Volume Title: Production Trends in the United States Since 1870

Volume Author/Editor: Arthur F. Burns

Volume Publisher: NBER

Volume ISBN: 0-87014-022-1

Volume URL: http://www.nber.org/books/burn34-1

Publication Date: 1934

Chapter Title: Measurement and Analysis of Production Trends

Chapter Author: Arthur F. Burns

Chapter URL: http://www.nber.org/chapters/c2261

Chapter pages in book: (p. 26 - 44)

Chapter II

MEASUREMENT AND ANALYSIS OF PRODUCTION TRENDS

A STATISTICAL technique is to be adjudged in the light of the purpose it is made to serve and of the data on which it is put to work. The aim of this chapter, accordingly, is to describe our technique of measuring secular trends, in relation to the underlying concept of secular trend of production and to the raw data on production. The measurements of secular trends will be analyzed in detail in later chapters, the primary aim being to throw light on the elements of order in the secular changes in the pattern of production of the United States, and in the quantitative increase of its total production. The special techniques employed in the analysis of the measurements of secular trends will be described fully at the points where they are introduced; but their general nature will be discussed briefly in the closing section of this chapter.

I. CONCEPT OF SECULAR TREND OF PRODUCTION

There is probably no concept in the whole field of contemporary 'quantitative' economics that is vaguer than that of secular trend. However, what the most appropriate denotation of secular trend should be is perhaps less important than that the term have real economic content, a fairly unequivocal meaning, and a uniform use in any given investigation.

The term 'secular' is derived from 'saeculum'; etymology might therefore require that we refer to a century when we speak of the 'secular trend' of some economic element. But there is a firm tradition in economics, going back to Cournot, which justifies a looser use of the term. The secular trend of an industry's production may be considered as the persistent, underlying movement of its output over a period which is 'long' in relation to the changes associated with the 'business cycle'.[1] So viewed, the secular trend is irreversible within the periods of a business cycle, though it may be reversible within longer periods. The secular trend can be represented graphically by a curve and may be given algebraic expression by a mathematical equation. A set of secular trend lines for the component branches of a national productive system will register the rapidity of advance (or decline) and the changing pattern of the parts of the system.

This statement of the meaning of secular trends does not suffice for the purpose of measurement. From a statistical standpoint, it is more convenient to define secular trends negatively. Accordingly, secular trends of production may be considered, on the economic side, as the 'non-cyclical' movements of series, and on the statistical side, as curves which delineate these movements. This view of the secular trend of production will be definite in the degree to which the idea of a production 'cycle' has definiteness. Any number of cycles may be distinguished in long production series; but we shall view a cycle arbitrarily as a period containing a rise and a fall, the cycle being the shortest that can occur in annual data. Such a cycle will have a minimum period of two years, and although the maximum period is indefinite, it will generally be only a few years—especially when the year-

[1] This term is used in Professor Mitchell's sense. See his *Business Cycles: The Problem and Its Setting* (National Bureau of Economic Research, 1927), particularly pp. 468–9. See also, p. 247, note 55.

to-year variations of a series are taken in the form of first differences, as may justifiably be done when production rises with exceptional swiftness.[2] The idea of a cycle, then, can be made definite enough for our purpose, thus leaving the present concept of secular trend reasonably precise. Being merely denotative, this concept is free from the question-begging notion that secular trends are measures of the effects of causes independent of those generating the cyclical, seasonal, and random variations in production series. Furthermore, it is free from the notion that secular trends are equilibria paths which quantities 'strive' or 'tend' to approach, and the notion that secular trends cannot themselves have undulatory contours.

But if cycles are viewed in a purely statistical way, the derivative trend concept may seem equally formal. A trend concept resting on a statistical definition of cycles is itself statistical. Its economic significance may well be questioned, for statistical notions concerning trends and cycles have disturbing logical implications. If a cycle be nothing more than a rise followed by a decline or a decline followed by a rise, a considerable number of trends and cycles may be established for almost any long production series. What have been defined as secular trends will also exhibit cycles, in the sense of up and down movements, and will therefore give rise to new lines of trend, which may show statistical cycles once more, and so on. Yet it is only natural to think that such progressive refinement of time series, actuated by a statistical urge, is more likely to result in statistical curiosities than in anything of economic importance. And this doubt also casts a shadow on the significance of the concept of secular trend of production which has been explicated.

