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PROGRAMMED SELECTION OF CYCLICAL TURNING POINTS

PRINCIPLES OF SELECTING TURNING POINTS

FOR THE CYCLICAL ANALYSIS of time series, distinction between different segments of cyclical movements is desirable. Such distinction provides a framework for orderly description. Also, behavior can be expected to differ from segment to segment, and it is hoped that this behavior is sufficiently homogeneous within segments to permit generalized description and explanation. Plausible distinctions exist between periods of cyclically high and cyclically low levels of activity or between periods of cyclical increases and declines. Combination of these two distinctions has led to various schemes of three, four, or even more phases. Characteristically, these schemes identify the neighborhoods of cyclical peaks and troughs, and partition the upswing and usually also the downswing. This leads to sequences such as recovery—prosperity—recession—depression; upswing—boom—downswing—depression; primary rise—secondary rise—boom—capital shortage—crisis—recession; or recovery—growth—contraction. In these sequences, like terms do not necessarily describe like periods. The segmentation may be determined on the basis of inflection points of fitted cyclical curves, intersection of trend and cyclical values, maximal changes in cyclical movements, attainment of prior peak levels, or by other criteria. Most of these criteria are not specific enough to yield unique statistical results. The segmentation tends to vary, for example, with the period for which cyclical curves or long-term trends are fitted, and with the choice of functions for these curves. Also, the statistical determination of fastest changes leaves much to the discretion of the investigator. Because of all these problems, it has been a widely accepted practice of the National Bureau of Economic Research to distinguish only two phases—expansions and contractions—which are delineated by cyclical turning points.[1] While the restriction to two phases reduces the statistical problem to that of determining cyclical turns—points that can be better defined and identified than most others—it does not eliminate the need for subjective decisions. This need may, however, be further reduced by the use of programmed procedures. It is the determination of specific cyclical turning points (peaks and troughs in specific time series) with which this chapter is concerned. This encompasses an exposition of the principles and problems as well as a discussion of programmed procedures.

SELECTING CYCLES

Chart 1 depicts time series of seasonally adjusted employment and unemployment, showing numerous fluctuations. The first problem is that of determining which of the fluctuations in these series should be recognized as cyclical (specific cycles). Basically, we are looking for clearly defined swings of the same order of duration as business cycles, that is, for swings that are longer than fifteen months but shorter than twelve years from trough to trough or from peak to peak. Most specific cycles identified by the National Bureau have lasted between two and seven years. We also require the amplitudes of specific cycles to be larger, on average, than those of irregular fluctuations encountered in the series.[2] In most instances, the identification of cycles in employment and unemployment is simple. The two series show well-defined swings with fairly certain highs and lows, which are indicated by X's on the chart. Even a casual examination reveals that the observed swings are rather regularly related to the expansions and contractions in general business activity, which are indicated on the time grid of the chart.

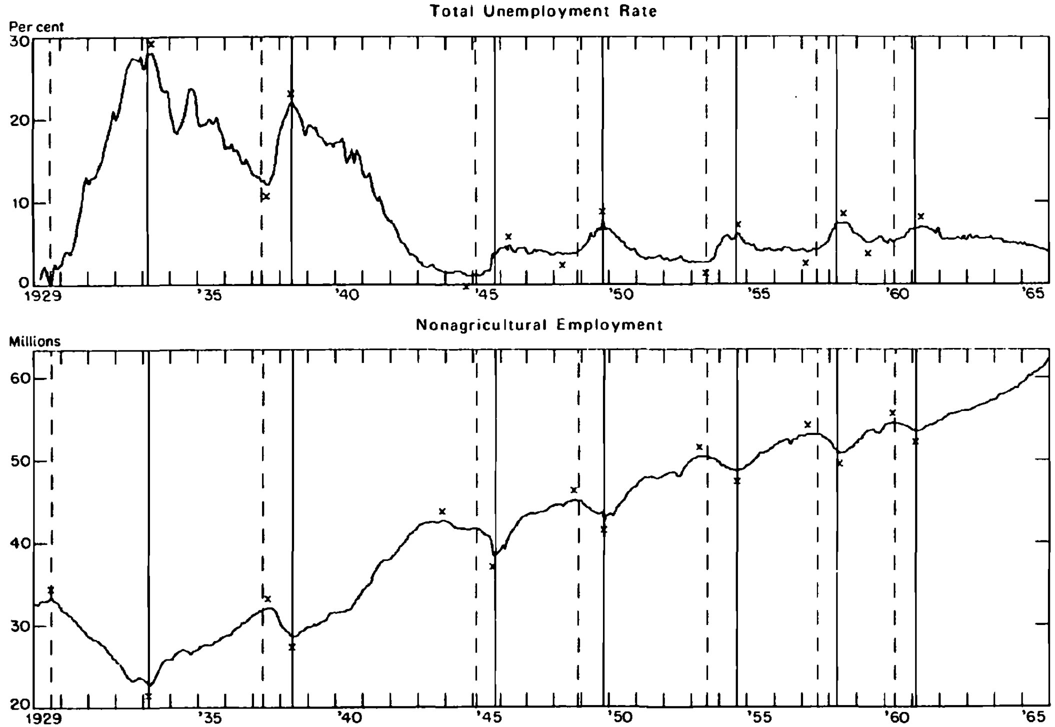
However, a number of problems may arise in conjunction with the identification and dating of specific cycles. Take, for instance, the question of whether or not a particular fluctuation in a time series should be recognized as a specific cycle. Chart 2, panel A, shows the problem in schematic form. Should the swing a–b–c be regarded as a cycle or as part of a larger expansion a–d? What criteria should

[1] The partition of expansions into recovery and growth periods is discussed in Chapter 3 (p. 71).

[2] See Arthur F. Burns and Wesley C. Mitchell, *Measuring Business Cycles,* New York, NBER, 1946, Part I, Chapter 4.

CHART 1

NONAGRICULTURAL EMPLOYMENT AND UNEMPLOYMENT RATE, 1929–65



guide such a decision? One National Bureau rule is that specific cycles should have a duration of at least fifteen months. Another is that the amplitude of a doubtful expansion or contraction should not be materially smaller than that of the smallest clearly recognized cycle in the series. Chart 1 gives a practical illustration of the problem. The increase in the unemployment rate in the second half of 1959, which occurred in connection with the steel strike, appears as a fluctuation of more than random character. It is not recognized as a specific cycle since it does not approximate, in duration or amplitude, the lower limit of cyclical fluctuations in this series. A similar situation exists around 1933–34.

It is not by chance that the activities here selected, employment and unemployment, contain clear specific cycles but no example of extra cycles, that is, of specific cycles in addition to those related to business cycles. This is due to the very broad coverage of the two series, both of which reflect changes in general business activity rather than circumstances peculiar to an industry or area or activity. However, the occurrence of extra cycles is far from rare. Many sensitive series show specific cyclical declines and subsequent recoveries during the years 1951–52 in connection with the Korean War, and many activities related to the automobile industry show extra cycles during 1954–57.

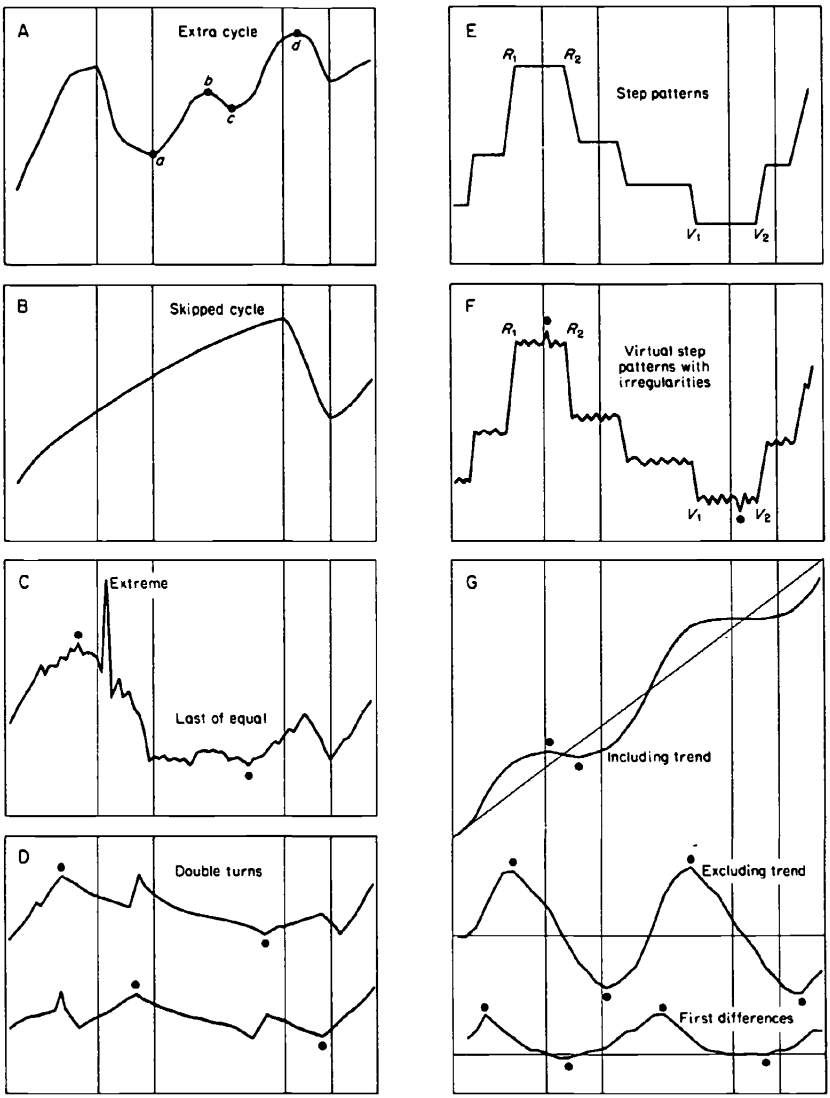
Specific cycles can also be considerably longer than reference cycles. This occurs particularly when business cycle contractions are "skipped," as happens frequently in rapidly growing industries, and when the business contraction itself is mild. For a schematic illustration, see panel B of Chart 2. Specific cycles can, of course, also be unrelated or only loosely related to business cycles. This is frequently found, for instance, in series describing the harvest of agricultural crops, the exports of specialties, or fashion goods. These activities are strongly influenced by factors other than domestic business conditions.

SELECTING PEAKS AND TROUGHS

After specific cycles have been identified, it is still necessary to pinpoint specific peaks and troughs. This may raise a large number of questions, some of which have to be answered on the basis of rules which, though occasionally arbitrary, are needed in order to ensure consistency of treatment. In general, cyclical peaks and troughs are placed at the highest and lowest points of the cyclical fluctuations. Peaks and troughs alternate; i.e., a peak cannot succeed another peak

CHART 2

PROBLEMS OF TURNING POINT DETERMINATION



Note: Circles denote specific cycle turning points. Vertical lines stand for alternating peaks and troughs in general business activity.

without an intervening trough. Hence peaks should not be identified at the ends of series unless it is clearly possible for the next succeeding turn to be a trough; analogous considerations apply to troughs. In case of equal values the rule is to choose the last one as the cyclical turn, i.e., the month before the reversal of the cyclical process begins. Exceptions to this general rule are necessary when the values in question are clearly extreme, isolated, and possibly compensated for or surrounded by other values that deviate in the opposite direction. Panel C of Chart 2 portrays this situation and the appropriate choice of turn, indicated by a circle. On Chart 1, the unemployment low in February 1960 provides an example from historical experience. The rate in that month is lower than the lowest rate in mid-1959, but the February low is comparatively isolated, and therefore the June 1959 position is regarded as the cyclical low point. When random movements complicate the determination of specific turns, some guidance can be obtained through smoothing by moving averages. The intermediate output tables and corresponding charts of some seasonal analysis programs [3] can be of great help in deciding doubtful cases, both with regard to recognition of cycles and determination of turns. But the cycles and their turning points are eventually identified in the seasonally adjusted data, not in the smoothed series.

