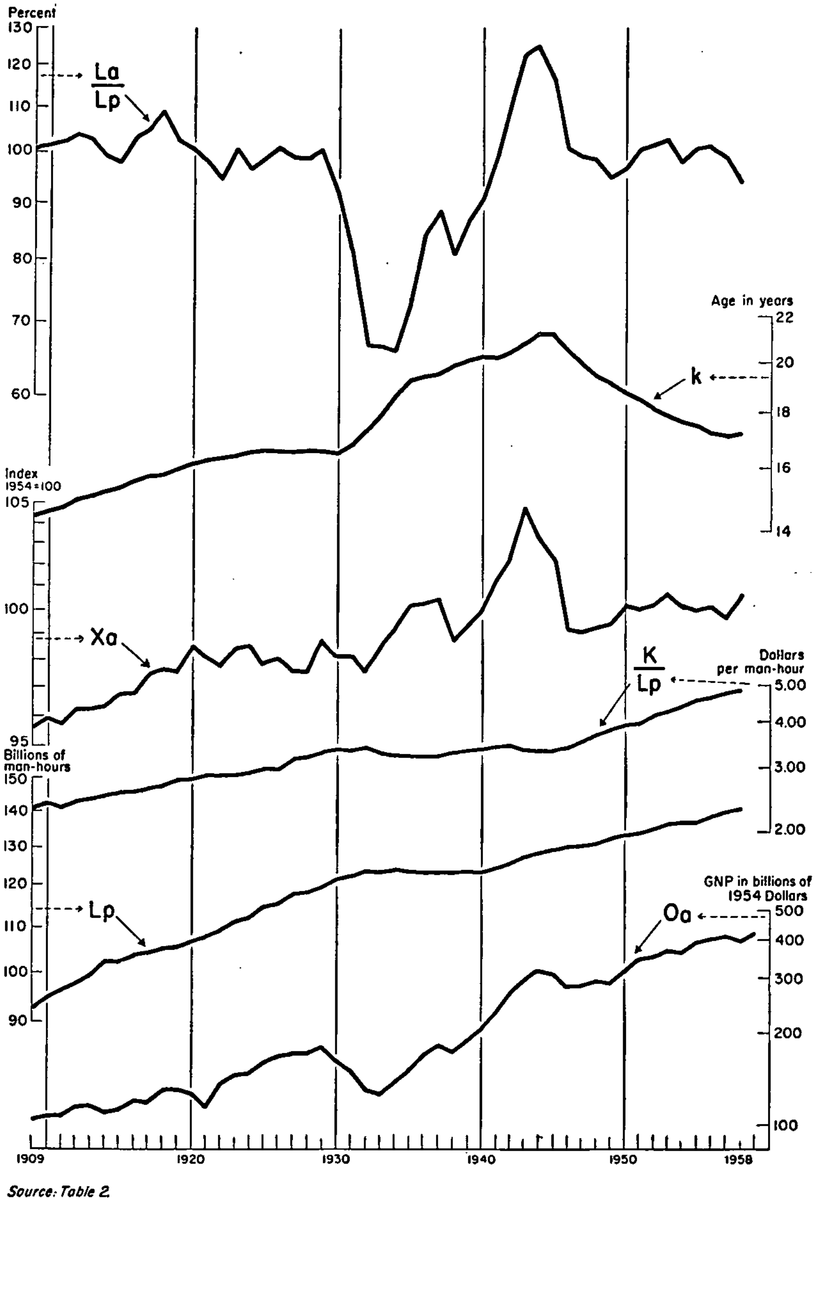
(1) *The cyclical term.*—The central focus, as already indicated, is upon the longrun or secular relationships. On the other hand, the actual historical data contained within themselves movements related to shortrun deviations from the secular movements, including, of course, those relating to the business cycle. It was necessary, therefore, to construct some term that could be used statistically to pull out or neutralize the influence on the relationships of these shortrun and cyclical movements in the historical data.

This was done by the use of the labor inputs. Both a measure of the potential labor input (Lp) and a measure of the actual labor input each year (La) were available. The ratio obtained by dividing the actual labor input by the potential labor input, which is divorced from cyclical and other shortrun movements, yields a variable which fluctuates with the cycle and other short-term deviations. It will be noted from the description of these two basic series above that this ratio represents the actual man-hours worked each year in the whole economy divided by the potential labor input in man-hours which could have been worked if the economy had operated smoothly in line with the longrun trends in population and labor force participation. By proxy, this variable also took care of any other cyclical or shortrun fluctuations, since these were very highly correlated with the ratio of man-hours worked to the potential man-hours. This cyclical variable is indicated at the end of the previous chapter $\left[\frac{La}{Lp}\right]$, and is shown as the top line on chart IV.

(2) *The capital transformation.*—It was obvious from the beginning that the stock of capital had grown very rapidly over the last 50 years and hence its movements would be highly correlated with the growth of the potēntial labor force and with the time variable. (See chart IV.) It was decided to transform the capital stock variable by dividing it by the measure of potential labor input giving the term $\left[\frac{K}{Lp}\right]$. Thus, taken in combination with the term Lp in the equation, we have a formulation in which the capital stock has an effect upon output independent of increases in the potential labor input, only if it rises faster or slower than the potential labor input, so that the capital-labor ratio rises ɪr falls. This means that the potential labor input (Lp) measures the influence on output of the increase in available labor and the associated capital at some constant capital-labor ratio, and with the average age, or technological state of the capital stock, held constant. The capital-labor ratio $\left[\frac{K}{Lp}\right]$ measures the effects on output of a deepening of capital—of a substitution of capital for labor in production.

CHART IV

GROSS NATIONAL PRODUCT IN CONSTANT DOLLARS AND RELATED VARIABLES, 1909-1958



Source: Table 2.

(3) *Index adjusting for the composition of demand.*—Each type of goods or service produced in the economy requires at any given point in time a certain amount of labor and capital for its production. The amount of each will depend on the state of technology, the character of the goods or services produced and the ratio of output to capacity. Naturally in historical series of data, changes in the composition of demand could bring about changes in the amount of goods and services that could be produced with given amounts of labor and capital if the change in the aggregate meant a shift toward products and services requiring more labor or more capital or less of either or both. In the measurement of productivity, this so-called mix effect has been widely recognized (35).

The procedure employed was to construct an index which measured the changes in the amounts of labor and capital required to produce a dollar of output of each of the major classes of goods and services measured in the GNP in constant dollars. The index was constructed by applying a set of capital-output ratios and a set of labor-output ratios to each of a number of categories of goods and services among the components of GNP (36). This variable, denoted Xa, is shown on chart IV.

It may be noted that the major influences on the movements of this index over time have been the decline in the relative importance of agriculture, shifts between goods and services, and shifts between government and private shares in the total GNP. The index also reflects in wartime the extreme shift of demand to fit the requirements of the war effort. In general, as will be noted on Chart IV, the economy can produce more from a given amount of capital and labor with the wartime composition of demand than when a more nearly peacetime composition of output is demanded.

TABLE 1.—*The variables used in the analysis, and their components, 1909–58*[1]

Year	Time units	Potential labor input: Total $=0.96M_pH_p$	Potential labor input: Potential labor force	Potential labor input: Potential average annual hours per employee	Actual labor input: Total $=E_a \times H_a$	Actual labor input: Actual employment, including Armed Forces overseas	Actual labor input: Actual average annual hours per employee	Ratio of actual to potential labor input	Gross tangible capital	Ratio of gross tangible capital to potential labor input	Average age of gross tangible capital	Mix factor for productivity of labor and capital: Potential	Mix factor for productivity of labor and capital: Actual
		L_p	M_p	H_p	L_a	E_a	H_a	$\frac{L_a}{L_p}-100$	K	$\frac{K}{L_p}$	k	X_p	X_a
	Years	*Billions of man-hours*	*(000)*		*Billions of man-hours*	*(000)*		*Percent*	*Billions of 1959 dollars*	*Dollars per man-hour*	*Years*[2]	*1954=100*	*1954=100*
1909	0	92.84	35,764	2,704	94.06	34,785	2,704	1.32	214.7	2.313	14.50	95.72	95.61
1910	1	94.86	36,596	2,700	96.59	35,708	2,705	1.81	219.9	2.381	14.60	95.90	95.87
1911	2	96.28	37,196	2,696	98.48	36,274	2,715	2.33	225.9	2.346	14.72	96.07	95.79
1912	3	97.65	37,785	2,692	101.64	37,341	2,722	4.09	234.1	2.397	14.87	96.25	96.27
1913	4	99.42	38,535	2,687	102.47	37,896	2,704	3.06	243.3	2.447	15.06	96.43	96.28
1914	5	101.16	39,274	2,683	100.70	37,475	2,688	−.04	252.0	2.491	15.19	96.61	96.33
1915	6	102.39	39,825	2,678	99.97	37,669	2,659	−2.42	258.6	2.526	15.37	96.78	96.70
1916	7	103.43	40,364	2,669	107.06	40,126	2,668	3.51	265.5	2.567	15.55	96.96	96.83
1917	8	104.54	40,921	2,661	110.70	41,531	2,665	5.88	273.9	2.620	15.69	97.14	97.47
1918	9	105.17	41,286	2,654	114.88	43,998	2,611	9.24	280.6	2.670	15.78	97.32	97.59
1919	10	105.35	41,540	2,642	107.94	42,313	2,551	2.45	287.9	2.733	15.97	97.50	97.47
1920	11	106.30	42,099	2,630	107.23	41,497	2,584	.88	297.3	2.796	16.10	97.68	98.47
1921	12	107.96	42,942	2,619	96.87	39,361	2,461	−1.41	303.8	2.814	16.21	97.86	98.10
1922	13	109.05	43,564	2,607	103.75	41,383	2,507	−5.10	309.4	2.837	16.34	98.02	97.89
1923	14	110.71	44,423	2,596	111.57	43,938	2,544	.79	319.2	2.874	16.40	98.11	98.51
1924	15	112.69	45,415	2,585	109.46	43,315	2,527	−2.94	331.1	2.938	16.43	98.19	98.60
1925	16	114.17	46,211	2,573	113.46	44,512	2,549	−.62	342.4	2.999	16.50	98.29	97.96
1926	17	115.59	46,995	2,562	117.38	45,795	2,563	1.56	354.2	3.064	16.48	98.38	98.04
1927	18	117.11	47,822	2,551	116.91	45,900	2,547	−.19	366.1	3.126	16.48	98.47	97.66
1928	19	118.55	48,624	2,540	118.04	46,382	2,545	−.44	377.7	3.186	16.50	98.56	97.52
1929	20	119.87	49,376	2,529	120.36	47,611	2,528	.42	390.9	3.261	16.49	98.65	98.81
1930	21	121.38	50,219	2,518	112.62	45,465	2,477	−7.77	403.1	3.321	16.47	98.74	98.13
1931	22	122.28	50,815	2,507	103.75	42,607	2,435	−17.87	409.2	3.347	16.78	98.83	98.09
1932	23	123.08	51,370	2,496	92.37	39,274	2,352	−33.23	408.8	3.321	17.30	98.92	97.59
1933	24	123.93	51,951	2,486	92.54	39,615	2,336	−33.91	405.3	3.270	17.91	99.02	96.68
1934	25	124.20	52,581	2,460	92.62	42,739	2,167	−34.09	402.0	3.237	18.53	99.11	99.21
1935	26	124.15	53,234	2,429	97.74	44,224	2,210	−27.03	400.4	3.225	19.19	99.20	100.10
1936	27	123.80	53,860	2,394	106.82	47,078	2,269	−15.90	401.9	3.246	19.31	99.29	100.30
1937	28	123.64	54,437	2,366	111.42	48,233	2,310	−10.97	406.5	3.288	19.48	99.38	100.40
1938	29	123.60	55,063	2,338	103.80	46,379	2,238	−19.10	409.6	3.314	19.81	99.47	98.79