[2] Thus, Professor Mitchell distinguishes cycles of acceleration and retardation of increase, which he has found to be particularly important in certain cumulative banking series.

Fortunately, this is largely an unfounded scepticism, for the statistically defined cycles are also important economic realities. They have broad economic significance, inasmuch as the various production series trace out patterns of fluctuation which have considerable similarity. It is, in fact, the high degree of synchronism in the movements of the ensemble of production and other economic elements that makes their fluctuations a *general* economic phenomenon and leads us to speak of *the* business cycle. The cycles of the individual production series reveal fluctuations of the total national economy, and for this reason, their elucidation is a problem in general economic theory. If the cycles of various industries evidenced little of a common pattern, we could hardly speak of general economic cycles at all. The problem of their elucidation would then fall outside the province of general theory, and would belong rather to the history of specific industries. But once it is recognized that cycles are a generic economic phenomenon, secular trends of production conceived of as non-cyclical movements also take on economic significance. They thus constitute a distinct economic movement or, perhaps, congeries of movements.

This conclusion, however, flows from a characterization of cycles that is somewhat too simple. The 'business cycle' rhythm is not revealed uniformly in all production series. The series which conform perfectly to the general business cycle still contain random elements in their cyclical course: many series occasionally either trace out cycles not found at all in the progression of the business cycle or else skip certain of the business cycles; and some series, especially the class of agricultural crops, have cycles which show little of a systematic time relationship to the swing of the cycle in general business.[3] These erratic cycles and random elements in cycles

[3] This problem is being investigated with great thoroughness by Professor Mitchell, who has devised an ingenious method for comparing the 'specific cycle' patterns of series with their 'reference cycle' patterns, the latter being

are but remotely connected with the 'business cycle' rhythm of the national economy and arise largely from causes peculiar to individual industries. However, for reasons of convenience, the term 'cycle' has here been defined as a congeries of short-run economic movements, those connected with the business cycle and those of a random character. Secular trends, viewed as non-cyclical movements, refer therefore to economic movements of longer duration, expressing the relatively long-run effects of the forces making for change. In view of the inclusion of random movements under cycles, the secular trend of a series, defined as its non-cyclical movement, must not be considered as strictly bisecting successive cycles; it may, at times, have to be considered with reference to several cycles taken together, so that the movement underlying the ensemble of cycles may be properly exposed. Understood in this way, secular trends are not perfectly precise components of the total movements of production, but they are sufficiently precise for statistical purposes. They are economic realities which invite systematic investigation, quite as much as the short-run fluctuations which have inspired such extensive study in recent years.[4]

II. MEASUREMENT OF PRODUCTION TRENDS

Secular trends of production express the growth (including decadence under this term) of industries; and it is only because the growth of economic quantities is a question of large interest that secular trends are important. In delineating secular trends of production, what we really do is to measure growth. But the mere direction of trend lines does not suffice for effective comparisons of the growth tendencies of

determined on the basis of turning points in general business. The results of his researches will be incorporated in Volume II of his *Business Cycles*, a forthcoming publication of the National Bureau.

[4] For a further discussion of the concept of secular trend, see this chapter, sec. III.

different industries in given periods or of given industries in different periods. A common unit of the direction of trend lines is necessary; this cannot be given by the absolute rate of movement of trend lines, but it can be given by the logarithmic rate of movement of trend lines, or the percentage rate of movement. Of the various attributes of trend lines, the percentage rate of change provides the common unit which should prove most satisfactory in comparing the secular trends of industries.