Sometimes a difficulty arises in cases of "double turns," that is, when a series returns to its previous peak or its previous trough level after some intermediate fluctuation. The decision in case of double peaks or double troughs is, of course, a very important one for timing analysis, since a minor difference in level and a marginal decision in the selection of turns can cause relatively large differences in timing and duration measures. The basic rules prescribe that the peak be the last high month just preceding the month in which the downward movement starts. However, if the period between the two peaks contains mainly downward movements and only one or two steep rises, the first high should be chosen. Panel D of Chart 2 depicts this situation as well as the application of the decision rule. The double turns in the unemployment rate during 1946 and 1958 do not really present a problem, since the turns to be chosen are obviously those that are later and higher.

There are cases in which, instead of showing clearly defined turns, the series maintains a peak or a trough level for several months in a

[3] Intermediate output tables of curves smoothed by a variety of moving averages can be found in the Census and BLS seasonal adjustment programs.

row. The basic rule is still to regard the last of the equal values as the turn, since the decisive change of cyclical direction manifests itself only after that month. However, if a series forms a definite step pattern in which plateaus and changes between plateau levels are common, the search for "turning points" may be inappropriate. In such instances it may be desirable to identify the beginnings and ends of ridges (*R*) and valleys (*V*), as illustrated in Chart 2, panels E and F.[4]

Some economic time series do not show actual cyclical declines, but do show clear cyclical behavior in terms of accelerations and retardations. Time series depicting economic activities with strong growth characteristics offer many examples of such behavior. The question is how such series, as illustrated by panel G of Chart 2, may be subjected to cyclical analysis. One possibility is to adjust them for trend, that is, to fit a trend line to the observations and to analyze the deviations from these trends. However, the trend will vary with the choice of the trend function, the criterion of best fit, and the time period covered. Any of these alternatives, and therefore also the incorporation of newly available information, influences the computed trend and hence the deviations and the cyclical measures. It may therefore be preferable to use a different approach and to analyze first differences or the month-to-month percentage change of the original data. When the original series undergoes cyclically regular accelerations and retardations, these derived data will show analyzable cycles.

Each solution, however, produces its own problems. First, absolute differences or rates of change are apt to show large random movements relative to the size of their cyclical component. This makes it difficult to date cyclical peaks and troughs. Second, the cyclical timing of these near derivatives differs systematically from that of the original series. First differences experience their highs at the points of the greatest absolute increase of the parent series—that is, whenever the expansion process is most rapid. The turns of these derivatives should, perhaps, be related to the points of maximum rate of expansion or contraction in the economy as a whole. Alternatively, locations corresponding to turning points in the original series could be determined by identifying shifts in the levels of first differences or rates of change.

[4] For examples of dating steps rather than turning points, see Gerhard Bry, *Wages in Germany, 1871–1945*, Princeton, N.J., Princeton University Press for NBER, 1960, p. 138; Daniel Creamer, *Behavior of Wage Rates during Business Cycles*, New York, NBER, 1950, pp. 6 ff.; Milton Friedman and Anna J. Schwartz, "Money and Business Cycles," *Review of Economics and Statistics*, Supplement, February 1963, pp. 35–37.

Such identification is simple if there are marked shifts, that is, if the original series has clear alternations of fast and slow growth. Identification of such shifts will be impossible if the growth of the underlying series changes gradually, e.g., if the cyclical component of the original series is sinusoidal rather than triangular. Economic time series are not likely to correspond to either extreme. Thus the feasibility of defining shifts in the derivatives (as approximations to turns in the original series) is an empirical rather than a theoretical question. Preliminary experiments with this approach seem promising. Further technical developments may widen the scope of its application.

Turning point determination might, finally, be influenced by the consideration of factors that lie outside the analyzed series. If one series is analyzed at a time, without reference to other activities, rigorous application of the standard rules is called for. However, in connection with a particular research project, substantive consideration may be overriding. Take, for example, the industry-by-industry analysis of the relation between peaks in hours worked, employment, and production. The steel strike at the end of 1959 affected the upper turns of many of these activities drastically. The measures of timing relations would vary in a haphazard manner if sometimes the prestrike, and sometimes the poststrike, maxima were selected as peaks. A research worker might thus be justified in basing his comparisons on, say, the poststrike peaks even if on occasion the prestrike maximum was a bit higher.

It is true, on the other hand, that such a decision might occasionally prejudice research results. For example, the arguments which suggested the selection of the poststrike peak in hours might also lead to the selection of the second peak in accession rates, although these rates typically show very early declines occurring shortly after the initial business recovery. Reasonable decisions on such matters can only be derived by an iterative process in which the growing knowledge of the subject matter is permitted to modify approaches and decisions.

PROBLEMS OF PROGRAMMED SELECTION

GENERAL CONSIDERATIONS

The importance of cyclical turning points for cycle analysis and the criteria for their selection were discussed above. Some rules were described which aimed at minimizing the role of individual judgment in the determination; yet in the formulation of these rules and still more in their implementation, individual judgment continues to play an important role. Determination of turning points can have far-reaching consequences for analysis; specifically it affects all basic measures of cyclical durations and amplitudes. Thus it is desirable to free the process as far as possible from the uncertainties of varying interpretation and from bias in the implementation of the basic rules. Progress toward greater independence from personal interpretation could be made, if it were possible to codify the relevant rules and considerations, to reduce the selection to a programmed sequence of steps, and to relegate the process to execution by electronic computer. The purpose of the efforts described in the present section is to test the feasibility of this approach.

The development of a programmed turning point determination is a process which has only recently been initiated. It may involve proliferation, tightening, or reformulation of rules, and it may necessitate some changes in the basic approach. Hence, what we have to report at this stage is provisional, much as was the case for the early programs for seasonal adjustment of economic time series. Since it is unlikely that all contingencies can be covered by any programmed approach, and since certain research objectives may require modification of rules, some overruling of the program will no doubt still be necessary in atypical situations and for special purposes. In such cases, the overruling should be explained and justified.

ALTERNATIVE APPROACHES

The technique described in this study is an adaptation of the National Bureau method. It converts this method to a sequence of relatively simple decision rules by which neighborhoods of turns and potential turning points are selected and tested for compliance with a number of constraints.

This obviously is not the only possible approach. One alternative—albeit complex and time consuming—would be the simulation of the process of turning point determination as practiced by an experienced analyst. The advantage as well as the difficulty of such simulation would lie in greater freedom when dealing with special circumstances. In such simulation, for example, turns in the neighborhood of strikes may more likely be rejected and turns in the neighborhood of business cycle turns accepted.

Another possibility would be to disregard the National Bureau method and to formulate a rigorous search-and-test procedure, based on strictly defined statistical properties of given time series. One suggested approach along these lines is based on the assumption that cyclical expansions and contractions in time series can be distinguished by the level of their first-order differences. Peaks are located where positive first differences change to negative differences, troughs where the obverse change occurs. Even cyclical changes in slopes or in rates of expansion and contraction could be similarly identified, except that here the "steps" in the first-order differences would not involve a change of sign. The statistical procedure to determine turning points and other changes in slope is a segmentation of time series on the basis of statistically significant steps in the levels of their first-order differences; the steps are selected by minimizing the variances within each segment.[5]

APPROACH EMPLOYED

The approach employed here is related to the process of turning point determination practiced by the National Bureau of Economic Research. It roughly parallels the traditional sequence of first identifying major cyclical swings, then delineating the neighborhoods of their maxima and minima, and finally narrowing the search for turning points to specific calendar dates. However, at the present time, the program neglects certain elements that are part of the traditional technique and uses some additional measures and rules.

The programmed strategy involves, first of all, the derivation of some moving averages representing trend and cycle elements only. These relatively smooth curves serve as the basis for determining the existence of expansions and contractions and for selecting the general neighborhoods of potential peaks and troughs. Local maxima and

[5] This approach was suggested by Milton Friedman, and a preliminary program was developed by Charlotte Boschan. It is particularly important in connection with the determination of cyclical phases in fast-growing series, as discussed above (see, for example, Ilse Mintz, *Dating Postwar Business Cycles: Methods and Their Application to Western Germany, 1950–67,* New York, NBER, 1970). Other approaches, incorporating perhaps some features of spectral analysis (e.g., to test the existence of cycles of a specified range of durations) are also worthy of exploration.

minima are excluded by postulating a minimum cycle duration; shorter fluctuations are eliminated in such a way that only major peaks and troughs remain. Next, the neighborhood of potential turns is redefined by identifying peaks and troughs corresponding to those of the trend-cycle curves on a time series that is only slightly smoothed by a short-term moving average. The objective here is to come closer to the eventual location by excluding the influence of values that may be several months removed from the final turns. Once the immediate neighborhood of potential turns is established on this curve, the analysis shifts to the unsmoothed data. The highest (or lowest) original values within a short span of the turns on the smoothed curve are chosen as preliminary turning points. These turns are tested for a minimum cycle duration rule and for compliance with some other minor constraints; elimination of disqualified fluctuations leads to the selection of final turns.

Consideration of this plan of attack makes it clear that numerous choices must be made in the implementation of the approach. What type of moving average, if any, should be chosen to represent trend-cycle elements of what length and using what weights? Should extreme irregular values be excluded in the derivation of these trend-cycle functions, and, if so, what are the criteria for exclusion and the rules of substitution? Within what span should a value on the trend-cycle curve be the highest (or lowest) to be recognized as establishing the neighborhood of a potential cyclical turn? Should there be minimum limits for the duration of cycles, for the duration of phases, or perhaps for expansions only? Should minimum durations be the same for expansions and contractions, and, if not, how should inversely related activities, such as unemployment, be handled? What should the values of these minima be? Should any minimum duration requirements, for full cycles or cycle phases, be applied to all derived curves, to some of them, or only to the unsmoothed data? Can amplitudes be safely ignored or must minimum amplitudes be specified?

The variety of possible answers to this sample of queries suggests that turning point determination is not simply a process of discovering "true turns." It cannot be regarded as objective in the sense that all reasonable and conscientious investigators would agree on the answers. Only agreement on the application of a specific set of detailed, and sometimes arbitrary, procedural conventions could bring about agreement on the choice of turns.