1939	30	123.60	55,686	2,312	108.53	47,769	2,272	−13.89	411.1	3.326	20.06	99.56	99.38
1940	31	123.55	56,306	2,286	113.58	49,606	2,277	−9.37	415.2	3.360	20.15	99.66	99.91
1941	32	124.48	57,124	2,270	124.42	54,097	2,300	−.05	422.3	3.392	20.11	99.72	101.10
1942	33	125.63	58,053	2,254	138.31	59,056	2,342	10.10	426.7	3.396	20.40	99.79	102.10
1943	34	127.10	59,155	2,238	156.31	64,864	2,410	23.00	425.4	3.347	20.80	99.86	104.70
1944	35	128.44	60,202	2,222	160.04	66,020	2,424	24.59	424.4	3.304	21.16	99.91	103.16
1945	36	129.23	61,010	2,206	150.03	64,363	2,331	16.09	427.2	3.306	21.21	99.98	102.30
1946	37	130.05	61,834	2,191	131.50	58,917	2,232	1.11	439.3	3.378	20.67	100.05	99.28
1947	38	130.78	62,630	2,175	130.32	59,264	2,199	−.35	460.0	3.517	20.04	100.09	99.10
1948	39	131.80	63,479	2,163	131.03	60,216	2,176	−.58	482.7	3.663	19.49	100.16	99.34
1949	40	132.98	64,409	2,150	126.38	58,702	2,153	−5.20	502.7	3.781	19.11	100.21	99.49
1950	41	133.68	65,134	2,138	128.90	60,491	2,131	−3.71	521.3	3.899	18.81	100.23	100.30
1951	42	134.60	65,942	2,126	135.89	64,191	2,117	.97	541.4	3.985	18.48	100.25	100.20
1952	43	135.44	66,705	2,115	137.90	65,264	2,113	1.81	561.7	4.148	18.12	100.25	100.30
1953	44	136.19	67,416	2,104	139.79	66,219	2,096	2.64	582.1	4.275	17.88	100.28	100.70
1954	45	137.07	68,145	2,095	134.51	64,829	2,075	−1.91	601.5	4.388	17.73	100.28	100.30
1955	46	137.92	68,854	2,086	139.01	66,260	2,098	.81	620.7	4.501	17.45	100.30	100.01
1956	47	139.00	69,692	2,078	141.04	67,483	2,090	1.46	642.5	4.623	17.21	100.30	100.10
1957	48	140.38	70,680	2,069	139.59	67,729	2,061	−.58	665.3	4.739	17.09	100.32	99.69
1958	49	141.48	71,538	2,060	133.11	65,896	2,057	−6.29	683.6	4.832	17.11	100.32	100.90

[1] For output (O_a), see table 2.

[2] Attention is drawn to the fact that age of capital, though presented here in conventional units, years, was used in the equation in units of decades (moving the decimal point to the left one place). In the logarithims, this meant that the characteristic was dropped and the mantissa used without rounding.

Fitting the production function to the historical data

The variables to be used to derive a production function for the American economy for the period 1909–58 now are complete. The six variables are shown on chart IV. The equation was fitted by the classic method of least-squares to obtain the regression of output (*Oa*) on the other variables, the equation being initially in the form given at the end of chapter II with modifications as will be seen below. The data were first translated into logarithms and punched on cards suitable for feeding as input to an IBM 650 electronic computer.

Seven separate runs of the data were made on the computer, each run yielding a correlation matrix, regressions between different combinations of the variables and various statistical measures such as averages, standard deviations, R^2, and a computation of the residuals for selected equations together with the Durban-Watson statistic to test for autocorrelation.

This procedure could be used only because of the generosity and cooperation of the Bureau of Labor Statistics and the Board of Governors of the Federal Reserve System, who made time available on their IBM 650 computers.

Two difficulties in finding the structural relationship involved in the aggregate production function have already been noted: a high degree of correlation of the dependent variable (*Oa*) and four of the dependent variables (*Lp*, *K/Lp*, *k*, and *X*) with the time trend (*t*); and the aggregation problems arising from combining data for a large number of enterprises with varying characteristics into a simple model for the economy as a whole. In addition, the usual complexities associated with time series of economic data had to be dealt with in the analysis. As is well known, in time series the data for each year are not independent observations arising from random samples of the unknown universe but instead values for each year depend on what happened in the preceding year or years. Furthermore, it was clear that both the variables and the equations were subject to error so that the structural parameters could not be determined accurately simply by a direct fit by the least-squares method.

The procedure evolved to overcome these familiar problems was as follows:

(1) Seven successive runs of the data were made on the IBM 650, with several forms of the equation being fitted on each run.

(2) After each run the coefficients for each variable in each form of the equation were tabulated, along with R^2, Durbin-Watson statistic, σ's and r's between variables; and charts were prepared showing—

(*a*) actual and computed values for the more promising equations;

(*b*) scatters of residuals from the equations with some or all of the variables; and

(*c*) interrelationships between values of the coefficients in the different equations—particularly the dependence of the coefficients of the other variables on the value of the coefficient for time (*t*).

(3) The several values of the coefficients for each variable found on each run were tested in the light of—

(*a*) their standard errors;

(*b*) results of other research reported in the literature;

(c) effects of variations in coefficients of other variables, particularly time (t);

(d) effects of variations in the values of the coefficients on the time pattern of the residuals; and

(e) the possible economic meaning of the coefficients, and hence their reasonableness from viewpoint of economic theory.

(4) The basic data was reexamined in light of the results to determine whether the tests pointed to possible errors or biases in the data themselves or in the form in which they were specified.

(5) In the light of analysis of each run, specifications were developed for the next run with two types of modifications each time:

(a) changes in the form of relationship specified for one or more variables; and

(b) specifications or restrictions as to the values which the coefficients of one or more of the variables would be allowed to assume.

In all, during the 7 runs over 50 variations in the basic equation were obtained. Furthermore, after the fourth run, the data were fitted by graphic correlation techniques to test visually what had been learned to that point concerning the shape, values, and implications of the most probable values of the coefficients. The equation at this point assumed its final form and the final runs merely refined the fit to take care of minor discrepancies revealed by the graphic test.

The final form of the equation, therefore, had to meet three tests. First, the meaningfulness of the regression coefficients, that is, do the coefficients make sense from a priori knowledge of the system? Second, what is the effect of additional variables, or of changes in the form in which variables are used in the equation, on R^2? Is the proportion of the variation in the independent variable (*Oa*) explained by the equation, as measured by R^2, raised enough by each variable to justify the loss of degrees of freedom involved by using it? Third, what is the effect on the standard deviation and the coefficients of the other variables of adding each variable to the system? What is the effect upon the Durban-Watson statistic, that is, on the autocorrelation?

The strictly statistical tests, by themselves, were informative but not decisive. The lowest R^2 obtained was .88 and the highest was .9964, with most of the equations having an R^2 between .94 and .97. In no case was the Durbin-Watson statistic large enough to warrant a belief that autocorrelation had been reduced to insignificant proportions. The value of R^2, however, was highly correlated with the values of the coefficients of some of the variables—especially the capital-labor ratio (K/Lp), time (t), and potential labor input (Lp). This made it possible, in combination with the charts showing the interrelationships of (Lp) and (K/Lp) with (t), to narrow the range within which would fall any acceptable values of the coefficients for these three variables. Both economic theory and previous studies provided bases for further narrowing the search for acceptable parameters—particularly for these three.

First, it was possible to define narrowly the range within which the coefficient for time (t) undoubtedly would be found. The runs included cases in which the time trend was free to assume any value, was restrained to predetermined values, and equations in which time was dropped out altogether. From these, it was possible to conclude that the (t) coefficient must be at least as large as .00753 or 1.75 percent per year and less than .00966 or 2.25 percent per year. If the time trend was outside this range, the signs of other coefficients came out reversed or the coefficients assumed nonsense values. With a high time trend (about 3–4 percent a year), the labor and capital coefficients either reversed or became insignificant. At the other extreme, for example, the coefficients for labor and capital (especially capital) became excessively high, indicating an annual rate of return to capital of almost 2 to 1.

In this study, time (t) is a proxy for the influence on output of shifts in the production function due to such factors as changes in qualities of inputs and changes in technology. Other studies have investigated this aspect in terms of trends in productivity of labor and capital. The two that are most nearly comparable to our (t) in concept and measurement are those of Kendrick (30) and Solow (19). Kendrick found that for the private domestic economy, physical output per unit of labor and capital combined (weighted) rose by 2.1 percent per year 1919–57 and by 1.3 percent per year 1889–1919. Solow arrived at an upward shift of the production function at about 1.5 percent per year for the period 1909–49 with the rate about 0.9 to 1.2 percent per year before 1930 and about 1.9 to 2.25 percent per year after that date. His analysis covered the private nonfarm economy. Both of these studies used data almost identical with that used in this study. In our analysis, the acceleration in the rate of change is accounted for largely by changes in the age of capital (k) So that the coefficient for (t) should lie with the range of Kendrick's and Solow's rates for the period after 1919—or in between 1.9 and 2.25 percent which is indeed the case.

The coefficient of the capital-labor ratio (K/Lp) was sensitive to values assumed by time (t) because of the high intercorrelation between the two variables (about .96). For time trends within the acceptable range arrived at above, the coefficient of K/Lp assumed values between .12 and .57 with values between .3 and .4 for the equations with the highest R^2, the most reasonable coefficients for other variables and the most rational pattern of residuals between actual and computed outputs (Oa–Om). Solow (19) found a value of .353 as a coefficient for his capital-labor ratio using an equation form of the Cobb-Douglas type. It seemed reasonable, therefore, in light of all considerations, to use a coefficient of .35 for the capital-labor ratio (K/Lp), especially as this would be consistent with the distribution of GNP between property and labor incomes.

With the time trend (t) assumed to lie close to 2 percent per year and the coefficient for K/Lp fixed at .35, experiments were possible with the coefficient of potential labor input (Lp) varied over a range from less than 1 (decreasing returns to scale) to above 1 (increasing returns to scale). Results of other investigators have been somewhat ambiguous but generally pointed to slightly decreasing returns to scale (38). Tests revealed no significant sensitivity of the equation to any reasonable variation in the coefficient of Lp away from 1.0, so it was finally fixed at unity.

With the coefficients of Lp and K/Lp fixed and that of (t) restricted to a narrow range, it was only necessary to arrive at the optimum forms for the cyclical component $\left[\frac{La}{Lp}\right]$, the capital age variable (k), and the mix variable (X); after which the optimum fit could be found by least-squares. The mix variable (X) by definition has a coefficient of 1 since it is a measure of changes in productivity of labor and capital combined, assuming all input efficiencies constant but the composition of demand variable.