1. Exponential Curves for Decade Periods

An excellent measure of the average percentage rate of change per time unit is yielded by a trend line of the simple exponential type.[5] However, when the periods of production series are long, exponential curves will ordinarily fail to embody the central notion concerning secular trends, explicated in the preceding section; for they will rarely trace

[5] Let the exponential function be written as $y = ab^x$, where y is production and x is time. Then, the average percentage rate of change per time unit is given by $100\ (\frac{ab^{x+1} - ab^x}{ab^x}) = 100\,(b - 1)$. The average percentage rate of change obtained from the equation of a simple exponential curve fitted to a production series gives a better indication of the average rate of growth than an average of percentage changes computed directly. An arithmetic mean of year-to-year percentage changes is defective because the theoretical scale of percentages is limited at one end but not at the other. A geometric mean of percentage changes is preferable to an arithmetic mean, since it is based on the logarithms of percentage changes (or rather link ratios), and therefore gives equal weight to changes of equal proportionate magnitude. The geometric mean of percentage changes has nevertheless a serious defect: it is absolutely conditioned by two items, the initial and final values, and these may of course be of 'accidental' magnitude. The geometric mean can report what happened from one time unit to another, but not what happened during the period marked off by them, and is therefore but poorly suited to yield the kind of information about growth that is here desired. Clearly, an exponential curve affords a better method of averaging year-to-year percentage changes: it embodies the essential idea of the geometric mean and, at the same time, takes full account of the internal structure of the historigram.

out the non-cyclical movements of the series accurately.[6] Hence, it has been deemed necessary to break up our series into segments, and to fit exponential curves to each of the segments. Such trend lines have an element of artificiality in that they are discontinuous. At times discontinuities in secular movements are real, as when a fundamental change takes place in the conditions underlying an industry's operation. But such changes do not occur frequently; and in order to approximate continuous trend lines for the various series and in that way obtain more faithful records of secular changes, exponential curves have been determined for two sets of successive segments for each series, one set overlapping the other.

Exponential curves have been fitted to intervals of about ten years, the length of the time segments being determined, however, only in part by logical considerations. It was desirable to make the periods fairly short in order to insure that the trend lines follow faithfully the paths of secular changes, but the periods had yet to be distinctly longer than the average duration of cycles in order to prevent a distortion of the trends by the cyclical factor. In pursuing our inquiry into secular movements, it was practically essential that the trends of the various series cover intervals of constant duration and identical calendar timing. In all, ten-year intervals of customary dating (1870–79, 1880–89, and so on) seemed satisfactory; but the circumstance of cyclical high points [7] in a fair number of production series at 1890, 1900, 1910, and

[6] To be sure, exponential curves give satisfactory fits in some cases, as in flaxseed consumption, fish catch, and cigarette production; but in the majority of cases, they afford inadequate fits; and occasionally, absurd fits, as in cane sugar or steel production. Even when an exponential curve yields a moderately good fit to a series taken as a whole, it may give an extremely poor fit to certain segments of the series, as when the fitted line of trend marches on imperiously at a rapid and uninterrupted pace, while the series shows a mild rise or even decline during some ten-year interval. A case in point is cigarette production, a very rapidly growing industry, which nevertheless experienced a declining trend during the decade 1895–1905.

[7] See below, pp. 38–40.

1920, and the desideratum of conveniently centered 'decades', led to the use of eleven-year periods bounded by round dates (1870–80, 1880–90, and so on).[8] These were supplemented by overlapping periods, shifted by five years from the first, to give another set of continuous time segments (1875–85, 1885–95, and so on). The term 'decade' is convenient and is used hereafter in referring to these periods.

Trend lines have been fitted to overlapping periods in order to establish a more detailed and faithful record of secular change than would otherwise have been had. In many series, a single set of successive decade trends would have left entirely unreported some significant change in the secular movement. The production of cottonseed cake and meal furnishes an instructive example. Starting with 1870, the output shows an upward trend in each decade. The same is true starting with 1875, except for the decade 1915–25. What happened is that cake and meal production rose more sharply in the first few years of the decade 1910–20 than it declined in the last few years, and rose more sharply in the last few years of the decade 1920–29 than it declined in the first few years. Clearly, what occurred during the decade 1915–25 is as much a part of the trend history of this industry as what happened during 1910–20 and 1920–29. To have worked with a single set of decades would have seriously restricted the validity of the further analysis to which the decade trends were subjected. The use of overlapping decade trends overcame—in a measure and, of course, implicitly—the difficulty of trend discontinuity.