Some of the choices among procedural alternatives can be made on the basis of traditional practices, that is, by decision rules that help to maintain consistency with existing procedures. Enforcement of a fifteen-month minimum duration rule for full cycles is a case in point. In other instances, one stratagem may be given preference over another for reasons of simplicity. It would, for instance, complicate matters considerably if the programmed determination of turning points specified amplitude minima.[6] Hence, the present approach neglects amplitude considerations, except for those implicit in the various smoothing processes. Other questions may have to be answered on purely pragmatic grounds. If the procedure recognizes too many short and shallow fluctuations as cycles, the admission criteria must be tightened. This can be done in a variety of ways, for instance, by choosing less flexible (longer-term or differently weighted) trend-cycle approximations, by lengthening the span within which a peak is chosen or by extending duration minima. In order to choose between these tactical alternatives, it is necessary to analyze not only the nature of the contingencies that should be avoided but also the effects of alternative stratagems on the over-all efficiency of the chosen procedure. The question is whether any proposed alternative improves the process at large or only the results for a particular activity. This characterizes the approach and the choice between alternative criteria of selection as essentially heuristic.

In order to describe the selection process as well as the direction of desirable improvements, the experimental procedure currently in use will be described in some detail and illustrated by the monthly bituminous coal production series from 1914 to 1938. The computer output of the analysis is presented in the Appendix to this chapter.

[6] The complication would arise from the difficulty of setting adequate standards. Minimum amplitudes should be different for volatile and for stable activities, and thus presumably should be expressed in terms of average cyclical volatility for a given activity during reference cycle phases (since the determination of specific cycles now would hinge upon the volatility measure). To apply uniform standards, these averages should cover the same time periods. Moreover, the mild response of a given activity to a mild contraction in general business conditions may well be cyclically significant, irrespective of contraction amplitudes during other cycles. This raises the problem of comparison of cyclical amplitudes for any given activity with swings in business conditions at large or in representative activities—certainly no simple matter. Although it may be theoretically and technically feasible to incorporate explicit amplitude considerations in programmed turning point selection, such incorporation would complicate the procedures considerably and perhaps render them impractical.

The procedure will then be applied to a group of time series—to wit, the leading, coinciding and lagging business cycle indicators as reported by the Bureau of the Census of the U.S. Department of Commerce in its monthly *Business Cycle Developments,* now renamed *Business Conditions Digest* (B.C.D.). On the basis of the selected turns, the efficacy of the process will be evaluated and the needs for further work pointed out.

PROCESS OF SELECTION

Bituminous coal production, 1914–38, is a series with a good number of turning point problems, such as the presence of strong random and other irregular movements (strikes), of double turns, and of minor cycles. In addition, it is a series that has been analyzed and discussed in detail by Burns and Mitchell in *Measuring Business Cycles.* The seasonaly adjusted series, several smoothed versions, and tentative as well as final turning points are presented in Chart 3. The lowest curve on the chart shows the time series of seasonally adjusted data. The three other curves represent the results of several smoothing processes—a twelve-month moving average, a fifteen-month Spencer curve,[7] and a four-month moving average, respectively. These three curves are used in the gradual approximation of turns in the unsmoothed series. The essential steps of the procedure are outlined in Table 1.

EXTREME OBSERVATIONS

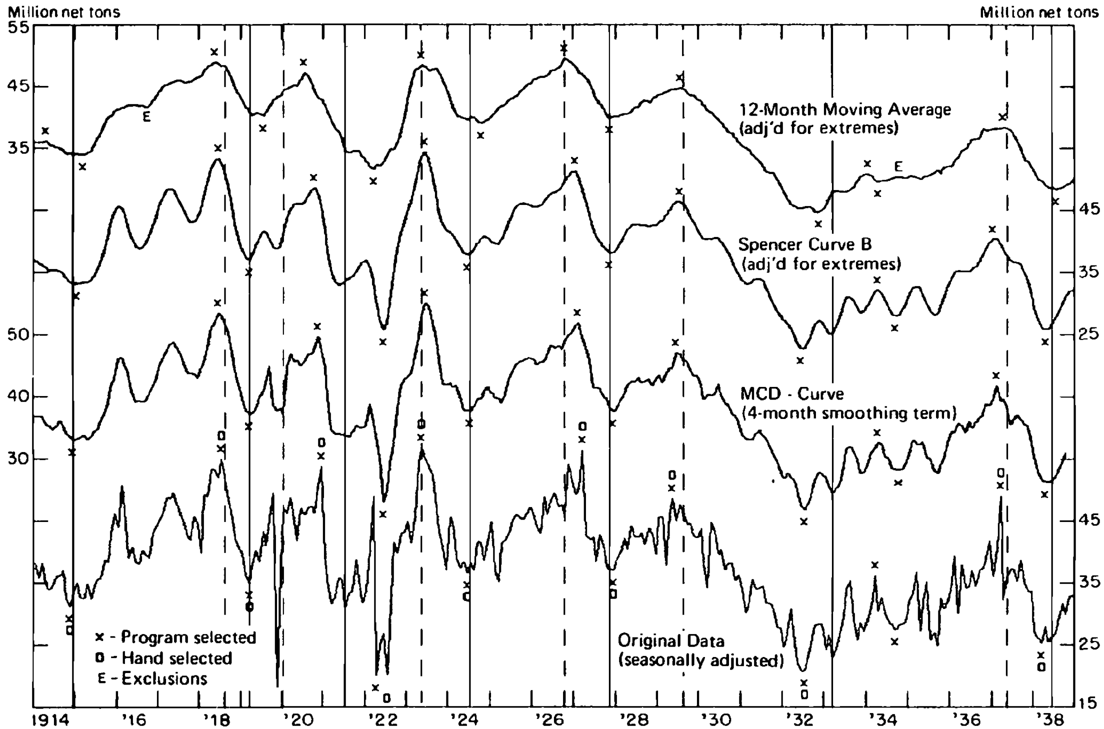
Since the representations of trend-cycle movements should be free of the influence of extreme observations, the identification of such observations and the derivation of suitable replacement values are the first steps in the program.

Extreme values are defined as values whose ratios to a fifteen-month

[7] This is a complex graduation formula, a weighted moving average with the highest weights in the center and negative weights at the ends, which ensures that the curve follows the data closely. Spencer curves can be considerably more flexible than an unweighted twelve-month moving average. This implies that the Spencer curve follows the original curve into peaks and troughs without drastic effects on the location of turning points—a valuable feature for a procedure of turning point selection. On the other hand, the flexibility of the Spencer curve causes it to follow minor fluctuations of less than cyclical importance and sometimes negligible amplitude. The latter feature may complicate the selection process, particularly if the procedure does not contain specifications for minimum amplitudes. Both curves are used in the present procedure.

CHART 3

BITUMINOUS COAL PRODUCTION AND MOVING AVERAGES, 1914–38



Note: Broken vertical lines denote business cycle peaks; solid vertical lines denote business cycle troughs.

TABLE 1

PROCEDURE FOR PROGRAMMED DETERMINATION OF TURNING POINTS

I. Determination of extremes and substitution of values.

II. Determination of cycles in 12-month moving average (extremes replaced).
  - A. Identification of points higher (or lower) than 5 months on either side.
  - B. Enforcement of alternation of turns by selecting highest of multiple peaks (or lowest of multiple troughs).

III. Determination of corresponding turns in Spencer curve (extremes replaced).
  - A. Identification of highest (or lowest) value within ±5 months of selected turn in 12-month moving average.
  - B. Enforcement of minimum cycle duration of 15 months by eliminating lower peaks and higher troughs of shorter cycles.

IV. Determination of corresponding turns in short-term moving average of 3 to 6 months, depending on MCD (months of cyclical dominance).
  - A. Identification of highest (or lowest) value within ±5 months of selected turn in Spencer curve.

V. Determination of turning points in unsmoothed series.
  - A. Identification of highest (or lowest) value within ±4 months, or MCD term, whichever is larger, of selected turn in short-term moving average.
  - B. Elimination of turns within 6 months of beginning and end of series.
  - C. Elimination of peaks (or troughs) at both ends of series which are lower (or higher) than values closer to end.
  - D. Elimination of cycles whose duration is less than 15 months.
  - E. Elimination of phases whose duration is less than 5 months.

VI. Statement of final turning points.

preliminary unadjusted Spencer curve (Spencer curve A) are outside a specified range. The present exclusion criterion is 3.5 standard deviations of the ratios, and is shown as "control limit = 3.500" on the title page of the output. The preliminary Spencer curve A is found in Output Table 2-2. The size of one standard deviation (7.853) is given at the bottom of this table, and the identification of extreme values is made in the subsequent lines. In the present case three values, all of them strike-related, are considered extreme: November 1919, March 1922, and April 1922—that is, all three of them deviate from Spencer curve A by more than 3.5 standard deviations. At the dates mentioned, the values of the unadjusted Spencer curve A are substituted for the extreme values in the original series in order to derive revised trend-cycle representations, i.e., Spencer curve B (not included in the output tables but presented in Chart 3) and a twelve-month moving average.[8] Note that July 1922, which has practically the same value as April 1922, is not excluded as extreme. The reason is that the unadjusted Spencer curve is much lower in July than in April (the value of which is strongly affected by the high extreme value of March), and thus the ratio of the July value to the Spencer curve value is less than 3.5 standard deviations from the mean of the ratios. In principle, an iterative procedure could lead to more consistent exclusions.

TURNS IN THE TWELVE-MONTH MOVING AVERAGE

The first curve from which turning points are determined, after adjustment for extreme values, is a twelve-month moving average (see Output Table 2-3 and the first curve in Chart 3). The reason for starting with the twelve-month moving average rather than with the Spencer curve is that the Spencer curve proved to be too flexible for our purpose (i.e., it contains too many minor fluctuations). The two curves can be compared in Chart 3. Most of the short fluctuations of the Spencer curve (1916, 1917, 1921, 1925–26, 1930–31, 1933, and 1935) are not reflected or only mildly reflected in the twelve-month moving average. Thus the latter curve seems to be a convenient means for eliminating fluctuations of subcyclical duration or of very shallow amplitude.

The selection of turning points is done in two steps: First, tentative turns are established, then these turns are tested for compliance with a set of constraint rules. Any month whose value is higher than those of the five preceding months and the five following months is regarded as the date of a tentative peak; analogously, the month whose value is lower than the five values on each side is regarded as the date of a tentative trough. In the case of bituminous coal production, the program picked a considerable number of such local maxima and minima, to wit, eight peaks and ten trough (see relevant output table). The turns selected on the twelve-month moving average are subjected to only one test—a check on the proper alternation of peaks and troughs. The elimination of multiple turns is simple. Of two or more contiguous peaks, the highest one (and if they have the same value, the latest)

[8] Experiments with alternative substitution rules, such as the replacement of extremes by the average of the nearest nonextreme values, led to the same or similar final results in practically all instances. Therefore, computations based on alternative substitutions were dropped from the procedure.

survives; and the analogous rule holds for troughs. In the present example, the excess troughs of September 1916 and April 1935 are removed (see Output Table 2-5). The remaining turns are marked by an X, the eliminated ones by an E in Chart 3.

TURNS IN THE SPENCER CURVE

The next step in the process is the determination of tentative and final cyclical turns in the Spencer curve. The Spencer curve is selected as the first intermediate curve because its turns tend to be closer to those of the original data,[9] a desirable step toward the final goal.

In principle, the program searches—in the neighborhood (delineated as ± five months) of the turns established for the twelve-month moving average—for like turns on the Spencer curve. That is, in the neighborhood of peaks, it searches for the highest of the eleven points on the Spencer curve; in the neighborhood of troughs, for the lowest. The Spencer curve turns thus located are subjected to two tests: (1) like turns must be at least fifteen months apart; and (2) the alternation of peaks and troughs must be maintained.