It was clear at an early stage that a linear form for the cyclical variable $\left[\frac{La}{Lp}\right]$ was not adequate and a nonlinear form had to be adopted. This was parabolic in logs—a result consistent with the economic theory of production with fixed supplies of factors, fixed technology, fixed mix of demand, and variable rates of use of inputs. The final equation therefore used both log $\left[\frac{La}{Lp}\right]$ and $\left[\log \frac{La}{Lp}\right]^2$ as variables.

The experiments clearly pointed to a nonlinear form also for the age of capital (k) but with a negative curvature in the relevant range. This agreed with expectations. An increase in age of the capital stock (k) implies that, other things being equal, the technological efficiency of the capital stock is reduced below what it would be if capital, on the average, were younger and approximated more nearly the best production techniques known at the time. The curvature also was reasonable since the older the capital stock becomes, on the average, the smaller would be the proportionate effect on efficiency of a further aging of the capital stock. Consequently, the age of capital entered the final equation as both log k and $[\log k]^2$.

The final equation

With these points arrived at, the final fit was arrived at on the seventh run.

The final equation chosen on the basis of the many tests was:

$$\begin{aligned}\log O_m = & -5.43104+\log L_p+.9104 \log (L_a/L_p) \\ & -3.39[\log (L_a/L_p)]^2+.35 \log (K/L_p)-5.6411 \log k \\ & +10.356(\log k)^2+X+.00884t\end{aligned}$$

N.B.—O_m is the predicted value of gross national product and is the equation's estimate of O_a. The relation of O_m to O_a is shown in column 3 of table 2.

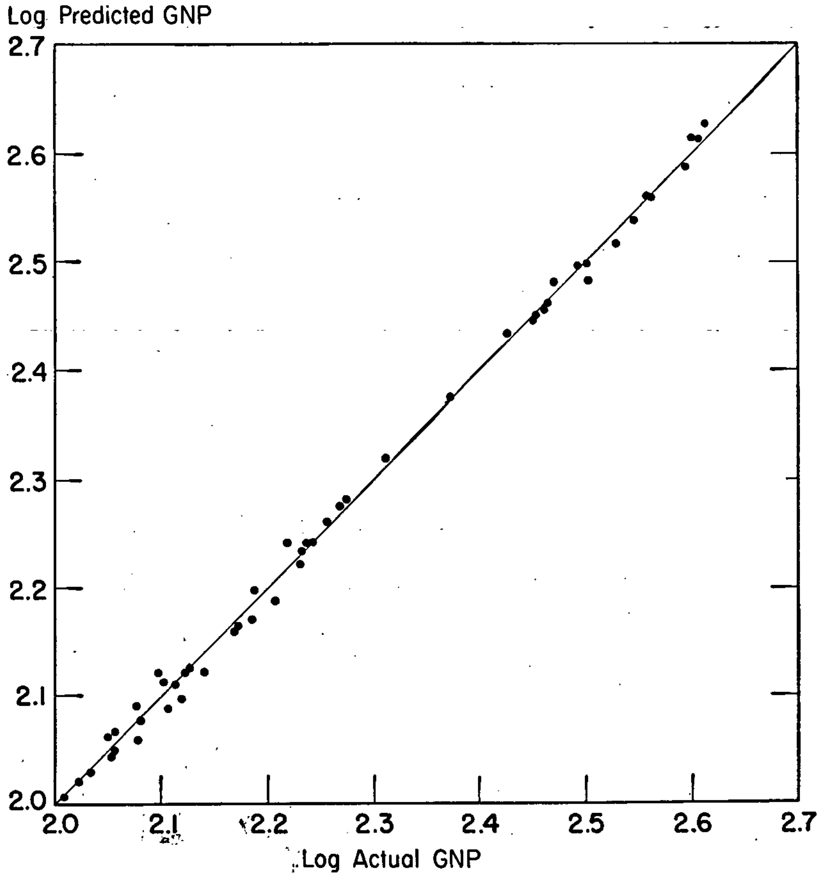
N.B.B.—The average age of capital k has been measured in decades when fitting the equation because of the scaling problem introduced by a squared term if coded input is used.

The equation provided a high degree of explanation of the variations in output (Oa). The R^2 was .9898 and the closeness of the fit can be seen from the chart V, where the log of the predicted value is plotted vertically against the log of the actual output on the horizontal axis. It will be noted that the dots, representing the various years, are clustered closely around the 45° line which represents a perfect correspondence between predicted and actual output. All of the variables were statistically significant as measured by their standard errors (37).

How sensitive are predicted values to variations in the equation? A test was made by making predictions of potential output for *1959* and *1975* using eight different versions of the equation and similar values for the inputs. The results showed a maximum deviation from the output computed by the final equation equal to about 12 percent, with six of the eight equations staying within 2 percent. Seven of the sixteen predictions fell within 1½ percent of the final equations results

CHAPTER V

GROSS NATIONAL PRODUCT IN CONSTANT DOLLARS 1909-1958, ACTUAL VS. PREDICTED



Source: Table 2.

and four were within less than 1 percent. The only predictions which deviated by more than 2½ percent were computed from two equations rejected because the time trends were 0 in one and 2.9 percent per year in the other—values which were both irrational and in disagreement with other previous results. Also, in both these equations, the coefficients of Lp and K/Lp were either statistically insignificant or assumed values which could not be accepted as reasonable on economic grounds. In particular, the coefficients of K/Lp in the two equations were extreme—indicating an almost insignificant contribution of capital deepening in one case and an excessively high contribution in the other.

Interpreting the production function in economic terms

What can be said about economic sense of this statistically derived production function? It is perhaps useful at the outset to consider the relative importance of the various factors in explaining changes in output.

(1) The increase in the potential labor input and the associated capital (capital-labor ratio held constant), accounts for between one-quarter and one-third of the change in potential output.

(2) The change in the ratio of the capital stock to the potential labor input accounts for between one-eighth and one-sixth of the change in potential output.

(3) The variation in the age of the capital stock accounts for between 2 and 4 percent of the change in potential output.

(4) The many factors represented by the time trend, as a proxy, account for between one-half and two-thirds of the total annual increase in potential output.

(5) The other changes in output were determined by changes in the mix or composition of demand as between industries with different rates of productivity and by variations in the ratio of actual man-hours to potential man-hours.

To students of the production function, certain economic implications of the present formulation will be readily apparent. The coefficient for the potential labor input (*Lp*) is given at unity. Since this term carries with it by implication an associated stock of capital with a fixed ratio to the potential labor input and a fixed average age of the capital stock, this coefficient of unity implies constant returns to scale. The work of Douglas, Tintner and Solow (38) reached the conclusion that there might be some evidence of a tendency toward decreasing returns to scale, at least in manufacturing. This study suggests that if any such tendency prevailed in the economy as a whole over the last half century, then it must have been quite small and was covered up during this period by the overriding effect of technological improvement which would tend to offset any tendency to diminishing returns (39). Experiments, which varied arbitrarily the coefficient of *Lp* above and below 1, gave no indication whatsoever of improvement of fit to the data.

The cyclical term in the final equation $\left(0.9104 \log \frac{La}{Lp} - 3.39\left[\log \frac{La}{Lp}\right]^2\right)$ seems reasonable in light of both theory and other empirical research. Its parabolic shape (due to the squared term) implies that at low rates of operation of the economy $\left(60 \text{ to } 90 \text{ percent for } \frac{La}{Lp}\right)$ an increase in inputs will yield a more than proportionate increase in output (*Oa*), i.e., there will be a cyclical rise in productivity. As operations approach full employment $\left(100 \text{ on the } \frac{La}{Lp} \text{ scale}\right)$, the cyclical change in productivity dies out and increases in inputs yield equivalent increases in output.

When demand pushes operations to exceptional high rates, as happened during World War II, output increases do not keep pace with rising inputs—all other variables held constant. This is consistent with the fact that at these high rates of operation it is necessary to bring into use less efficient resources; older, standby plant and equipment are put back into use, and less efficient labor is employed. Furthermore, with labor markets exceptionally tight (unemployment fell below 1 percent at the peak of war production), there is a tendency to hoard labor so that available labor is not used at its most efficient rate.

The value of 0.35 for the coefficient of the capital-labor ratio (*K*/*Lp*) appears consistent with some prior studies. For manufacturing Douglas found values for his capital coefficient ranging from 0.10 to 0.31 for time series data and from 0.25 to 0.47 for cross-section studies (40). Solow obtains a value of 0.353 for the coefficient of his capital-labor ratio, when a Cobb-Douglas type function was fitted to data for the private, nonfarm economy (41). Tintner obtained a coefficient for capital of 0.332 for the total private economy (42).

The comparison of these other results with our own are not conclusive in view of the differences in data coverage, definition and form in which the capital variable is introduced into the production function. The previous study closest to this one in its treatment of capital in capital-labor ratio form (Solow's) gives the same result, as already indicated.

That version of Douglas' own functions which comes closest to this study (time series for American manufacturing; series IV) adjusted each variable for time trends and correlated deviations from these trends. This is equivalent to introducing time as an explicit variable as done above (43). In this version Douglas found his capital coefficient (*j*) to be 0.30—a value also close to the 0.35 found for the total economy. Douglas, himself, came to the conclusion that the long-run norm for (*j*), his capital coefficient, for the period he studied (1899–1922) was probably about 0.34 in manufacturing.

If the compensation of capital roughly corresponded to the contribution which an increase in the *K*/*Lp* ratio made to output (*Oa*), then with a coefficient of 0.35 for *K*/*Lp*, we would expect the property share in GNP on the income side of the national account to be between 30 and 40 percent. Depending on the definition of the property share adopted, its value is in this range, and a rough estimate for the 1909–58 period is about 35 percent.

With a *K*/*Lp* coefficient of +0.35, we would expect the capital output ratio (*K*/*Oa*) to be falling and at a roughly proportionate rate over the long run. Indeed, this is the case.

The influence of the age of capital (*k*) is inverse and nonlinear as one would expect on theoretical grounds. This variable is an indirect measure of the degree to which the capital stock (*K*) incorporates the latest technology; when the average age rises, the capital stock is less modern, and vice versa. It would be expected, a priori, that an increase in the average age of the capital stock (*k*) would be accompanied by a reduction in the output (*Oa*) obtained from any given combination of *K* and *L* so the coefficient of *k* would be negative as it is.

Further, the influence would be expected to be nonlinear. When the average age is low—stock generally very up to date—an increase in the average age would imply a larger proportionate drop in technical efficiency, than when the average age is quite high and the capital stock already relatively out moded on the average. The negative slope of *k* and its parabolic shape give this result for the relevant range of the curve.

The time trend (0.00884) has a rate of rise of 2.07 percent per year and over the period 1909–58, it accounts for between one-half and two-thirds of the rise in output. This result agrees closely with those of Kentrick (44), Solow (45), the Bureau of Labor Statistics (46), and the staffs' study of 1957 (47).