In the substantive parts of this work, our interest will be confined to the average annual percentage rates of change which the exponential curves yield. These average annual percentage rates of change over decade intervals may be

[8] Since most of the series analyzed do not extend beyond 1929, the period 1920–29 is an exception.

briefly termed 'decade rates'. Before going further in the description of our technique of trend measurement, it is important that the exact significance of the decade rates for a given production series be fully understood. Each set of successive decade rates records the average annual rate at which production increased (or declined) decade after decade during the period covered by the series. The two sets of successive decade rates, taken separately, may show somewhat different patterns of growth; but this is only to be expected, first, because the full periods covered are not exactly the same, second, because secular trends may be reversible over periods longer than a business cycle. Once the two sets of decade rates are combined in a chronological sequence, the technical limitations of each are largely overcome, while the meaning of the now overlapping decade rates is in no way beclouded. For some purposes it is desirable to view them as rates at which production increased at the central dates of the decades, since the decade rates are but slope readings (speaking loosely) of the exponential curves.[9] Regarded from this standpoint, the decade rates constitute quinquennial observations on the slope of the secular trend. But it is often preferable to view the decade rates as applying to the full decade intervals. The fact that the decade rates of a given series refer to overlapping periods should not detract from their clear import of being equitemporal observations on the rate of growth of an industry.

2. Correction for the Cyclical Factor

It remains to describe the details of the technique of determining the decade rates. Clearly, a rigid use of calendar decades would have led to considerable error in the trend computations. Since decade intervals of production series only

[9] In speaking of the 'slope' of the secular trend, we shall mean the percentage rate at which the secular trend rises or declines.

infrequently contain an integral number of cycles, trends for such short intervals are likely to reflect the cyclical factor as well as the trend proper. For any given decade, the possible extent of trend distortion depends upon the relative magnitude of the cyclical swings with respect to the trend slope. When the slope is steep and the cyclical amplitude small, the distortion will be negligible; but in the case of a rather mild trend slope and sharply defined cycles, the distortion may be considerable.

In order to prevent an admixture of trend and cycle elements in the decade rate computations, the fixed calendar decades have been used as reference periods for the decade rates, but these rates themselves have been computed for periods of only approximate decade duration. Let us speak of the actual periods for which trend computations have been made as 'working decades', and the periods to which the computations are taken to refer as 'reference decades'. The boundary dates of a given working decade were chosen so that the end values were approximately at the same cyclical phase, and in this way a cyclical bias in the trend of the working decade was in large part prevented. Since the trend computations for the working decades were to apply to their respective reference decades, it was necessary to circumscribe the procedure of locating the boundary dates of working decades so as to insure as small a deviation from the reference decades as was compatible with the principle underlying the use of working decades. The observance of several mechanical rules [10] limiting the freedom of choosing boundary dates in-

[10] The rules used to limit the choice of boundary dates are as follows: (1) the working decades were allowed to vary from a minimum of nine years to a maximum of thirteen years, (2) the maximum leeway allowed on either side of the reference decade was two years, (3) at least nine years of the reference decade had to be included in the working decade. However, these rules were relaxed considerably in the computations for 1920–29 (several series extend to 1930) because: (1) the period is one year shorter than the others, (2) the finality of the closing year (the investigation was begun in 1930) made ac-

sured a close time union between the working and reference decades; at the same time, it gave sufficient flexibility to the technique of trend measurement to free the decade rate computations from the larger part of the cyclical bias.

This is the general method which has been used to reduce the influence of the cyclical factor on the decade trend computations. The exact procedure was more laborious. The first step was to select, for a given reference decade, that working decade [11] whose trend seemed to contain a minimum cyclical bias; when several working decades were equally acceptable, that one was chosen which conformed most closely in time position to the reference decade. The next step was to choose, for the same reference decade, that working decade which seemed best calculated to compensate for whatever cyclical bias there was in the trend of the first working decade; here again, the subsidiary canon of choice was closeness of time conformity to the reference decade. Quite frequently, still a third working decade was chosen to offset the net cyclical bias of the others.[12] These additional steps were necessary because an integral number of cycles does not in itself insure that the cyclical factor will not influence the trend computations.[13]

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curate determination of boundary dates for working decades intrinsically more difficult than for other periods, and (3) it was desirable to limit the influence of the extreme cyclical trough in 1921 on the trend calculations for this decade. For special technical reasons, the rules for determining boundary dates were relaxed somewhat in a few cases for other periods.