The stipulation that turns must not be closer than six months from the end of the series is, of course, introduced to avoid spurious highs or lows that have no cyclical significance. In the present illustration, the search did not turn up a Spencer curve peak that corresponded to the local maximum of April 1914 on the twelve-month moving average. This is expressed in the message "First turn is too near the beginning." Note that the search located a Spencer curve trough corresponding to the twelve-month moving average low of July 1938. The Spencer curve turns located by the described procedure are then listed.

The next test is designed to enforce a minimum-duration rule for recognized cycles. The adopted rule is that peaks as well as troughs must be at least fifteen months apart from like turns. After identifying like turns that are too close, the program excludes the lower of two peaks and the higher of two troughs. Exclusion of any turn requires elimination of an opposite turn to maintain the proper alternation of peaks and troughs. Sometimes this presents no problem. However, if there are several corresponding turns less than fifteen months apart,

[9] The equal-weight scheme of the twelve-month moving average can distort the location of turning points considerably. Compare, for instance, the turns in the twelve-month moving average, in the Spencer curve, and in the original data around the 1927 peak or the 1932 trough of the bituminous coal series.

a procedure must be used that will eventually lead to the elimination of several peaks and troughs. In the present example, no cycles on Spencer curve B are eliminated because of insufficient duration. This is almost entirely due to the use of the twelve-month moving average as a preliminary screening device. If the procedure had started with the Spencer curve, several of the short fluctuations mentioned before would have been provisionally recognized and later excluded under the fifteen-month duration rule.

The last test is designed to avoid "crossovers." If a contraction in the twelve-month moving average is less than ten months long, the searches for peaks and for troughs on the Spencer curve overlap. Hence the searches could conceivably lead to a Spencer curve contraction in which the low precedes rather than follows the peak. Since the conditions leading to such a crossover throw doubt on the existence of a genuine contraction, both turns involved are omitted.

The remaining turning points in the Spencer curve are listed in the output tables and were marked by us in Chart 3. It will be useful to review the efficacy of the procedure up to this point. On the whole, the delineated cycles seem reasonable; in particular, the omission of most of the briefer fluctuations should be regarded as successful. The only problem is the recognition of the brief 1934 contraction as cyclically significant, whereas the 1935 contraction is not recognized. The mechanics of the selection process are clear enough: The twelve-month moving average did not have a peak in the winter of 1934–35, and this eliminated April 1935 as a (multiple) trough. Thus the year 1935 did not fall into the search range of the program. The consequences of this restriction will be reflected in the final turning point determination, as will be seen later on.

IMMEDIATE NEIGHBORHOODS OF FINAL TURNS

It could be argued that the Spencer curve cycles should form the basis of cyclical analysis, since conceptually they are closest to the trend-cycle component of the observed values. However, as in all long-term moving averages, Spencer curves tend to shift turns, affect slopes, and convert irregular fluctuations into smooth wavelike patterns. Thus, analysis cannot be based on smoothed series alone, but must consider the behavior of unsmoothed observations.[10] Moreover, the exclusive use of smoothed series would not only make cyclical analysis depend-

[10] For a discussion of this problem, see Burns and Mitchell, *op. cit.*, pp. 310 ff.

ent upon the particular smoothing term and weighting scheme but would also be a radical departure from cycle measures previously used by the National Bureau and other investigators, and would impair comparability of research results. Cycles, as analyzed by the National Bureau, are based on unsmoothed values. Thus the search has to continue for values close to the Spencer curve turns that are peaks or troughs in the original seasonally adjusted data. This search could be carried out in the neighborhood of Spencer curve turns without use of any further intermediate curve, but there are possible drawbacks to such a procedure. The Spencer curve is a long-term moving average, quite capable of imparting a bell-type smoothness to data that form double or triple peaks or troughs (compare the curve contours in 1916, 1917, 1921, and 1935). Hence, the turns in the original data might be quite far from those of the Spencer curve, and consequently the procedure would require a correspondingly broad search range in order not to miss the turns. However, such a wide range would catch irregular maxima or minima that are not cyclically significant peaks and troughs. For this reason it was thought better to redelineate the neighborhood of the final turns by searching in the neighborhood of the Spencer curve turns for corresponding turns in a short-term moving average.

A curve that represents the original seasonaly adjusted data smoothed by a short-term average is the MCD curve. MCD stands for months of cyclical dominance. The MCD of any series is the number of months required for the systematic trend-cycle forces to assert themselves against the irregular time series component. If a series has strong cycles and little irregularity, it will not take long (perhaps not longer than one or two months) until the average change in the trend-cycle component exceeds the average change in the irregular component. If a series has shallow cycles but is very choppy, it may take many months before the cyclical movement asserts itself. In the first case no smoothing, or smoothing by only a very short-term average, is required to bring out the cyclically relevant movements; in the second case a correspondingly longer term is needed.[11] The MCD curve is the curve representing the data smoothed by the MCD term appro-

[11] Technically, the number of months required for dominance of the cyclical over the irregular component is that span over which the average change in the irregular component becomes smaller than the average change in the trend-cycle component. For further explanation, see Julius Shiskin, "How Accurate?" *American Statistician*, October 1960, pp. 15 ff.

priate for the relationship of trend-cycle and irregular movements in the analyzed activity. In order to reduce the effect of irregular changes and the influence of remote values, the span of the smoothing term used is confined to the narrow range of three to six months. For measured MCD's of one and two months, a three-month term is applied; for MCD's of seven or more months, a six-month term is used.

The MCD for bituminous coal production is four months. The MCD curve is plotted as the third curve of Chart 3 and is based on Output Table 2-4. The method of deriving turning points in the four-month moving average is practically the same as that described in the preceding section. Turns are determined by selecting the highest peak on the MCD curve within a span of five months from the dates of the peaks on the Spencer curve; MCD troughs are analogously selected. Before this determination is made final, turns at the very beginning and end of the MCD series are omitted, the minimum duration rule is enforced, and the turns are tested for crossovers. In the present case, no further exclusions result from the application of these tests. The remaining turns are reported in the output table as turning points in four-month moving average; they are marked by crosses on the third curve of Chart 3.

SELECTION OF FINAL TURNING POINTS

The last step of the procedure is to find the peak and trough values in the unsmoothed data that correspond to the MCD turns previously established.[12] This simple search is analogous to the previous transitions (from turns in the twelve-month moving average to Spencer curve turns and from Spencer curve turns to MCD curve turns). The program establishes the highest values in the unsmoothed data within a span of ± MCD or ± four months (whichever is longer) from the peak in the MCD curve; correspondingly, the lowest value of the unsmoothed data in the neighborhood of MCD troughs is established. No turns closer than six months from the ends are accepted. Also, the first and last peak (or trough) must be at least as high (or as low) as any value between it and the end of the series. The resulting turns are reported in Output Table 2-8.

[12] Again it could be proposed that the dates and values of the MCD turns should be regarded as those relevant for cyclical analysis, since the unsmoothed series is modified by irregular elements that are not intended to affect cyclical measures. Whatever the merits of this view, the present analysis ignores it in order to adhere as closely as feasible to standard practices.

The final tests deal with the duration of cycles and cycle phases. Full cycles (peak-to-peak and trough-to-trough) are checked for a minimum duration of fifteen months. The fact that this criterion was applied earlier to the trend-cycle curve does not necessarily mean that the related cycle in the unsmoothed data satisfies the condition, as the actual initial and terminal turns can be closer than the related turns on the Spencer curve. In the present example, however, the application of the test does not lead to further exclusion of cycles. The last constraint for which the turning points are tested is a five-month minimum rule for phase durations. There is no equivalent rule in the standard analysis of the National Bureau. However, early experiences showed that some sharp, short episodic movements (such as strikes) can be redistributed by the various moving averages into fluctuations of cyclical contours and durations. The minimum-phase-duration rule, which at present is set at five months, is a possible remedy.[13] This rule could be readily modified if experimentation or extended experience should prove it to be inadequate.

The final turning points are listed on Output Table 2-8 and marked by crosses on the lowest curve of Chart 3. Comparison with those previously selected,[14] and marked by squares on the same curve shows one minor and one major discrepancy. The minor difference consists in the selection of April 1922 instead of July 1922 as a trough. The situation here is that of a characteristic double trough. The earlier trough, in April, is slightly lower and thus was selected under the specified procedures.[15] The difference is unimportant and could be passed over without comment were it not that it illustrates some characteristics of programmed turning point determination. The National Bureau's selection of the July turning point is explained as follows:

> The trough in 1922 exemplifies a "double bottom." There is a deep trough in April 1922, when a strike—probably the greatest in the history of this afflicted industry—broke out. A slight revival occurred during the next two months, and a relapse in July, when the railroad shopmen's strike produced

[13] Different minima for expansions and contractions were considered, in view of the longer durations of expansions in historical business cycles, but were ruled out in order to make the program equally effective for series with positive and inverted conformity and for series with rising and falling long-term trends.

[14] Burns and Mitchell, *op. cit.*, pp. 60 ff.

[15] April 1922 was identified above (p. 21) as an extreme value. This does not prevent it from being chosen as a turning point. Prevailing practice is to accept extremes as turning points if they occur in a turning point neighborhood.

an acute car shortage in the non-union field. The seasonally adjusted figure is fractionally higher in July than in April (20.2 against 20.1 million tons). But the difference is negligible, and in line with our rules, the trough is dated in the later month.[16]

Apart from the consideration of historically unique events, such as the two strikes, it would be difficult to program a provision to neglect "negligible" differences. When is a difference negligible? Should the same standard be applied to all series, whatever their volatility? And if there are several alternative troughs, each negligibly different from the other but arranged in ascending order, should the last one nevertheless be selected? While it is not technically impossible to incorporate these and similar considerations in a programmed selection, it would lead to a proliferation of tests that might make the process unwieldy and perhaps impractical—at least at the present state of the art.

The major discrepancy between the traditional and the programmed turning point determination is the recognition by the programmed procedure of a cyclical contraction in 1934. The problem is not only the debatable recognition of any contraction at all but the specification of the contraction as lasting six months, from March to September 1934, instead of lasting for one more year, to September 1935. The latter would be the more plausible version, in view of the behavior of the actual data. The technical reason for the programmed determination was discussed before in connection with the turning point selection on the Spencer curve. It goes back to the use of the twelve-month moving average as the first step in the process of cycle identification. It would, of course, be quite simple to *increase* the flexibility of the first average, decrease the span, and thus permit consideration of the events of 1935. Alternatively one could *decrease* the flexibility of the first curve, and thus eliminate the cycle in question altogether. Whatever the solution to the problem, its formulation and acceptance cannot be based on the analysis of programmed turning point determination for a single series or even for a few series. It is always possible, and relatively easy, to modify the program to cover a small number of contingencies. The goal is to develop rules that operate in a satisfactory manner for most economic time series. Thus, experimentation with a fairly large sample of series must be resorted to in order to establish the efficacy and the shortcomings of a given set of rules.

[16] Burns and Mitchell, *op. cit.*, p. 63.

Analysis of programmed turning points and modification of procedures must be based on experiences with such a sample. This is the concern of the following section.