Potential output: 1909–60

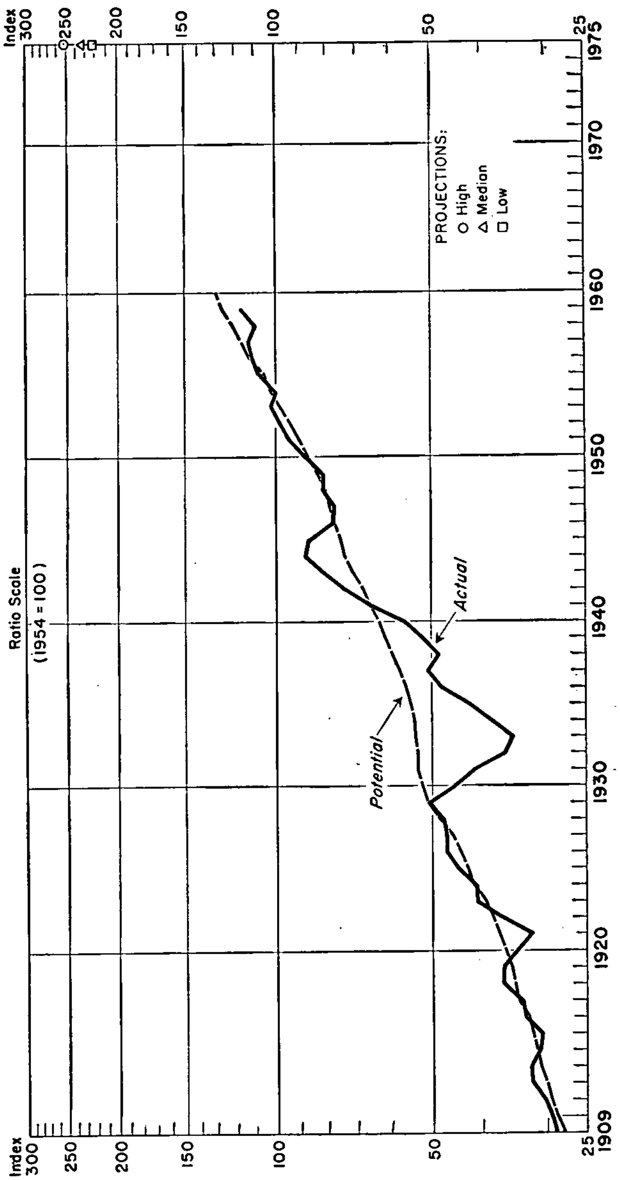
The production function derived above can be used to compute what the potential output could have been each year if there had prevailed a state of full use of resources. Two assumptions must be made. First, a value must be assumed for the cyclical term in the equation $\left(\frac{La}{Lp}\right)$. This variable was constructed on the assumption that Lp, the potential labor input, reflected a constant rate of employment of 96 percent of the labor force and that average annual hours worked followed their trend without short-run, cyclical variations. If we use this as our standard for full employment, La can be set equal to Lp each year, the cyclical term becomes 1 and can be dropped out. The second assumption is that the potential output must reflect history as it had happened up to each year—bygones must be bygones. Thus, the Lp, K, and k assume the values in their actual historical series without adjustment for what might have been if full use of productive resources had in fact been continually achieved.

Potential output computed on this basis is shown in table 2, p. 37, and on chart VI. The movements are what one would expect—rapid growth during periods of relatively continuous prosperity with minor setbacks, as in the 1920's and 1950's, with actual output (Oa) varying around the potential (Op). On the other hand, the potential grew more slowly during the depressed years of the 1930's and output (Oa) fell substantially below potential (Op).

CHART VI

POTENTIAL GROSS NATIONAL PRODUCT COMPARED TO ACTUAL 1909-1959, AND PROJECTED FOR 1975

(In constant prices)



Source: Actual, Department of Commerce;
Potential, Staff, Joint Economic Committee.

Revised Annual Data and Preliminary Quarterly Estimates
for Table 2, page 37, of Study Paper No. 20,
"The Potential Economic Growth in the United States"

[In billions of 1954 dollars]

Year and quarter	Actual GNP O_a	Potential GNP O_p	$O_a \div O_p$
1947:	282.3	284.3	.993
I	278.4	282.2	.987
II	280.4	283.5	.989
III	282.9	285.0	.993
IV	287.2	286.5	1.002
1948:	293.1	290.8	1.008
I	286.4	287.8	.995
II	293.3	289.4	1.013
III	295.6	291.5	1.014
IV	297.3	294.5	1.010
1949:	292.7	303.1	.966
I	291.5	298.9	.975
II	290.3	301.7	.962
III	295.6	304.5	.971
IV	293.0	307.3	.953
1950:	318.1	314.1	1.013
I	302.7	309.7	.977
II	312.0	312.5	.998
III	325.6	315.5	1.032
IV	331.6	318.7	1.040
1951:	341.8	326.6	1.047
I	334.0	321.8	1.038
II	340.0	324.9	1.046
III	346.3	328.1	1.055
IV	346.9	331.5	1.046
1952:	353.5	340.2	1.039
I	349.6	335.0	1.044
II	349.3	338.4	1.032
III	352.6	341.9	1.031
IV	362.3	345.5	1.049
1953:	369.0	354.6	1.041
I	368.9	349.1	1.057
II	373.2	352.7	1.058
III	370.2	356.4	1.039
IV	363.9	360.1	1.011
1954:	363.1	369.2	.983
I	360.4	363.4	.992
II	359.4	367.1	.979
III	362.1	371.0	.976
IV	370.1	375.3	.986
1955:	392.7	386.0	1.017
I	382.2	379.6	1.007
II	389.5	383.7	1.015
III	397.5	388.1	1.024
IV	401.1	392.7	1.021

MORE

(Revised Table 2, p.37, Study Paper No. 20, continued)

[In billions of 1954 dollars]

Year and quarter	Actual GNP O_a	Potential GNP O_p	$O_a \div O_p$
1956:	400.9	404.5	.991
I	398.8	397.7	1.003
II	398.9	402.2	.992
III	400.2	406.8	.984
IV	405.5	411.3	.986
1957:	408.6	423.3	.965
I	409.6	416.7	.983
II	410.0	421.4	.973
III	411.0	425.6	.966
IV	403.8	429.5	.940
1958:	401.3	437.8	.917
I	393.0	431.7	.910
II	395.2	435.5	.907
III	402.9	439.7	.916
IV	413.6	444.2	.931
1959:	428.6	456.3	.939
I	421.7	449.8	.938
II	434.0	454.3	.955
III	427.6	458.5	.933
IV	431.1	462.6	.932
1960:	440.2	472.8	.931
I	440.9	466.5	.945
II	442.3	470.7	.940
III	439.7	474.9	.926
IV	437.7	479.0	.914
1961:	447.9	488.4	.917
I	433.9	481.9	.900
II	443.9	485.9	.914
III	450.4	490.4	.918
IV	463.4	495.3	.936
1962:	471.5p	508.2	.928
I	467.4	500.9	.933
II	470.8	505.7	.931
III	471.6	510.6	.924
IV	476.1p	515.6	.923
1963:		528.4	
I		520.7	
II		525.8	
III		531.0	
IV		536.2	
1964:		549.4	
I			
II			
III			
IV			

p=preliminary.

TABLE 2.—*Actual, predicted, and potential gross national product in 1954 dollars for the United States, 1909–60*

[In billions of 1954 dollars]

Year	Actual gross national product in 1954 dollars O_a	Predicted gross national product in 1954 dollars O_m	$O_m \div O_a$	Potential gross national product in 1954 dollars O_p	$O_a \div O_p$
1909	104.1	102.2	0.982	101.0	1.031
1910	106.8	105.6	.989	103.9	1.028
1911	109.5	108.3	.989	106.4	1.029
1912	116.1	112.7	.901	108.9	1.066
1913	117.0	114.1	.975	111.3	1.051
1914	112.1	113.7	1.014	114.5	.979
1915	114.4	113.8	.995	116.5	.982
1916	120.0	122.2	1.018	118.7	1.011
1917	120.5	128.1	1.063	121.8	.989
1918	132.9	134.3	1.011	125.0	1.063
1919	132.6	129.4	.976	126.7	1.047
1920	125.6	132.5	1.055	130.4	.963
1921	114.9	120.0	1.044	134.4	.855
1922	133.2	131.1	.984	137.9	.965
1923	149.2	144.6	.969	143.0	1.043
1924	149.0	146.1	.981	149.5	.997
1925	161.8	153.6	.949	154.9	1.045
1926	170.8	163.3	.956	161.6	1.057
1927	170.5	166.8	.978	168.5	1.012
1928	171.8	172.6	1.005	175.2	.981
1929	181.8	183.6	1.010	178.5	1.018
1930	164.5	175.1	1.064	190.1	.865
1931	153.0	158.1	1.033	192.5	.795
1932	130.1	129.4	.995	192.2	.677
1933	126.6	130.1	1.028	193.0	.656
1934	138.5	131.8	.952	195.2	.710
1935	152.9	148.9	.974	199.5	.766
1936	173.3	174.5	1.007	204.1	.849
1937	183.5	189.7	1.034	209.7	.875
1938	175.1	175.2	1.001	216.3	.809
1939	189.3	192.6	1.017	222.7	.850
1940	205.8	209.1	1.016	229.0	.899
1941	238.1	239.4	1.005	236.1	1.008
1942	266.9	271.1	1.016	246.0	1.085
1943	296.7	305.5	1.030	256.9	1.155
1944	317.9	315.9	.994	268.8	1.183
1945	314.0	314.3	1.001	277.1	1.133
1946	282.5	280.3	.992	279.5	1.011
1947	282.3	280.6	.994	284.3	.993
1948	293.1	290.7	.992	290.8	1.008
1949	292.7	299.9	1.025	303.1	.966
1950	318.1	303.7	.955	314.1	1.013
1951	341.8	329.5	.964	326.6	1.047
1952	353.5	346.1	.979	340.2	1.039
1953	369.0	364.3	.987	354.6	1.041
1954	363.1	363.2	1.000	369.2	.983
1955	392.7	387.9	.988	386.0	1.017
1956	400.9	409.0	1.020	404.5	.991
1957	408.3	418.6	1.025	423.3	.965
1958	399.0	413.9	1.037	437.5	.912
1959	425.6p			456.1p	.931p
1960				472.6p	

p=preliminary.

CHAPTER IV. POTENTIAL GROWTH: PROSPECTS AND PROBLEMS

The preceding chapters have reviewed the relationship of potential output to the goals of the Employment Act; the problem of analyzing output in terms of an aggregate production function; and derived statistically the coefficients for such a function. In the present chapter, attention turns to the future. How fast could the American economy's output grow over the next decade or two if the full production potential for growth which is inherent in the structure of the economy is achieved? What are the implications for policy of different assumptions as to the underlying factors influencing our economic growth? What range of possibilities can we reasonably contemplate as a basis for discussion of the issues of public and private economic policy?

At the outset it must be recognized that the further ahead we attempt to project our potential for economic growth the more uncertain are the resulting estimates and the less likely it is that we can really effectively apply the results. On the other hand, too short a period would not allow time for underlying forces to work out their longer term consequences. After a review of the various considerations it was decided that the year 1975 would be the terminal date for these projections. It is to be understood that the projections for the year 1975 are an average of expectations for several years centered at 1975.

The preparation and analysis of potentials for future growth of the U.S. economy proceeds below in three stages: (1) the alternative assumptions corresponding to high, medium, and low projections will be reviewed; (2) the projections themselves will be presented together with analysis of the reasons for deviations, if any, of the future potentials from past trends; and (3) the implications of future potential growth rates will be explored, particularly in respect to policy issues which may be associated with them.