11 The rules for choosing working decades (see the preceding note) allowed nineteen sets of combination dates. The range of practical choice was of course very much smaller, since the aim was to choose working decades whose end values were approximately at the same cyclical phase.

12 Moving decade trends might have been employed to a greater extent than they were, and had that been feasible, something would have been gained in the later analysis, especially in Chapter V. But the extent to which the apparatus of moving decade trends could be reasonably employed was limited by the technique of locating boundary dates for working decades. Only a single set of overlapping reference decades, separated by a five-year span, seemed at all practicable, and this was used.

13 When cyclical crests or troughs at the boundary dates are not of the same magnitude, the cyclical factor will still enter into the computations of trends;

With the rates of growth for two or three working decades for a given reference decade at hand, an arithmetic mean was struck to give the 'final decade rate'. It is submitted that these final decade rates, generally referred to hereafter simply as 'decade rates', are the best measures that can be achieved of the average annual rates at which the trends of production advanced during the reference decades. The decade rates for the series listed in Table 1 are presented in Appendix A, Table 45.

Of course, the procedure of determining the decade rates involves considerable arbitrariness, and is not 'objective' in one of the many senses of this ambiguous term. But there is no reason to suppose that a careful and intelligent use of the technique by another investigator would lead to results which would differ sufficiently to place any class of facts in a different light. There is a tendency to overrate the value of 'objectivity' in statistical methods. The fact that two or more persons may go through the same standardized technique and obtain the same results is no recommendation, as such, either for the technique or for the results. Certainly, a mechanical method is as arbitrary as any other, but the arbitrariness is fixed and therefore frequently overlooked. Judgment must always play a dominating rôle in the choice of statistical techniques, and the only question that really matters is whether the judgment is 'good' or 'bad'. It should be self-evident that the final decade rates computed from working decades have much better claim to significance and representativeness with re-

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and when cyclical crests or troughs of extreme size occur at or near the boundary dates, they may, in fact, dominate the trend. Even with all the precautions taken to restrict the influence of the cyclical factor, no more can be claimed for our method than that it generally reduced the cyclical bias to small proportions. It was not always easy to achieve a nice balance between the cyclical biases of the working decades of a reference decade. But this was most difficult in those cases where the residual cyclical bias was relatively small; and here, of course, it made little difference whether or not the most suitable working decades were chosen.

spect to the reference decades than rates computed directly for such reference decades. It is only because the rates computed for calendar decades would tell a spurious story in many instances about production trends during these decades that a much more laborious, and non-mechanical procedure has been used.

3. Method of Curve-Fitting

Exponential curves are most commonly fitted by the method of 'least squares', the criterion of least squares being applied to the deviations of the logarithms of observation data from a straight line fitted to the logarithms. Exponential curves may also be fitted by the method of 'moments', the criteria of moments being applied directly to the observation data. The results obtained by the two methods will differ significantly only when there are cyclical extremes at either end of the period for which an average rate of growth [14] is computed. Because the method of least squares involves the use of logarithms, a low cyclical extreme exercises a larger influence on a rate of growth computed by this method than on a rate of growth computed by the method of moments; the opposite is true when the cyclical extreme is a high point. Offhand, it might seem that, if the reduction of the influence of extreme cases is desired, there is little to choose between the two methods. But it is known empirically that a downward cyclical movement generally proceeds at a faster rate than an upward movement in practically all industries outside of agriculture; this is another way of saying that extreme cyclical troughs in production are more numerous than extreme peaks. There is, then, some theoretical basis for preferring the method of moments,[15] and this method has been

[14] Except where otherwise stated, 'average rate of growth' or just 'rate of growth' is taken to mean 100 (b—1), the constant b being derived from the function $y = ab^x$, in which y is production and x time expressed in years.

[15] A minor advantage of the method of moments is that it may be used

used in the fitting of exponential curves to our series. The device of multiple working decades in itself tended to preclude cyclical distortion of the rates of growth calculated,[16] but trend-fitting by the method of moments contributed further to this end.