EMPIRICAL EVALUATION OF PROCEDURE

DESCRIPTION OF SAMPLE

The sample chosen for the experiment is the collection of leading, lagging, and coinciding business cycle indicators for the period starting 1948, as published monthly in *Business Cycle Developments*.[17] There are several reasons for this choice. First, the sample covers a large number of important activities representing various aspects of economic life in the United States. Second, the selected series exhibit a great variety of behavior: there are series with relatively large random components and little trend, such as temporary layoffs; there are smooth series, with little random and strong upward trend, such as personal income; there are positively conforming series, and there are inverted series; there are monthly and quarterly series; there are series with and without negative entries. Third, the series were all available, in up-to-date and seasonally adjusted form, in *Business Cycle Developments*, thus reducing or eliminating the chores of data collection and seasonal adjustment. Fourth, and for present purposes most important, cyclical turning points have already been established by the National Bureau for all these series, based on the rules given by Burns and Mitchell in *Measuring Business Cycles*. This makes comparisons of previously selected and program-selected turns possible for all series. *Business Cycle Developments* reports thirty leading, fifteen coinciding, and seven lagging indicators, or fifty-two altogether. One series, new approved capital appropriations (series 51), had to be omitted because of several discontinuities. Thus, fifty-one series were left for experimentation—a sufficiently large and variegated sample for present purposes.

Despite its broad coverage, the sample described has one serious bias that may affect its value for testing the broad applicability of programmed turning point determination for economic time series in general. The bias arises from the fact that most of the series shown in *Business Cycle Developments* were chosen because their marked

[17] The sample used was published in *Business Cycle Developments* before the changes instituted in the April 1967 issue.

cyclical characteristics made the series valuable for diagnosis of current business conditions. That is, most of these series have recognizable if not pronounced cycles, show good conformity to several business cycles, and are not excessively affected by random elements. The greatest difficulties in turning point determination arise when cyclical components are weak and irregular factors are strong—and this situation is rare in the selected sample. However, at the present stage of development the programmed approach cannot be expected to solve problems that proved intractable before. Thus, although the sample excludes series whose cyclical behavior is particularly uncertain, it will serve well to test the broad applicability of the approach and to suggest the direction in which further progress should be sought.

CRITERIA FOR EVALUATION

Before reporting the outcome of the experiment, it might be well to consider the criteria by which the results should be evaluated. An obvious standard for evaluation is the turning point selection that had previously been made for these series. Although for many reasons—particularly comparability with previous work—this appears to be a desirable standard, it is not without weaknesses.

For one thing, the general rules of turning point determination are subject to interpretation; and, if a basic rule permits more than one choice, the choice actually made in the past should not serve as criterion for the evaluation of the programmed selection. Second, in the selection and analysis of cyclical indicators, doubtful cases might have been resolved by accepting fluctuations that conformed to fluctuations in business activity at large.[18] Thus, neither the programmed selection of additional intraphase turns nor the omission of conforming but otherwise doubtful phases should necessarily be regarded as a defect of the program. Third, it is possible that the technology of programmed selection requires somewhat different rules than those developed as guides for the exercise of judgment by individuals. Thus, there exists the possibility that the ground rules may have to be changed to facilitate programmed selection. Such changes should, of course, be made only if clearly justified by the results of broad experimentation.

The preceding remarks should not be interpreted as a defense of

[18] Burns and Mitchell, *op. cit.*, p. 58.

the programmed selection of turns whenever these depart from those previously determined. After all, the program is experimental and excludes from consideration certain criteria, such as comparative amplitude and runs of changes in the same direction, which proved to be valuable guides in the past. It is precisely the purpose of this report to establish whether programmed selection can safely ignore some of these guides or whether the program must be amended to reflect these and other considerations. The most important criterion for the general usefulness of the program is whether basic research findings are affected by its use.

PROGRAM-DETERMINED AND STAFF-DETERMINED TURNS

In Chart 4, the turns picked by the program are marked by crosses placed close to the line and those chosen previously by the Bureau are marked by squares. Even a casual examination of the chart reveals that in most instances the program picked the same points as those established earlier, but that the program often recognized a number of short and mild fluctuations as cyclical that were not so regarded in previous analyses. The opposite situation, that of fluctuations recognized previously but not by the program, occurs less frequently. In comparing the results, a distinction must be made between the identification of specific cycles, and the precise dating of their turns. The first implies the recognition of certain neighborhoods as turning point neighborhoods; the second involves specification of the month in which the turn occurred. Let us begin with the question of recognition.

In the following analysis, interest is concentrated on the differences between the results of programmed and nonprogrammed determination of turning points. Table 2 shows that the program found 432 specific phases, as against 384 found by the nonprogrammed approach. Identical phases were found by both approaches in 346 cases. That means the program found 90 per cent of the phases previously established by the National Bureau staff. Since the program found 48 more phases than the Bureau, the phases found by both approaches constitute only 80 per cent of all phases determined by the programmed approach.

The net difference of 48 does not provide a satisfactory criterion for evaluating the similarity of the results. The net difference hides the fact that there are 124 phases that were chosen by one approach

CHART 4

BUSINESS CYCLE INDICATORS, TURNING POINTS SELECTED BY PROGRAMMED AND NONPROGRAMMED APPROACH, 1947–67

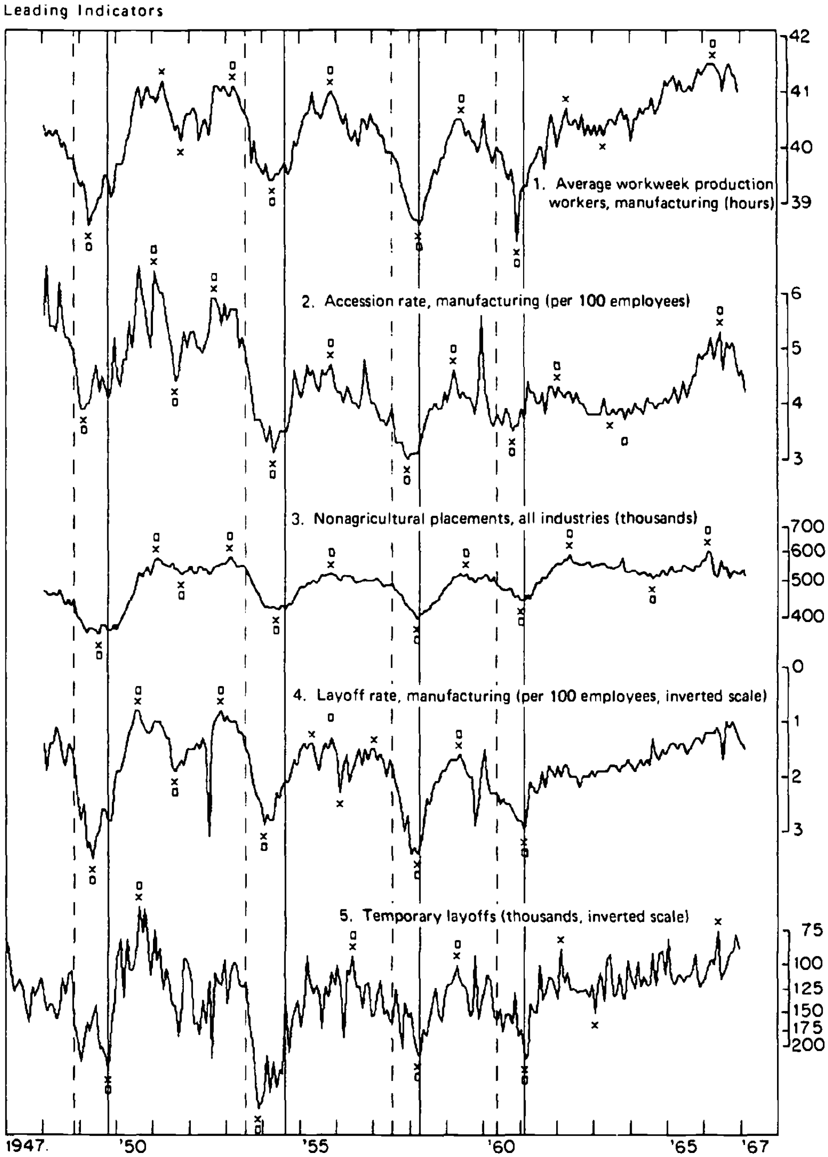


CHART 4
(Continued)

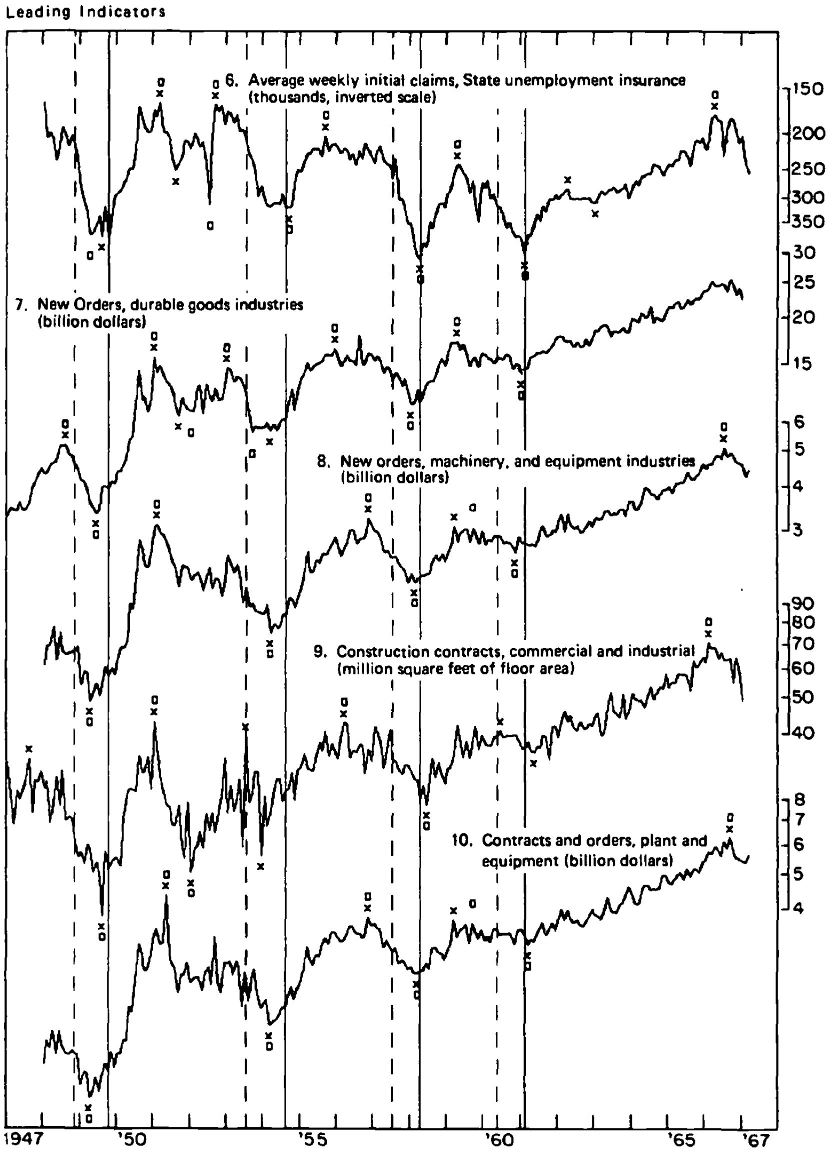


CHART 4

(Continued)