Alternative assumptions: 1959–75

Three alternative projections of potential output and of its rate of growth to 1975 were prepared; high (labeled A), medium (B), and low (C). These projections reflect trends of population, participation in the labor force, unemployment, hours of work, changes in the capital stock, and the average level of prosperity. These projections, which, of course, are subject to some error, are designed to indicate a realistic range of potential growth rates that our economy might experience over the next decade. Table 3, page 40, summarizes these projections.

The projections of population and labor force used in the three alternative projections to 1975 are derived from those prepared by the Bureau of the Census, U.S. Department of Commerce (48) and the Bureau of Labor Statistics, Department of Labor (49). These were modified slightly to maintain consistency with the other assumptions of the three projections.

(1) *The A or high projection.*—Projection A assumes that our economic affairs are managed in both the private and public area to maintain a high level of prosperity. While occasionally minor recessions might occur, it is assumed that the Nation will not experience a deep and prolonged depression, such as interrupted growth during the decade of the 1930's. The precise combination of public and private economic policies this projection would require is left unspecified.

Unemployment is assumed to average about 3 percent by the mid-1970's, i.e., about 97 percent of the labor force will be employed in an average prosperous year in the 1970's compared to the 96 percent assumed in computing the potential output for 1909–60 in chapter III. Under such conditions, job opportunities could be expected to be sufficiently abundant to attract a relatively large proportion of the population into the labor force.

In line with the degree of tightness in labor markets, average annual hours are assumed to decline at a rate of about 0.4 percent per year, slightly slower than the rate of fall over the last half century.

The rate of capital accumulation (rate of growth of the gross capital stock) is assumed to proceed at a rate of 3.2 percent per year, a rather conservative estimate of the rate in view of past periods of prosperity (50).

The composition of demand is assumed to follow the historical patterns typical of previous periods of strong growth, with allowance for the effects of continued strong national security demands. This implies about the same share of services in GNP as in 1955–57, reflecting a rise in the share for private housing and government and a fall for consumer services other than housing. The shares of construction and nondurable goods are assumed to fall moderately, while the share of durables rises somewhat above the 1957 share.

(2) *The B, or medium projection.*—The medium projection (B) assumes somewhat more modest success in maintaining continuous maximum employment, but again assumes no deep, prolonged depression will occur.

Unemployment is assumed to average about 4 percent, the same assumption used in preparing the historical potential output estimates in chapter III, shown on chart VI. This means 96 percent of the labor force employed on the average. Labor markets, therefore, would be somewhat less tight than under "A" and participation rates of the population in the labor force would represent a continuation of recent trends.

Average annual hours of work are assumed to decline at a rate of about 0.5 percent per year, slightly less than the average rate over the last half century.

The rate of capital accumulation is assumed to be more modest but still in line with the assumption that serious depression will be avoided. This means that the gross stock is assumed to rise at 2.7 percent per year.

The composition of demand is assumed to have little effect on the growth rate directly through the mix variable, with the rise in the mix term (Xp) being only 0.001 percent per year.

(3) *The C or low projection.*—The low (C) projection assumes a continuation of public and private policies in such mixture that there will be fairly frequent interruptions to growth, inadequate mobility of capital and labor, and more slack on the average than in each of the other two projections.

Unemployment is expected to average somewhat higher than in the past best years or about 5 percent. Employment will average, therefore, about 95 percent. Such slack in labor markets is assumed to be accompanied by a slower rate of growth in the labor force as participation rates reflect the lower level of job opportunities.

In line with the degree of slackness in labor markets, average annual hours of work are assumed to decline at an average rate of about 0.6 percent per year. This is about the average over the past half century—an acceleration over the A and B assumptions consistent with past experience that reduction in hours of work are more likely under slack conditions than when labor markets are relatively tight.

The rate of capital accumulation is assumed to be lower as industries are constantly faced with the threat of excess capacity at higher investment rates and labor is freely available to substitute for capital at peak demand periods. This means a rise in gross stocks at about 2.2 percent per year, a low rate compared to past periods of prosperity.

In all three projections the assumed change in the age of the capital stock reflects the corresponding rates of growth of capital stock, though the assumptions may tend to underestimate the rate of decline in the age of the capital stock under the assumed conditions. If this is the case, then a downward bias is imparted to the three projections.

The alternative projections

The alternative projections, derived by inserting the above assumptions in the formula for output derived in chapter III, yield a series of estimates of potential output of GNP in 1954 dollars for the year 1975. The time trend was not varied between the alternative projections and was the same as derived for the period 1909–58. The rates of growth implied by these are summarized in table 3.

TABLE 3.—*Selected indicators of economic growth potentials, 1959–75* [1]

[Percent increase per year [2]]

Indicator	Rate of growth, 1909-58	Projected potential growth rates, 1959-75		
		A	B	C
Total labor force	1.4	1.9	1.7	1.5
Total employment, including the Armed Forces	1.4	[3] 1.9	[4] 1.7	[5] 1.5
Average annual hours of work	-.6	-.4	-.5	-.6
Total man-hours	.9	1.6	1.2	.9
Stock of private plant and equipment in constant prices	2.4	3.2	2.7	2.2
Average age of capital stock	.3	-.2	-.1	0
Composition of demand	.1	.015	.001	-.005
Gross national product in constant prices	2.9			
From 1959, actual (preliminary estimate)		5.2	4.7	4.2
From 1959 potential		4.6	4.0	3.5

[1] Some rates of change in this table vary slightly from those given in the similar table 4-1, p. 101 of the "Staff Report on Employment Growth and Price Levels" because of the incorporation of later data and refinements of analysis not then available.
[2] Computed by compound interest formula, using initial and terminal years.
[3] Assumes 97 percent of the labor force employed in 1975.
[4] Assumes 96 percent of the labor force employed in 1975.
[5] Assumes 95 percent of the labor force employed in 1975.

It should be repeated at this point that the projections for the year 1975 do not necessarily assume achievement of maximum economic growth each and every year between now and 1975. It is quite obvious that economic ffuctuations or international complications or changes in policies, public and private, other than assumed, could increase or decrease the Nation's production potentials by 1975. Long-run tendencies, incorporated in the production function used to make these projections, indicate that economic growth at these rates is a feasible achievement.

Even if these rates are achieved or even exceeded, it does not follow that output in the year 1975 will fall precisely in line with one of these projections. Any individual year, such as 1975, may exhibit short-run characteristics driving it ahead of or causing it to fall below the long-run rate. In addition, our national economic accounts undoubtedly will be much improved in scope and accuracy over these 16 years and such revisions may appreciably affect the projected levels as well as rates of growth. Finally, it must be reemphasized that these projections assume a stable level of prices—more technically—they assume that the GNP deflator will remain unchanged at the level of 1954. The projections, therefore, represent changes in real output valued at 1954 prices.

A glance at the projected rates of growth in table 3 reveals that the lowest rate of growth (C) is expected to be about 3.5 percent, measured from the potential output calculated for 1959 or about 4.2 percent per year measured from the preliminary estimate of the actual output for 1959. This, the lowest of the three projected rates, is significantly higher than the 50-year average of about 3 percent per year.

The middle or B projection, indicates a projected rate of growth of potential output of 4 percent per year, measured from the output potential for 1959 or 4.7 percent per year, measured from the preliminary estimate of actual output during 1959. The highest projection (A) indicates a possible rate of growth of 4.6 percent per year measured from 1959 potential output levels and about 5.2 percent measured from the preliminary estimate of actual output for 1959. Both the A and B projections indicate rates of growth that substantially exceed the average rate over the last 50 years.

Why do these projections, even the lowest, show an acceleration of the growth rate compared to the average rate of 3 percent achieved over the past 50 years? The first and foremost reason for this difference is found in one basic assumption used for the projections: namely, there will be no deep, prolonged depression during the next 15 years such as interrupted growth during the preceding 50 years—specifically, the period from 1929 to 1941. This assumption has deep and pervasive influences on the projections. Increased stability of the economy makes a very substantial contribution to an increase in the growth rate, affecting the rate of growth of the labor force, the rate of decline in hours of work, the rate of accumulation of capital, the speed with which new technology is incorporated in actual production processes and the composition of demand. The pervasive influences of this assumption together with other developments are reflected in three main factors which account for most of the difference between past and future growth rates:

1. The annual average rate of growth in the total labor force over the next 15 years is likely to range between 1.5 percent and 1.9 percent per year as compared to an average over the previous 50 years of about 1.4 percent. The growth of the population of working age, therefore,

will make possible a somewhat higher rate of growth in the future than over the past 50 years.

2. The gross stock of private plant and equipment in constant prices is assumed to grow between 2.2 percent and 3.2 percent per year over the next 15 years compared to an average of about 2.2 percent per year over the preceding half century. It is notable that the average rate of increase over the past 50 years has been held down by the fact that between 1929 and 1939 there was very little growth in the stock of capital due to the low levels of investment during this decade. In fact, from 1930–31 until 1945 the growth in gross capital stock (K) was barely sufficient to keep pace, on the average, with the rise in the potential labor input (Lp) so that the capital-labor ratio remained almost constant for over a decade. There was a capital widening to keep up with growth in the labor supply, in other words, but no capital deepening to contribute to a rise in the productivity of the system.

3. The average age of the capital stock is assumed to remain constant or decline slightly over the next 15 years, whereas the average age of the capital stock actually increased over the preceding 50 years, reaching a peak during World War II and declining since that time. (See chart IV, p. 24.) The average rate of increase over the entire 50-year period was about one half of 1 percent a year, but over most of the period (1909–45) the rate of increase was slightly over 1 percent per year. Since an increase in the average age of the capital stock tends to retard the rate of growth, and a decline in the average age tends to stimulate the rate of growth, this factor will be a modest stimulant to the economy over the next 15 years, whereas it has been a restrictive influence over most of the preceding half century.

It should be noted that the different assumptions as to the rate of employment (or unemployment) have little direct impact on the rates of growth projected to 1975. In fact, the direct effect would show up in the second or third decimal place, if at all. The differences in this assumption have their effects indirectly through effects on the other variables: Labor force, hours of work, capital stock, age of capital, and composition of demand.

In general, the assumptions chosen for these three projections are conservative. Competent students of the various component factors have prepared analyses of historical tendencies and future prospects under reasonably prosperous conditions which would lead to even higher rates of growth. (39) Indeed, no allowance has been made in these projections for an acceleration in the time trend which has prevailed over the last 50 years. This time trend of approximately 2 percent per year expresses the average influence over the past half century of a wide range of forces which we could not measure directly but which have strong influences on the growth of the economy. These include the level and progress in educational achievements for the population, the extent and nature of research and development efforts, and any changes in the speed with which improved production arrangements—other than those requiring significant changes in the capital stock per man-hour—are introduced throughout the production processes.

It would not be at all surprising if the accelerated rate of research and development of recent years, assuming this continues in the future, should have some tendency to accelerate the rate of growth through its impact on the state of technology. Nor would it be surprising if efforts in the educational field should succeed in raising the efficiency of labor and management in the private and public areas of economic activity faster than occurred over the past half century during which efforts in these directions were interrupted for extended periods of time by both wars and depression. Finally, it would not be surprising either if a more pervasive knowledge among managements of the best production practices would raise productivity faster than in the past. Even today, in the United States there are very significant differences, far wider than seems unavoidable, between the best practices and those of the least efficient firms in any given line of production.