The method of moments was preferred also on practical grounds. With the aid of Glover's 'mean value table', exponential curves may be fitted quite expeditiously by the method of moments.[17] The burden of computation was further reduced by the aid of a device which made it unnecessary to compute independently the rates of growth for the various segments of each production series. Preliminary to any of the calculations of rates of growth, a basic table was set up which contained, first, the original data, second, progressive cumulatives of the data, and third, cumulatives of the first set of cumulatives. It was then possible to compute from this basic table the average rate of growth for any period by going through a few simple arithmetic steps.[18] The routine burden involved in the determination of the considerable set of rates of growth for each series was smaller than, say, the computing work in fitting a 'least squares' second degree

when there are zeroes among the observation data; of course, this is impossible in the least squares method. This fact is of some practical import; for example, no sulphur output was reported during a few scattered years in the period surveyed.

16 Were it not for this, it would have been desirable to use the method of least squares when high cyclical extremes occurred, and the method of moments when low cyclical extremes occurred.

17 See J. W. Glover, *Tables of Applied Mathematics in Finance, Insurance, Statistics* (George Wahr, 1923), pp. 468–81. Except where otherwise stated, this method has been used also in all supplementary calculations of average rates of growth. As Glover's table does not go beyond increases of 10 per cent per time unit, it was necessary to extend the table in order to calculate values above this point.

18 This simplification is a product of the ingenuity of Mr. Howard G. Brunsman, now of Ohio State University. Considerations of space make a description of the method impractical; this is also unnecessary, as Mr. Brunsman plans to publish the method in connection with a larger subject.

parabola to the logarithms of a sixty-year series by the customary method.

III. ANALYSIS OF PRODUCTION TRENDS

The decade rates, already described, constitute a set of fundamental measurements of the secular trends of industries. An inquiry into the behavior similarities of the production trends of individual industries, and into the elements of regularity in the trend of total production, is carried through in the following chapters on the basis of these measurements. It is no part of our aim to survey at this point the substantive problems of this study, or to describe the various statistical techniques which are employed in the course of their exploration. Such matters are best treated as they come up. But there are certain general aspects of the later statistical analysis, which may well be noted in this place.

Granting our definition of secular trends, the form of the secular trend line of a production series, in any particular period, is largely independent of varying predilections of statisticians, and of the full period to which a line of secular trend may be fitted; that is to say, it is possible to measure secular trends with fair 'precision'. But the secular trends of industries are complex in their nature, and must be analyzed from various angles in order to be grasped fully. Lines of secular trend trace out paths more or less undulatory and also have an underlying general sweep; both types of movement are of interest and significance.

It is convenient to refer to the general sweep of the secular trend of a series as its 'primary trend'.[19] A line of primary

[19] This term is used in a broader sense than by Professor Kuznets. See his *Secular Movements in Production and Prices* (Houghton Mifflin, 1930), pp. 70–2. The term 'trend' is used frequently in this work without qualification: ordinarily, 'trend' refers to 'secular trend'; at times, it refers to 'primary trend'; and in some cases, as in the title of the work, it refers generically to 'secular trend' and 'primary trend'. However, the meaning should be clear

trend will trace out synoptically and elegantly the general secular movement, without giving much heed to the details of the movement. If the secular trend has already been determined, the primary trend may be established by fitting a simple mathematical curve to the ordinates of secular trend; this may be done irrespective of whether the line of secular trend is continuous or discontinuous.[20] If the secular trend has not yet been determined, the primary trend may be established by fitting a simple mathematical curve directly to the data. In either case, the line of primary trend will generalize movements of longer duration than those generalized by a line of secular trend.

While the secular trend, as we have defined it, can be measured with a fair degree of 'precision', the primary trend cannot. There is considerable latitude for judgment in choosing a curve to represent the primary trend; and its exact form is not independent of the period covered, even with a given type of curve. However, if the primary trend be viewed instrumentally, a degree of certainty can be attained in its measurement. The nature of the problem leading to the measurement will then determine whatever definiteness and significance the primary trend will have.[21] Thus, if there is little point in inquiring about the average annual rate of increase in the world output of wheat since 1500, a primary trend embodying an answer to this question will also lack significance. On the other hand, if there is some point in inquiring about the average annual rate of increase of wheat pro-

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from the context, since qualifying terms have been added where the sense might be ambiguous.