Leading Indicators

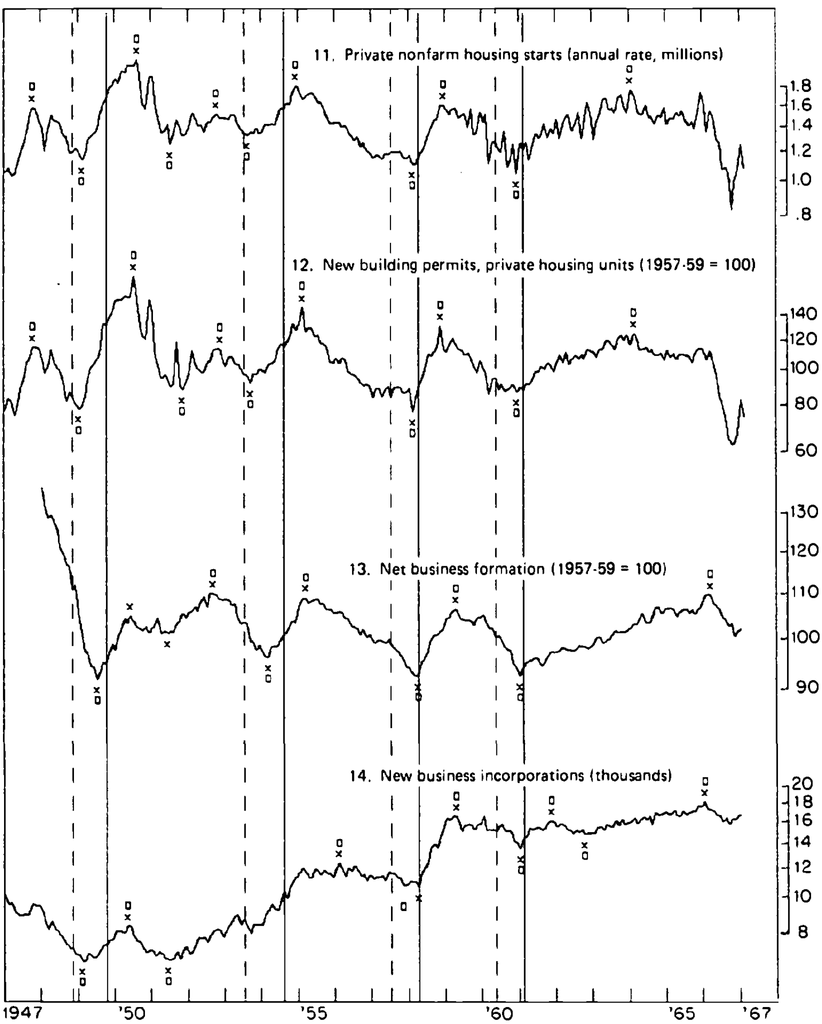


CHART 4
(Continued)

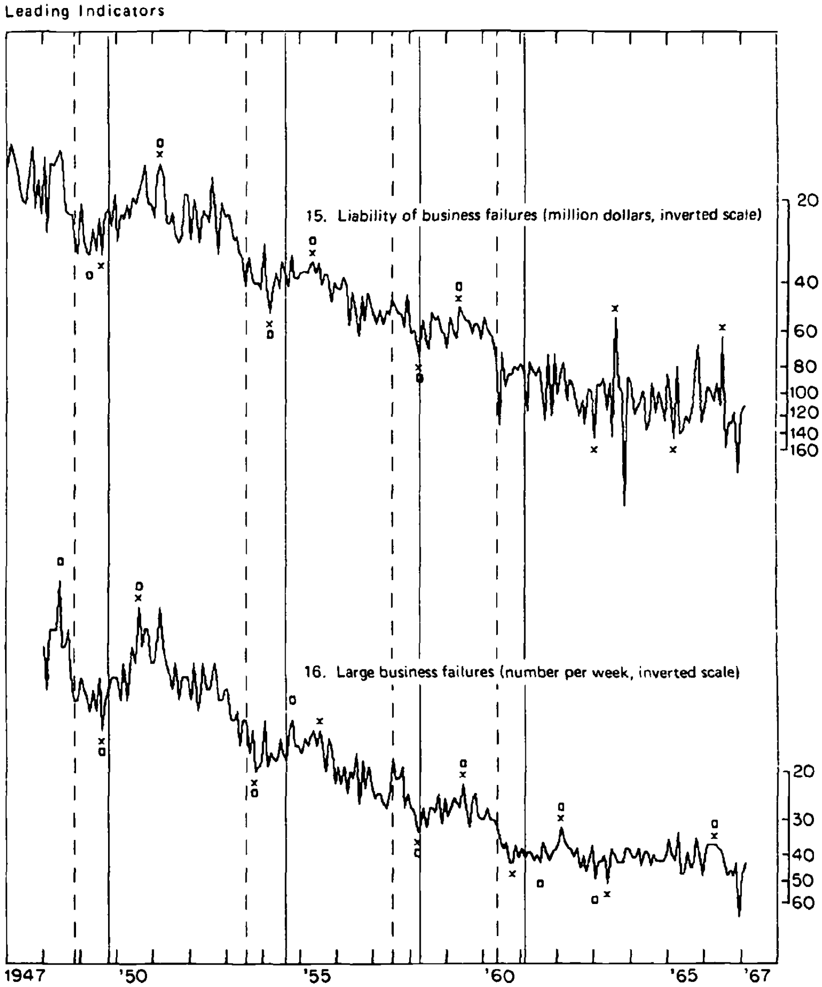


CHART 4

(Continued)

Leading Indicators

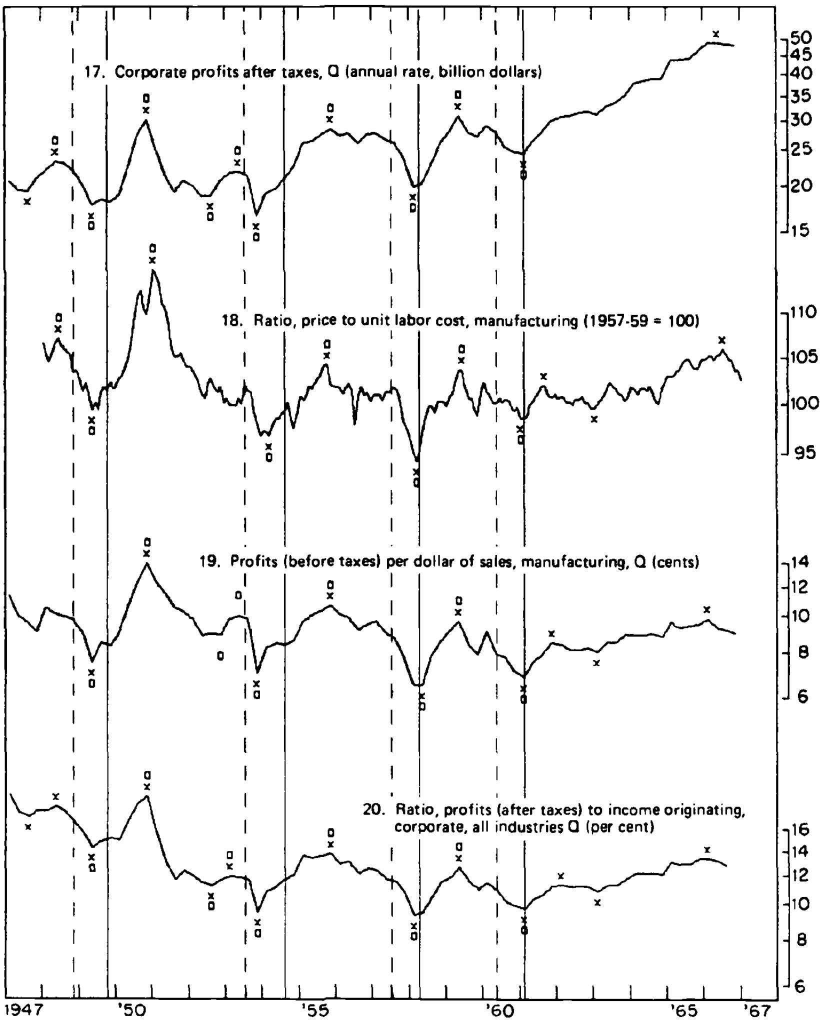


CHART 4
(Continued)