Studies of the Bureau of Labor Statistics in connection with its direct collection program in the early years following World War II developed a considerable body of information about individual plants within certain industries. For example, when the plants in certain industries were classified into four groups ranging from the lowest to the highest in man-hour requirements in unit of output, wide variations showed up. In gray iron foundries, the highest group, the least efficient, that is, required almost four times as many man-hours per unit of output as the lowest or most efficient group. Furthermore, the lowest group obviously contained some plants which did better than the average and some plants in the highest group exceeded the group average. The spread, therefore, was even wider than the group figures revealed (51).

Implications of the projections

These projections have the following implications:

(1) Without changing our economic system in any fundamental way, that is, without instituting elaborate controls or having the Government impose a pattern of consumption, and without Government-imposed, forced high rates of capital accumulation, our economy can grow at a rate as high as 4.6 percent per year. On the other hand, it could prove extremely difficult to achieve rates substantially greater than this within our economic system.

(2) If we avoid stumbling into real depression, the rate of growth may be only as low as 3.5 percent per year, higher than the 50-year average of 3 percent per year which was achieved despite a prolonged interruption in the 1930's. Thus, there is a considerable range of possible growth rates, even within a range of assumptions which exclude depression and a forced-draft economy.

(3) There is a moderate inherent tendency for the rate of growth of the economy to rise in the coming decade if unemployment can be held on the average to about 4 percent, or less, of the civilian labor force. This is due to the increase in the rate of growth in the labor force and to the fact that the rate of increase in the capital stock and the decline in the average age of the capital stock would not be restricted as in the past by long periods of low investment such as occur in periods of prolonged depression. So long as recessions are neither too frequent nor deep, the rate of accumulation of capital can be quite favorable to growth.

(4) Our economic growth is within our own control. If the Government pursues growth-facilitating policies, the economy will expand near the upper limit of the range. If, on the other hand, the Government, as a matter of policy, sacrifices economic growth to the pursuit

of other objectives, our economy will perform sluggishly, will add less to our capacity, and our potential growth will tend to be near the lower limit of the above range or even below.

(5) In recent years, including currently, the output of the economy has been well below its potential and probably would be in the 1970's under the assumptions of the C projection.

From the standpoint of public and private policy, this study and these projections imply that wide differences in the rate of growth can develop in the future, depending on the degree to which public and private policies contribute: (1) To increased mobility of labor and capital to meet the changing demands of our dynamic economy; (2) to a rapid rise in educational attainment to keep pace with requirements of the changing technology associated with higher rates of growth and the high mobility this technological change requires; (3) to a high and growing rate of research and development expenditures as a basis for a high rate of technological progress; and (4) to maintenance of such proportions between the growth in investment and in consumption as will not only provide for a high rate of growth of capital stocks and the achievement of a relatively low age of the stock, but also will produce a growth in final demand for private and public consumption sufficient to maintain operations of the continually growing capacity at rates of operation which will maintain private incentives for a high rate of investment and of technological progress.

PART II

TECHNICAL MATERIALS

These technical materials supply explanations of terms, sources, and expansions on details of technique to supplement the discussion in part I. The sections of these materials below are numbered in sequence, numbers corresponding to those inserted at appropriate places throughout part I.

(1) This prevision of America's future was that of George Tucker, writing in 1912. See Joseph Dorfman, "The Economic Mind in American Civilization," volume II, pages 540–541, the Viking Press, New York, 1946.

(2) This forecast, made in 1872 by a Connecticut doctor, is an interesting, and indeed curious, example of reason and imagination applied to the problem of predicting future economic, social, political, and technological changes. See L. P. Brockett, M.D., "Marvels That Our Grandchildren Will See; or One Hundred Years Progress in the Future," published as part of L. Stebbins, "One Hundred Years Progress of the United States," Hartford, Conn., 1872.

(3) The Employment Act of 1946, section 2.

(4) Ibid.

(5) The legislative history of the Employment Act of 1946 was reviewed by the staff of the Joint Economic Committee and a memorandum prepared in April 1955 entitled "The Significance of the Words 'Maximum Employment' as Used in the Employment Act of 1946." See hearings on relationship of prices to economic stability and growth, Joint Economic Committee, 85th Congress, 2d session (1958), page 1.

(6) During World War II and the transition in 1945–47, a number of projections were made of postwar prospects and of the postwar levels of employment and output consistent with full employment. Among these were:

Bassie, V. Lewis, "Consumers' Expenditures in War and Transition," Review of Economic Statistics, August 1946.

Cornfield, Jerome, Evans, W. Duane, and Hoffenberg, Marvin, "Full Employment Patterns 1950," U.S. Department of Labor, Bureau of Labor Statistics, serial No. R1868, reprint from Monthly Labor Review of February and March 1942.

Dewhurst, J. Frederic, and associates, "America's Needs and Resources," The Twentieth Century Fund, Inc., New York, 1947.

George, E. G., in Dun's Review:

I. Gross National Product Projections: "The Background and Relation to Current Issues," March 1945, pp. 9–14.

II. Contrasting Estimates; Range and Reasons, May 1945, pp. 9ff.

III. Measuring the Labor Force in 1950, June 1945, pp. 9ff.

Goldenweiser, E. A. and Hagen, E. E., "Jobs After the War," Federal Reserve Bulletin, May 1944.

Hagen, Everett E. and Nora B. Kirkpatrick, "The National Output at Full Employment in 1950," American Economic Review, September 1944.

Hart, Alfred G., "Model Building and Fiscal Policy," American Economic Review, September 1945.

Hauser, Philip M., "Wartime Population Changes and Postwar Prospects," Journal of Marketing, January 1944, pp. 238–247.
Johnson, Arno H., "Fifty-Seven Million Jobs," address before the Sales Executive Club of New York, Feb. 6, 1945.
Livingston, S. Morris, "Markets After the War," U.S. Department of Commerce, Washington, D.C., March 1943. [Available as S. Doc. 40, 78th Cong., 1st sess.
"Postwar Manpower and Its Capacity to Produce," Survey of Current Business, U.S. Department of Commerce, April 1943.
"Postwar Income Potentials," in Measuring and Projecting National Income, National Industrial Conference Board, Studies in Business Economics, No. 5, March 1945, pp. 23–27.
Mayer, Joseph, "Postwar National Income," The Brookings Institution, pamphlet No. 55, Washington, D.C., 1944.
Montgomery, D., "Reconversion to What?", Antioch Review, September 1945, v. 5, pp. 309–319.
National Planning Association, "National Budgets for Full Employment," planning pamphlets Nos. 43 and 45, April 1945—study made during spring and summer of 1944.
Roos, C. F., hearings on S. 380 (Full Employment Act 1945) before a subcommittee of the Senate Banking and Currency Committee, 1945, pp. 906–912.
Schlotterbeck, Karl T., "Postwar Reemployment," The Brookings Institution, pamphlet No. 54, Washington, 1943.
Slichter, Sumner H., "Jobs After the War," Atlantic Monthly, October 1944.
Tucker, Rufus S., "Projections of National Income," National Industrial Conference Board, Business Record, December 1944 and January 1945.
U.S. Department of Agriculture, "What Peace Can Mean to American Farmers," miscellaneous publications: No. 562, May 1945; No. 570, July 1945; No. 582, October 1945; and No. 589, December 1945.
U.S. Department of Commerce, Bureau of the Census, "Normal Growth of the Labor Force in the United States: 1940 to 1950," prepared by John D. Durand, mimeographed series, P–44, No. 12, June 12, 1944.
Warburton, C., "Normal Production, Income, and Employment, 1945 to 1965, Based on a Statistical Analysis of Past Data." Southern Economic Journal, January 1945, v. 11, pp. 219–245.
Weiler, E. T., "Wartime Savings and Postwar Inflation," Survey of Current Business, July 1943.
Woytinsky, W. S., "Prospects of Permanent Full Employment," International Postwar Problems, American Labor Conference on International Affairs, September 1944, vol. 1, pp. 485–515.
"Postwar Economic Perspectives," Social Security Bulletin, March 1946, vol. 9, pp. 11, 25; December 1945, vol. 8, pp. 18–29; January 1946, vol. 9, pp. 8–16; and February 1946, vol. 9, pp. 9–16.

(7) Projections of employment, production and purchasing power needed to carry out the policy declared in section 2 of the Employment Act were made in accordance with section 3(a) of the act in the Economic Report of the President from 1947 to 1952. These are cited below:

Date of report:	Pages
January 1947	9–11
January 1948	45–47
January 1949 [1]	36, 38
January 1950 [1]	75, 78, 80
January 1951 [1]	76–77
July 1951 [2]	60–63
January 1952 [1]	113–114

[1] Contained in the Annual Economic Review, a Report to the President by the Council of Economic Advisers. (This review is printed with the Economic Report of the President.)
[2] Contained in The Economic Situation at Midyear, a Report to the President by the Council of Economic Advisers.

(8) Projections of the levels of employment and production needed to carry out the objectives of the Employment Act and, summaries of the economic outlook based on the annual Economic Report of the President, the Joint Economic Committee's hearings, and other

sources, have been made by the staff of the Joint Economic Committee for use of the committee. For these, refer to Joint Economic Committee's Reports on the Economic Report of the President, as follows:

		Page
1948	Staff report	11 ff.
1950	Staff materials	37 ff.
1951	Staff materials	26 ff.
1952	National defense and the economic outlook for 1953 (fiscal year)	29 ff.
1954	Staff materials	35 ff.
1955	Staff materials	79 ff.
1956	Staff materials	77 ff.
1957	Staff materials	38 ff.
1958	Staff materials	17 ff.
1959	Staff materials	45 ff.

Also the following other publications:

"The Economic and Political Hazards of an Inflationary Defense Economy," (materials prepared by the staff of the Joint Economic Committee), committee print, February 1951.

"Inflation Still a Danger," (report of the Joint Economic Committee, together with materials on national defense and the economic outlook prepared by the committee staff) (S. Rept. 644), August 1951.

"Sustaining Economic Forces Ahead," (materials prepared for the Joint Committee on the Economic Report by the committee staff), committee print, December 1952.

"Potential Economic Growth of the United States During the Next Decade," (materials prepared for the Joint Economic Committee by the committee staff), committee print, October 1954.

(9) This was discussed at length by various witnesses and contributors to the study by the Joint Economic Committee in 1958, entitled "The Relationship of Prices to Economic Stability and Growth." See especially the summary of the arguments by Beryl Sprinkel in his paper "Maintaining Economic Growth, Stability, and Stable Prices," in the commentaries submitted by economists from labor and industry, pages 63 ff.; also, in the compendium of papers submitted by panelists appearing before the Joint Economic Committee in connection with the same study, see those contributed under part I, on "Employment Act Objectives and the Stabilization of Prices" (pp. 1–74).

(10) This was outlined at length by Dr. Edwin G. Nourse in his paper "Employment Act Objectives and the Stabilization of Prices," in the study mentioned in note 9 (compendium of papers submitted by panelists appearing before the Joint Economic Committee, pp. 13–22).