20 In the case of our measurements of secular trends by 'decade rates', discontinuous lines of trend are only implicit; but they can be made explicit by the use of the criterion of the zero moment. See Ch. IV, sec. I, for another approach.

21 Professor Mitchell has pointed out the serious limitations which attach to an empirical approach to trends; see his *Business Cycles*, cited above, pp. 212–26. Kuznets' *Secular Movements*, previously cited, is an example of an inquiry into production trends guided by the light of theory.

duction in the United States since 1870, a primary trend embodying an answer to this question will also have some significance. But the form of the primary trend will still be indefinite, since it may be either a straight line or an exponential curve, according as average annual rate of increase is regarded in absolute or percentage terms; the problem will therefore have to be defined more specifically before the primary trend can be determined with assurance. Or take another problem, which brings out more forcefully the correspondence between questions concerning long-range movements and the primary trends to which they lead. Suppose that growth at a declining percentage rate is considered as the outstanding characteristic of the history of pig-iron production in the United States, and that it is desired to give mathematical expression to this characteristic. In this case, the choice of a mathematical curve to represent the primary trend is limited to functions—such as the simple logistic, the Gompertz equation, or the 'logarithmic' parabola—which possess the characteristic of advance at a declining percentage rate. Suppose, now, that the aim is not only to indicate the presence of decline in the percentage rate of growth of pig-iron production, but also to measure the average rate of retardation per time unit over the period covered. In this case, a parabola fitted to the logarithms of the production data is the proper mathematical curve to represent the primary trend; for only this function can answer directly the question which has been asked.

Two conceptions of primary trend form the basis of much of the later statistical analysis: that defined by the average percentage rate of growth, and that defined by the average percentage rate of retardation. The former is investigated in section I of Chapter III and section II of Chapter VI, the latter in Chapter IV and section III of Chapter VI. It goes without saying that the full significance of the specific questions implicit in these measurements of primary trends can be clearly seen only in the light of the more general purposes which those questions subserve. If a summary of the progress of the iron industry were confined to two formulations of primary trend, one yielding an average rate of growth and the other an average rate of retardation, their significance might be small. But when measurements of the primary trends of this industry are taken together with similar measurements for many industries, as is done in this study, they acquire considerable significance; for the ensemble of primary trends serves to indicate certain general characteristics of national progress.

The detailed course of the secular movement of an industry may be investigated by a variety of methods. If the aim of these methods be summarization, they will have the common feature of measuring the undulatory movement of the secular trend—that is, its instability. There are various aspects of the instability of the secular trend of a series, which different methods will seek to ascertain. If interest center in the continuity of growth of an industry, the degree of uniformity with which its secular trend has an upward direction will be determined; if in the persistence of growth of an industry, the frequency with which its secular trend changes from an upward to a downward direction, and vice versa; if in the variability in the rate of growth of an industry, the degree of variation in the slopes of its secular trend at different periods. Similar questions concerning instability may arise with respect to retardation of growth, and they may be similarly resolved. Finally, the instability of the secular trend of an industry may be considered from the standpoint of the amplitude of its oscillatory movement, the primary trend, appropriately measured, having first been eliminated. The more important of these aspects of the instability of secular trends are considered in the following chapters—chiefly in section II of Chapter III, section II of Chapter IV, Chapter V, and section III of Chapter VI.

Measures of the detailed course of the secular trend may or may not prove useful summaries in the case of any one industry. But when a large number of industries is covered, such measures become powerful instruments in the description of the general characteristics of industrial progress. For this purpose, however, detailed measurements of the oscillatory movements of the secular trends of industries, an adjustment having been made for their primary trends, are probably more significant than any summary measures of the instability of secular trends; for a large degree of industrial concurrence in such oscillatory movements—we may speak of them conveniently as 'trend-cycles', that is, cycles in secular trends—would indicate that a long-term rhythm was pervasive in the economy. If the trend-cycles of individual industries were uncorrelated, they would be of little importance except for an understanding of the histories of specific industries. On the other hand, if they synchronized to a considerable degree, they would indicate the existence of a general trend-cycle in the economic system. They would furnish, therefore, an important datum for the acumen of the theorist. The oscillatory movements of production trends are investigated in detail in Chapter V.