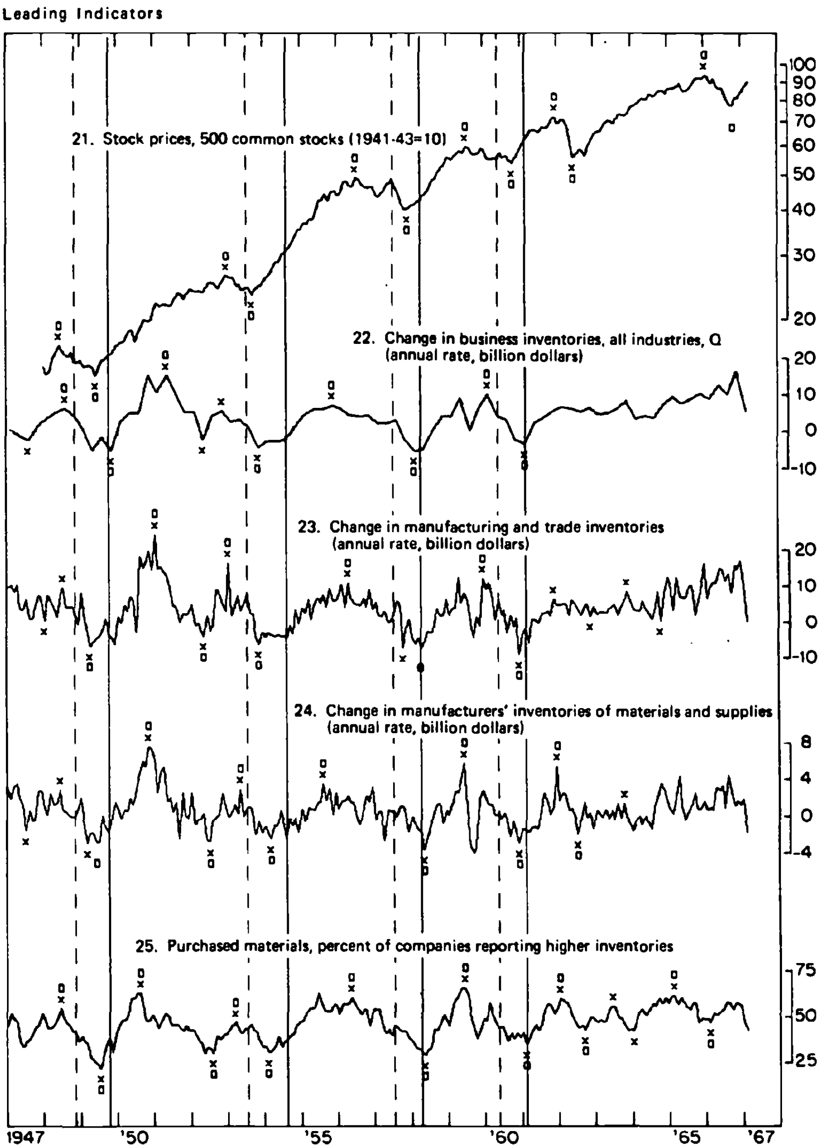


CHART 4

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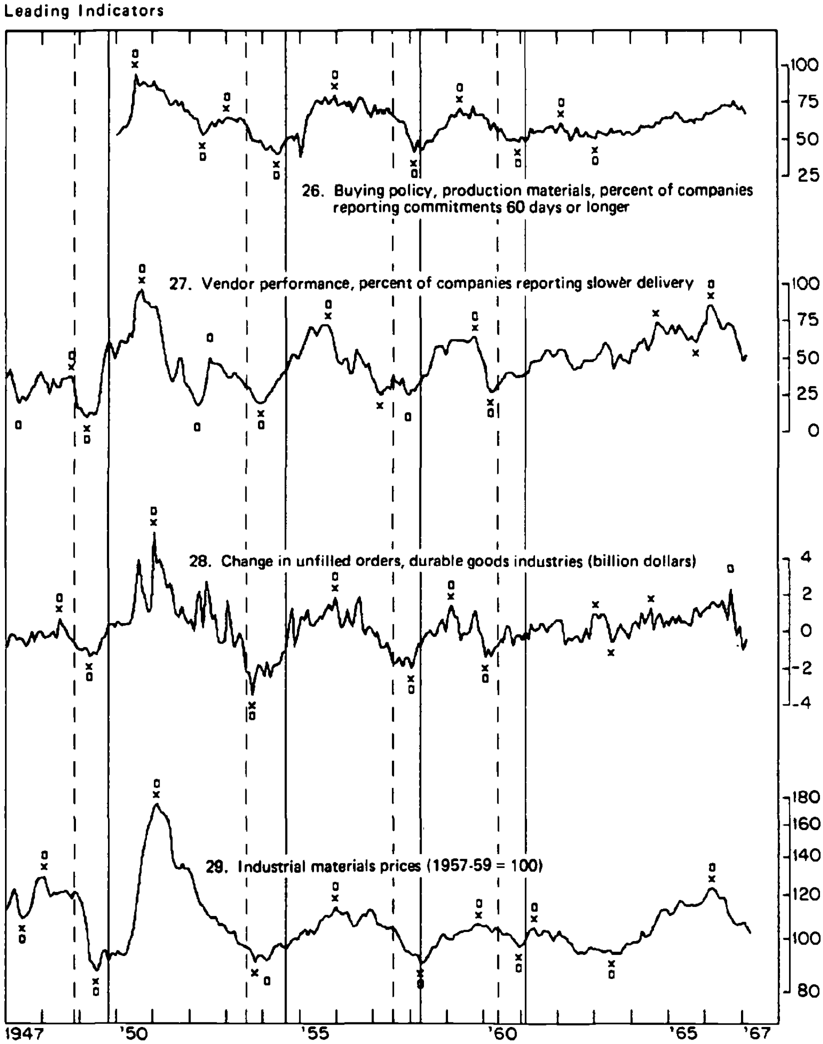


CHART 4
(Continued)

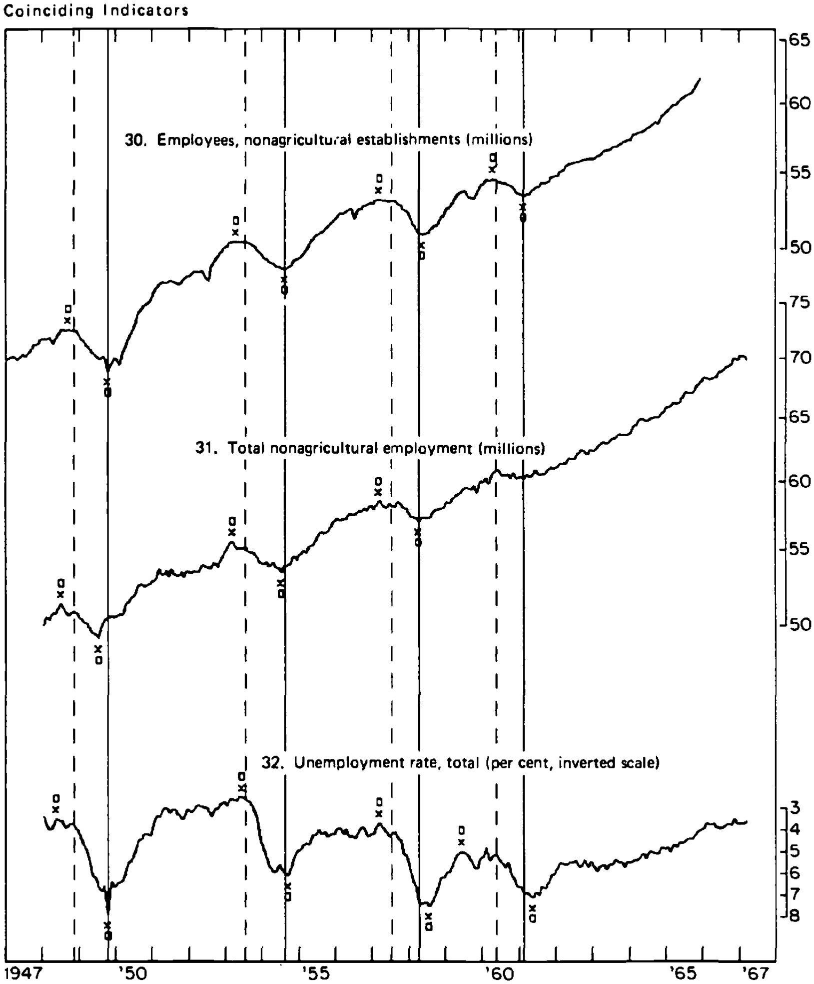


CHART 4

(Continued)

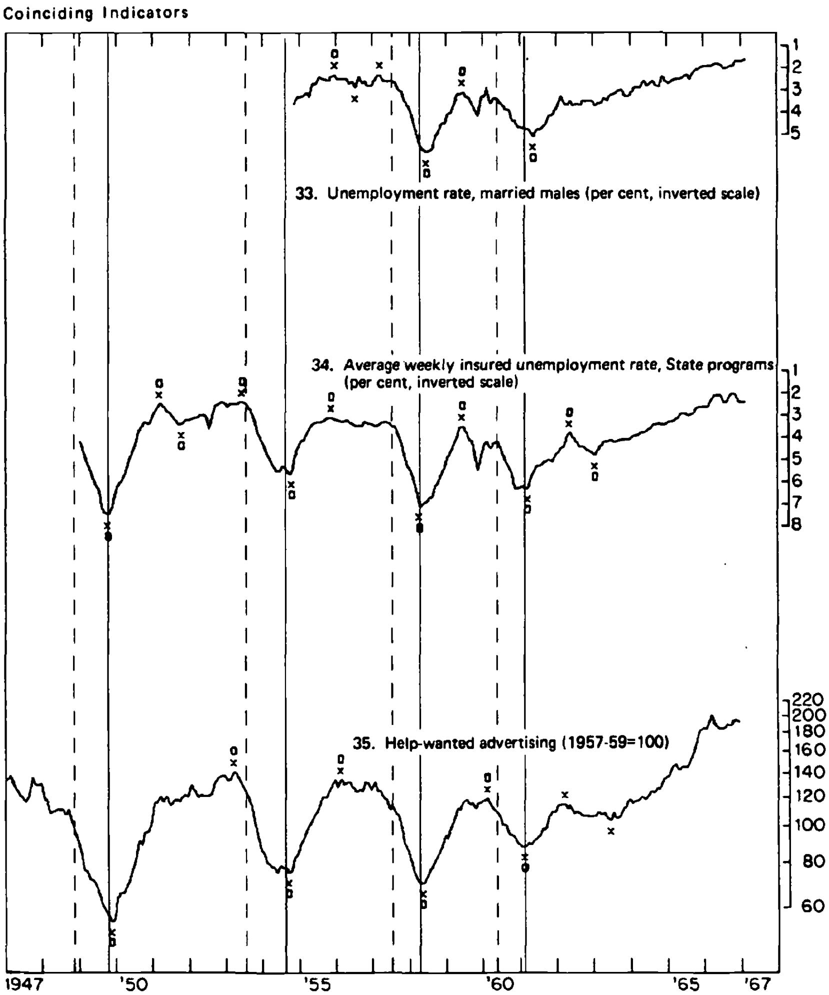


CHART 4
(Continued)

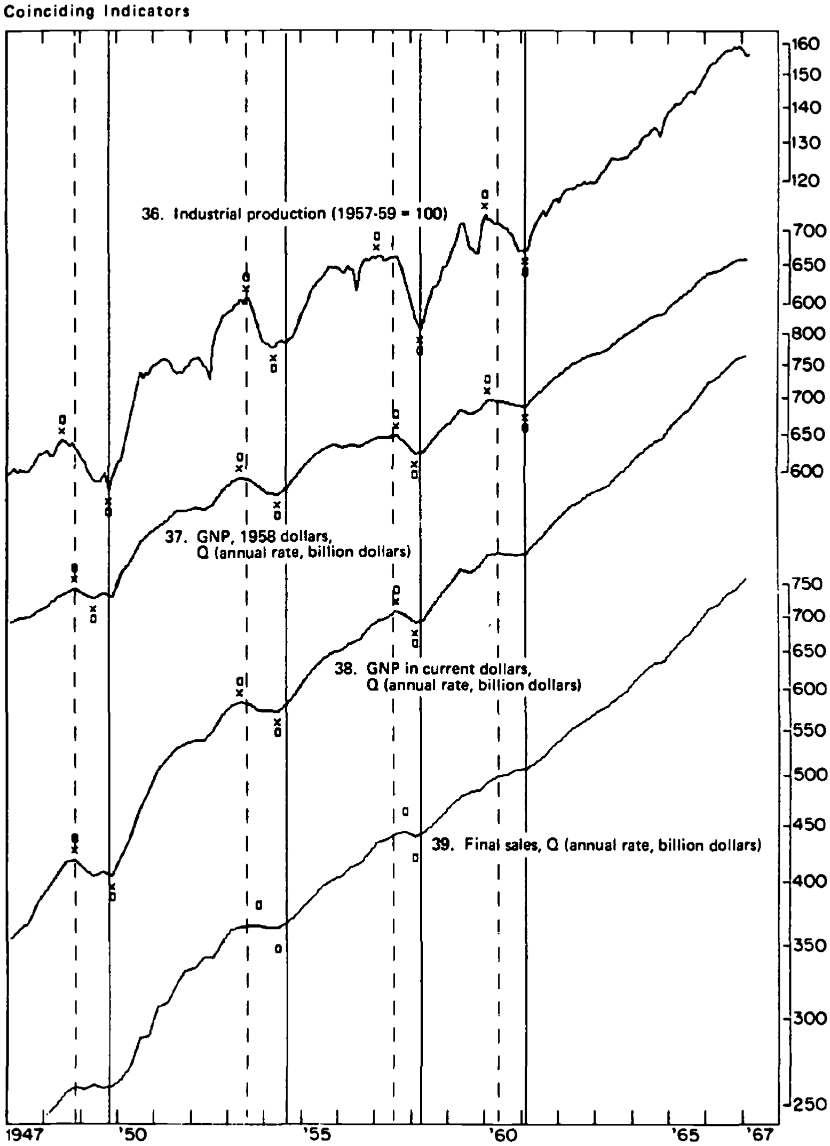


CHART 4

(Continued)