(11) For a discussion of the definition and nature of economic growth and its study see:

Paper by Grover W. Ensley, entitled "The Employment Act of 1946: The Dynamics of Public Economic Policy." Compendium of papers submitted by panelists appearing before the Joint Economic Committee, in connection with its study of the relationship of prices to economic stability and growth, pages, 1–12. (85th Cong., 2d sess.)

Goldsmith, Raymond W., "The Comparative Study of Economic Growth and Structure," National Bureau of Economic Research, 1959.

"Staff Report on Employment Growth, and Price Levels," prepared by Joint Economic Committee staff, especially chapter II, pages 33–34. (86th Cong., 1st sess., December 1959).

(12) Perhaps the most provocative and widely discussed recent essay based on the distinction between an increase in material goods and services and an increase in welfare was the book by John K. Galbraith, "The Affluent Society," Houghton Mifflin Co., Boston, 1958.

(13) The monthly report on employment, labor force, and unemployment is based on the monthly current population survey of a sample of households. The basic concepts, definitions, and classification scheme remained unchanged from the survey's inception in 1940 until January 1957. There have been a number of changes in sample design and procedures.

Civilian labor force data beginning with May 1956 are based on a 330-area sample. For January 1954–April 1956 they are based on a 230-area sample; for 1946–53 on a 68-area sample; for 1940–45 on a smaller sample; and for 1929–39 on sources other than direct enumeration.

Effective January 1957, persons on layoff with definite instructions to return to work within 30 days of layoff and persons waiting to start new wage and salary jobs within the following 30 days are classified as unemployed. Such persons had previously been classified as employed (with a job but not at work). The combined total of the groups changing classification has averaged about 200,000 to 300,000 a month in recent years. The small number of persons in school during the survey week and waiting to start new jobs are classified as not in the labor force instead of employed, as formerly. Persons waiting to open new businesses or start new farms within 30 days continue to be classified as employed.

Beginning July 1955, monthly data are for the calendar week ending nearest the 15th of the month; previously, for week containing the 8th. Annual data are averages of monthly figures.

For the years 1940–52, estimating procedures made use of 1940 census data; for subsequent years, 1950 census data were used. The effects of this change on the historical comparability of the data are explained in the Annual Report on the Labor Force, 1954, series P–50, No. 59, April 1955, page 12.

These changes have had measurable effects on the magnitudes shown by the survey. For example, for 1957, unemployment was 4.0 percent of the civilian labor force on the old definition but 4.3 percent according to the new definitions adopted January 1957.

(14) Stanley Lebergott has shown that, although the proportion of the population exposed to possible unemployment has risen markedly since the early years of the 19th century, the average percent of the labor force unemployed has shown no distinct trend at all. Changes enabling the economy to operate with lower unemployment in proportion to the numbers exposed to its threat have fully offset the increase in the proportion of the population exposed to possible unemployment. See hearings, "Study on Employment, Growth, and Price Levels," part 3, pages 577–585.

(15) The effects of job shifting, labor mobility, changes in the age-sex composition of the labor force, and other factors on unemployment rates was examined in two new studies made for the Joint Economic Committee in connection with the current study of employment, growth, and price levels, by the Bureau of Labor Statistics, U.S. Department of Labor. See Study Paper No. 6, "The Extent and Nature of Frictional Unemployment," and No. 23, "Unemployment in Surplus Labor Market Areas," in press, January 1960.

(16) This was not a determination by the staff that 4 percent was the percentage consistent with the objectives of the Employment Act.

Indeed, it would have no authority to make such a determination. The staff has stated a number of times that this percentage was derived from studies of the past history of employment and unemployment of the United States. See, for example, "Potential Economic Growth of United States During the Next Decade," opere citato, page 6.

(17) Domar, Evsey D., "Essays in the Theory of Economic Growth," New York, Oxford University Press, 1957, page 16.

(18) The pioneering work of Prof. Paul H. Douglas, his early colleague, Charles W. Cobb, and his other associates in his work on the production function was incorporated in a long series of journal articles and in his book on wages. The first of these was: Cobb, C. W., and Douglas, Paul H., "A Theory of Production," American Economic Review, supplement, volume XVIII, March 1928, pages 139–165.

The results were incorporated in Professor Douglas' book on wages in 1934 and later work in a further series of articles. This work was summed up and evaluated in his presidential address before the American Economic Association at Chicago, Ill., December 29, 1947, entitled "Are There Laws of Production?" The most convenient source for his work on this problem is the reprint of his book on wages: "The Theory of Wages," by Paul H. Douglas, incorporating a reprint of the article "Are There Laws of Production?", Augustus M. Kelley, New York, N.Y., 1957.

(19) See:

G. Tintner, "A Note on the Derivation of Production Functions from Farm Records," Econometrica, volume 12 (1944), pages 26 ff.

——— and O. H. Brownlee, "Production Functions Derived From Farm Records," Journal of Farm Economics, volume 26 (1944), pages 566 ff.

C. G. Hildreth, "A Study of Production Functions From Farm Record Data" (unpublished thesis, Ames, Iowa, 1947).

W. H. Nichols, "Labor Productivity Functions in Meat Packing," Chicago, 1948.

M. J. J. Verhulst, "The Pure Theory of Production Applied to the French Gas Industry," Econometrica, volume 6 (1948), pages 295 ff.

E. O. Heady, "Production Functions From a Random Sample of Farms," Journal of Farm Economics, volume 28 (1946), pages 989 ff.

W. W. Leontief, "Introduction to a Theory of the Internal Structure of Functional Relationships," Econometrica, volume 15 (1947), pages 361 ff.

Robert M. Solow, "Technical Change and the Aggregate Production Function" in the Review of Economics and Statistics, August 1957, volume XXXIX, No. 3, pages 312–320.

(20) On linear programing, see:

Robert Dorfman, Paul A. Samuelson, and Robert M. Solow, "Linear Programing and Economic Analysis," New York: McGraw-Hill Co., Inc., 1958

T. C. Koopmans (ed.), "Activity Analysis of Production and Allocation," John Wiley & Sons, Inc., New York, 1951.

Robert Solow, "On the Structure of Linear Models," Econometrica, volume 20 (1952), pages. 29 ff.

(21) On input-output, see, for example:

Oskar Morgenstern (ed.), "Economic Activity Analysis," John Wiley & Sons, Inc., New York, 1954.

Netherlands Economic Institute, "Input-output Relations," Proceedings of a Conference on Inter-industrial Relations Held at Driebergen, Holland, 1953, H. E. Stenfort Kroese N. V., Leyden, 1953.

Conference on Research in Income and Wealth, "Input-Output Analysis; An Appraisal," Studies in Income and Wealth, volume 18, Princeton University Press, Princeton, N.J., 1955.

W. D. Evans and M. Hoffenberg, "The Interindustry Relations Study for 1947," The Review of Economics and Statistics, volume 34 (1952), pages 97 ff.
Wassily W. Leontief, "The Structure of American Economy, 1919–1939," 2d ed., Oxford University Press, New York, 1951.
——— and others, "Studies in the Structure of the American Economy," Oxford University Press, New York, 1953.

(22) For critical analyses of production functions, see:

M. Bronfenbrener, "Production Functions," Econometrica, volume 12 (1944), pages 35 ff.
D. Durand, "Some Thoughts on Marginal Productivity, With Special Reference to Professor Douglas' analysis," Journal of Political Economy, volume 45 (1937), pages 740 ff.
J. Marschak and W. H. Andrews, "Random Simultaneous Equations and the Theory of Production," Econometrica, volume 12 (1944), pages 143 ff.
H. Menderhousen, "On the Significance of Professor Douglas' Production Function," Econometrica, volume 6 (1938), pages 143 ff.
M. W. Reder, "An Alternative Interpretation of the Cobb-Douglas Functions," Econometrica, volume 11 (1943), pages 259 ff.
E. Schneider, "Theorie der Produktion" (Vienna, 1934).
R. G. D. Allen, "Mathematical Analysis for Economists," London, 1938, pages 502 ff.
S. Carlson, "A Study in the Pure Theory of Production," London, 1939.
P. H. Wicksteed, "The Coordination of the Laws of Distribution" (reprint), London, 1932.
Burgess Cameron, "The Determination of Production," Cambridge University, 1954.
Francis Seton, "Production Functions in Soviet Industry," American Economic Review; Papers and Proceedings, volume 49 (May 1959), No. 2, pages 1–14,.
W. P. Hogan, "The Limitations of Capital Coefficients: A Comment," American Economic Review, volume 49 (March 1959), No. 1, pages 138 ff.
Irma Adelman, "Some Observations on Full Employment Versus Full Capacity," American Economic Review, volume 46 (June 1956), No. 3, pages 412 ff.
D. Hamberg, "Production Functions, Innovations, and Economic Growth," Journal of Political Economy, volume LXVII (June 1959), No. 3, page 228 ff.

(23) There is an extensive literature on the definition of measurement of capacity. In recent years, attempts at constructing statistical indicators of capacity, or of changes in capacity, have brought about renewed discussion of some of these points in a more practical setting. These include the series of surveys of manufacturing capacity made by the Department of Economics of the McGraw-Hill Publishing Co. in connection with their annual survey of business plans for capital expenditures. See particularly their checkup on manufacturing capacity in connection with the survey in the fall of 1958, dated October 6, 1958; the discussion by Sanford S. Parker and his associates of Fortune magazine in their September 1958 issue in an article entitled "How Much Over-capacity in U.S. Manufacturing?", and his talk before the American Statistical Association, December 10, 1958; and the paper by William F. Butler, entitled "Capacity Utilization and the Rate of Profitability in Manufacturing," American Economic Review, proceedings, May 1958, volume XLVIII, No. 2, pages 239–248. Dr. George Teborgh has also considered this capacity problem and some of his work is presented in "Capital Goods Review," published by Machinery and Allied Products Institute. See particularly No. 39, September 1959, and No. 22, May 1955.

(24) See Paul H. Douglas, "Are There Laws of Production?", and his other works as cited above in technical note No. 15. Also Gerhard Tintner, "Econometrics," John Wiley & Sons, Inc., New York, 1952, particularly pages 51–53.

(25) See Tintner, opere citato, pages 53, 55–56, 91–132, 303–304, and other studies cited in his notes.

(26) See Tintner, opere citato, pages 134–143; Robert M. Solow, "Technical Change and the Aggregate Production Function" in The Review of Economics and Statistics, August 1957, volume XXXIX, No. 3, pages 312–320.

(27) For a convenient survey of the theory of production and production functions, see Paul H. Douglas, opere citato, and Sune Carlson, "A Study on the Pure Theory of Production," Kelly & Millman, Inc., 1956.

(28) Douglas, opere citato the reprint of his address, "Are There Laws of Production?"

(29) The series used was taken from "U.S. Income and Output," a supplement to the Survey of Current Business, table I–2, pages 118–119, and table I–16, pages 138–139.

(30) For employment and hours of work, the figures used were preliminary data prepared by Dr. John Kendrick in his study for the National Bureau of Economic Research entitled "Productivity Trends in the United States" (in preparation), a summary of which was presented by Dr. Solomon Fabricant in his statement before the Joint Economic Committee at hearings in connection with the Study of Employment, Growth, and Price Levels (pt. 2, "Historical and Comparative Rates of Production, Productivity, and Prices," p. 281). We are indebted to the National Bureau for permission to use these preliminary data in our study prior to completion and publication of Dr. Kendrick's volume.

(24) *Derivation of potential labor input* (L_p).—The potential labor input variable (L_p) measures the total amount of man-hours potentially available for economic activity during the calendar year. It is, conceptually speaking, equal to the potential labor force multiplied by the average of the potential annual hours of each employee. The labor force was assumed to be 96 percent employed, that is, an arbitrary level of 4 percent unemployment was postulated for the model. This figure was selected because there was the self-imposed constraint that the model would be built within the existing institutional framework, one characteristic of which is an amount of frictional unemployment. On the basis of past experience, 4 percent seemed to be representative of unstrained full employment. It is underlined, however, that this figure intends no policy recommendations or value judgments.

For purposes of the model, the figure is unimportant because the mathematical technique used—that is, correlation analysis in logarithms—turns this percent into a constant that is absorbed in the constant of the equation without effecting the regression coefficients or the forecast. With the assumption of a constant level of unemployment, movement within the labor input series reduces to changes in the labor force and changes in the average annual hours. The final data used for both of these series is a smoothed aggregation of individually derived subseries. The procedure was different for each series.

Potential labor force (M_p).—The derivation of a potential labor force faces both conceptual and technical problems. On the one hand there is the difficulty of reconciling the pre-1940 definitions of gainfully employed with the subsequent labor force concept, which itself has changed even as recently as 1957. Then granting the solution of this problem there is the difficulty introduced by inaccurate measurement particularly in the earlier period and by shifting patterns of employment in several of the age-sex groups.

These problems seemed to call for an indirect derivation using population figures and participation rates. Available MRLF data were used in the later period, and decennial census figures with interpolations covered the earlier years.

The participation rate of each of the age-sex groups in table 4 of Bureau of the Census series P–50, were fitted in a multiple regression against an index of unemployment, armed forces, and time. The results proved to be consistent with previous studies in this area and provided a basis from which to project the growth of the labor force. The most significant changes seemed to be the increasing participation of women and the decreasing participation of men under 20 and over 64 years of age. The trend value of the participation rate depicting full employment was then applied to the population within each age-sex group and the resulting aggregation provided a potential labor force for the early years which was consistent in concept and level with the more reliable recent years. The aggregated series was tied in at 1950 to the trend labor force figures provided by the Bureau of Labor Statistics. See table 1, p. 111, "Hearings on the January 1959 Economic Report of the President."

Potential average annual hours (*Hp*).—A satisfactory mathamatical representation of the changing average annual hours proved to be extremely difficult because of substantial structural and institutional changes during the period. The general pattern was a gradual decline until the thirties, a sharp decline until the late forties and then a slowing down of the decline into the fifties. There are of course several explanations for this behavior. In the early third of the period both the general shortening of hours and the shift of labor out of agriculture into the relatively shorter houred industrial occupations account for much of the decline. The major downturn in the thirties, particularly after 1934, seems to come from a combination of the effects of the depression, minimum age and wage laws, and of the increased effectiveness of organized labor. The sharp impact of these institutional changes seems to have run its course by the late forties and the lower rate of decline of the earlier period returns, this time partially accounted for by increasing proportion of women in the work force, the added premium of leisure, and longer vacations, among other reasons.

The functional representation of the otherwise logical pattern is troublesome. A constant rate of decline over the entire period, that is a linear function in logarithms, is scarcely representative of any part of the period and makes economic nonsense when extrapolated. A second-degree parabola is impossible because the series shows an inflexion point during the thirties. Yet, a cubic parabola, though fitting the period under observation satisfactorily, will provide a minimum point and eventually an upturn on extrapolation because of the nature of the equation. And, the logistic curve, sometimes called the Pearl-Reed growth curve, proved too inflexible to fit the data.

The hurdle was finally overcome by a hand-fitted series for the potential hours. Essentially this boiled down to making linear interpolations over short and economically meaningful periods for hours in each of three sectors—agriculture, private nonfarm, and government. This resulted in about a 0.4 percent rate of decline in the most recent years which corresponds closely to the rate of decline in the early years, and a more rapid rate in the 1930's and 1940's.

(32) The estimate of capital stock, prepared by Dr. Terborgh, is that underlaying Capital Goods Review, No. 39, September 1959, published by Machinery & Allied Products Institute, Washington, D.C.

(33) Dr. Terborgh describes the procedure and his results in Capital Goods Review, No. 39, September 1959. He comments on possible shortcoming of his procedure as follows:

> This calculation is subject to at least one serious defect. The same estimated survival curves are used throughout. Even if these curves were correct for assets installed in one period, they would not necessarily be so for the installations of other periods. There is no reason to believe that mortality rates have held constant in the past. Because of this instability, actual changes in stocks must have differed appreciably from changes computed on the assumption of constancy.
>
> It is difficult to appraise the magnitude of the errors arising from this assumption. They may be substantial. We are reasonably sure, however, that they are not sufficient to vitiate the computed results fundamentally. Though no more than crude approximations, these results offer a significant indicator of major changes in the stock of productive facilities. Needless to say, they should be read for major changes only.
>
> A further warning is in order. Since our calculations relate to the grand total of business capital goods—agricultural, industrial, public utility, transportation, commercial, and miscellaneous—extreme care should be exercised in drawing inferences for particular classes or product lines. There have been wide differences from one line to another in past installation and survival rates, and the overall picture may, therefore, be of limited significance for any one of them taken singly.

(34) See Capital Goods Review, No. 40, Machinery & Allied Products Institute, December 1959. The average age refers to a weighted combination of the Terborgh series for plant and for equipment.

(35) The problem of allowing for the influence of changes in the composition of demand on productivity and costs was discussed in "Productivity, Prices, and Incomes" (materials prepared for the Joint Economic Committee by the committee staff), committee print, June 1957. See particularly the analysis of effects on share of employee compensation in national income (a related issue), pages 49–50, 59–60. See also, hearings on employment, growth, and price levels part. 2, testimony of Soloman Fabricant, page 281 and following pages; Bulletin No. 1249, U.S. Department of Labor, "Trends in Output Per Man-Hour in the Private Economy, 1909–58," January 1960, especially pages 12–14; and Study Paper No. 17, "Prices and Costs in Manufacturing Industries," by Charles L. Schultze and Joseph L. Tryon.

(36) In the past, two basic techniques have been used, particularly in the study of productivity, to make allowance in time series for the influence of changes in the composition of demand. One of these used by Kendrick, for example in the study cited in note 30 above, involves combining the inputs with weights reflecting the relative importance of each industry or, as in Kendrick's case, by the average compensation. The other technique derives measures, such as measures of productivity, for each of a number of components of the gross national product, then combines the outputs resulting from the component

sectors such as agriculture, private, nonfarm, manufacturing, government, etc. In this study we constructed instead a so-called mix index (X) making use of a breakdown of GNP by type of product or service recently initiated by the Department of Commerce and the input-output technique. First, estimates were prepared, utilizing mainly the Department of Commerce data on GNP, by type of product for each year 1909–58. These values were in constant 1954 prices. The breakdown was that provided in "*United States Income and Output*," A Supplement to the Survey of Current Business, November 1958, table VII–6, page 224. The input- output-table developed by the Federal Government at the Bureau of Labor Statistics for the year 1947 was utilized to distribute estimates of man-hours worked in each of about 50 industries and capital stocks in each of these industries to the final goods and service accounts in the GNP. The procedure made use of the table given by Evans and Hoffenberg (note 21 above) showing the direct and indirect deliveries of each of the 50 industries to each of the number of final demand sectors. The contributions of each industry to each of these broad final demand sectors was broken down into the final categories required for our purposes by inspection of the basic input-output table. Some rough tests showed that more refined procedures would not make enough difference to be worthwhile at this point.

With the man-hours and capital stocks distributed from industries to final goods and service categories, these were then totaled for each category of the gross national product. We then had the total number of man-hours and the total stock of capital employed in producing the particular quantity of goods or services produced in each category. Dividing the man-hours by the gross national product in each category gave a labor-output coefficient and division of the capital stock by the output gave a capital-output coefficient for each category of GNP.

These two sets of labor and capital ratios were used as weights in combination with the annual estimates of GNP by categories of goods and services to derive an index with 1954 equal to 100. Since this index used the changing composition of demand for each year at a constant set of labor-output and capital-output ratios, the resulting index expressed the change in the output which the system is capable of generating each year because of changes in the mix of demand but assuming that the efficiency with which inputs were used would remain constant throughout all years.

Potential mix index (X_p) was computed by fitting a trend through the actual index for the individual years. In both the index of actual mix (X_a) and the index of potential mix (X_p) the labor and capital components were combined with changing weights based essentially on those used by Kendrick. See note 30 above.

The GNP categories and the corresponding labor and capital coefficients are as follows:

GNP category	Capital per dollar of output	Labor man-hours per dollar of output
Services:		
Government gross national product	0	0.478
Other	1.3	.404
Net exports	2.71	0
Housing	4.807	.045
Other consumption		.4
Construction	1.205	.650
Nondurables:		
Consumers	1.422	.530
Government	2.317	
Net exports	8.196	
Change in business inventories	1.534	
Durables:		
Consumers	1.345	.476
Government	1.322	
Net exports	2.502	
Change in business inventories	1.335	
Producer	1.02	

(37) The coefficients and their standard errors were:

Variable	*Coefficient*	*Standard error*
$\log \frac{La}{Lp}$	$+.9104$	$.0591$
$\left[\log \frac{La}{Lp}\right]^2$	-3.39	$.58$
$\log k$	-5.6411	$.7069$
$\left[\log k\right]^2$	$+10.356$	1.358
t	$+.00884$	$.00025$

The coefficients of Lp and K/Lp were stipulated on the final run as a result of the preceding tests. However, their coefficients were statistically significant on those runs where their coefficients came out close to the final values stipulated on the seventh run.

(38) See Douglas, opere citato, and Solow, opere citato, for discussion of relation of production function to returns to scale.

(39) See, for example, William Fellner, "Trend and Cycles in Economic Activity," Henry Holt & Co., New York, 1956, chapters 8 and 9.

(40) See Professor Douglas' presidential address, reprinted in the Kelly reprint of his "Theory of Wages," note (15) above.

(41) Solow, opere citato, page 319.

(42) Tintner, opere citato, pages 134–138.

(43) See for example, Tintner, opere citato, pages 301, 302.

(44) See hearings, part 2, pages 283–346.

(45) Solow, opere citato.

(46) Bureau of Labor Statistics, Bulletin No. 1249, "Trends in Output Per Man-Hour in the Private Economy, 1909–58."

(47) See "Productivity, Prices, and Incomes," Joint Economic Committee, opere citato.

(48) U.S. Bureau of the Census, series P–25, No. 187, November 10, 1958, "Illustrative Projections of the Population of the United States, by Age and Sex, 1960 to 1980."

(49) U.S. Bureau of Labor Statistics, Bulletin No. 1242, "Population and Labor Force Projections for the United States, 1960 to 1975."

(50) George Terborgh has prepared projections of installations and gross stocks which are somewhat higher than our assumptions. See Capital Goods Review, No. 22, May 1955.

(51) See the speech of Ewan Clague, Commissioner of Labor Statistics, before the Chicago Association of Commerce and Industry, May 26, 1959, entitled "Productivity—What It Is and How It Is Measured," especially page 6 and chart 2.

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