Coinciding Indicators

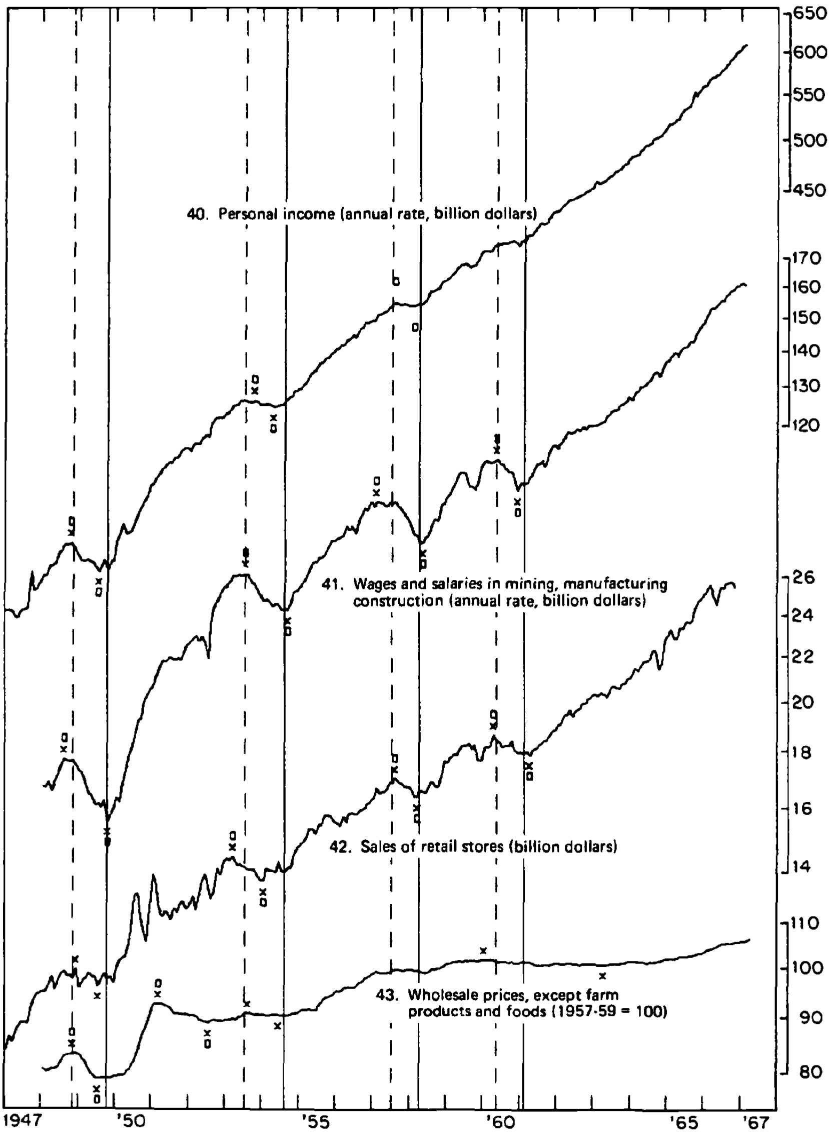


CHART 4

(Continued)

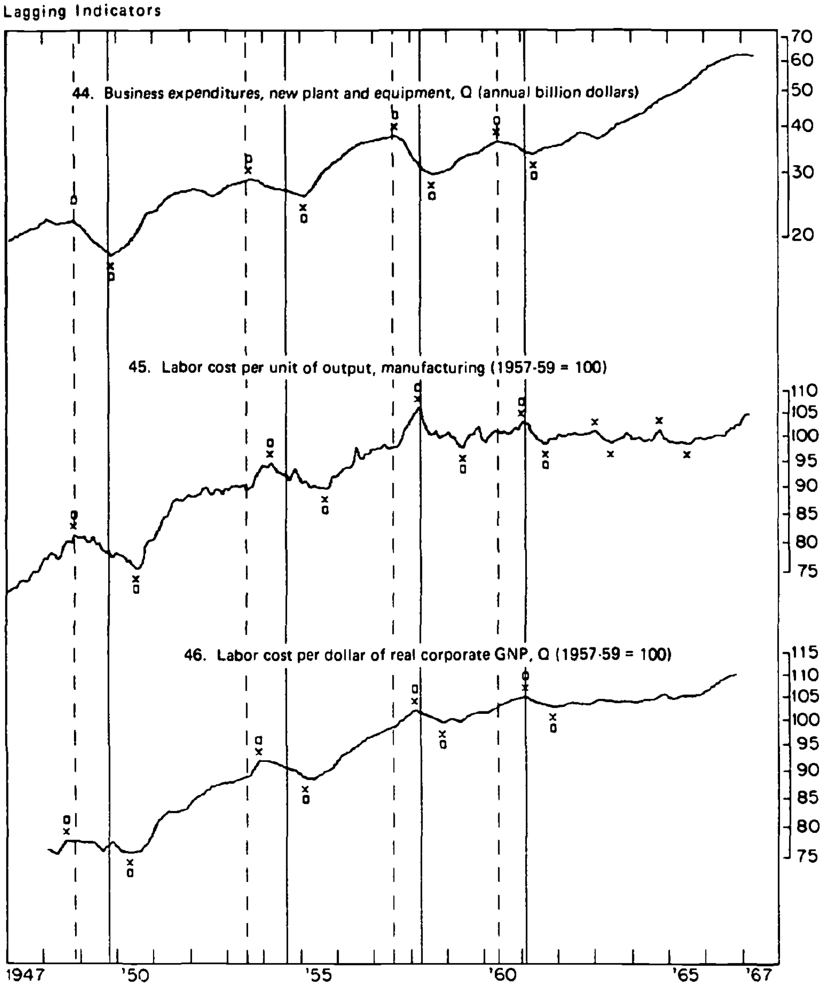
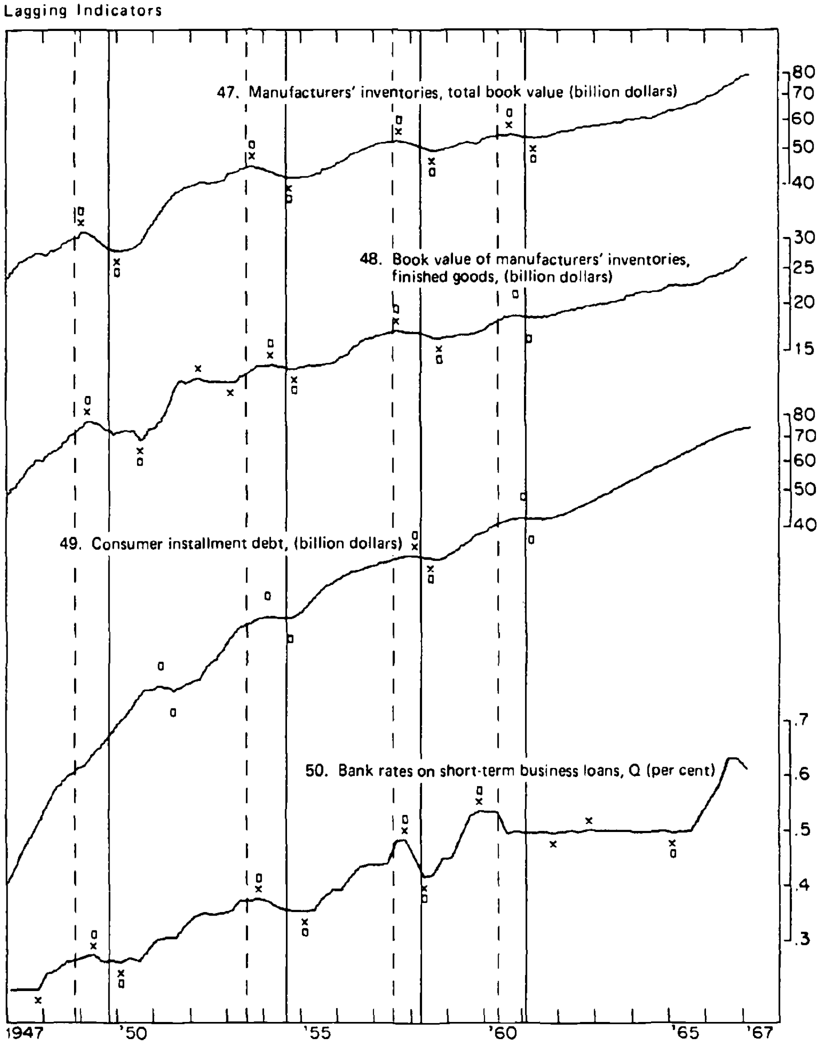


CHART 4

(Concluded)



Note: Crosses denote program determined turning points of the specific series; squares denote turning points of the specific series previously determined by the National Bureau staff. Broken vertical lines denote business cycle peaks; solid vertical lines denote business cycle troughs.

TABLE 2
SPECIFIC-CYCLE PHASES
IN BUSINESS CYCLE INDICATORS,
PROGRAMMED AND NONPROGRAMMED APPROACHES,
1947–67

	Expansions	*Contractions*	*All Phases*
1. All specific phases found by programmed approach	214	218	432
2. All specific phases found by nonprogrammed approach	186	198	384
3. Specific phases found by both programmed and nonprogrammed approach[a]	166	180	346
4. Specific phases found by programmed but not by nonprogrammed approach	48	38	86
5. Specific phases found by nonprogrammed but not by programmed approach	20	18	38
6. Phases found by both approaches as a percentage of those found by nonprogrammed approach	89	91	90
7. Phases found by both approaches as a percentage of those found by programmed approach	78	84	80

Source: Chart 4.
[a] Phases with corresponding initial and terminal turning points only.

but not by the other—86 by the program but not by the National Bureau staff, and 38 by the staff but not by the program. On the other hand, the differences shown in the table overstate the differences in the results of the two approaches. Phases are regarded as corresponding only if both the initial and the terminal turning points correspond. That is, if the program finds an intermediate contraction during a cyclical upswing of the nonprogrammed approach, this is counted as four differences—three extra phases found by the program and one extra phase found by the National Bureau staff. An example can be found to illustrate this point in the first expansion of the average workweek series, the first series shown in Chart 4. Here the contraction found by the program in 1951 gives rise to the report of four noncorresponding phases, i.e., of the three phases found by the program (1949–51, 1951–51, 1951–53) and the noncorresponding expansion found by the National Bureau staff for 1949–53.

TABLE 3
CYCLICAL COUNTERPHASES IN BUSINESS CYCLE INDICATORS, PROGRAMMED AND NONPROGRAMMED APPROACHES, 1947-67

Specific phases found by both programmed and nonprogrammed approach			346
Counterphases found by programmed but not by nonprogrammed approach			40
Corresponding to business cycle phases		8	
Not corresponding to business cycle phases		32	
Corresponding to business cycle retardations	19		
Counterphases found by nonprogrammed but not by programmed approach			14
Corresponding to business cycle phases		8	
Not corresponding to business cycle phases		6	
Corresponding to business cycle retardations	1		

Note: Counterphases are extra expansions (contractions) according to one approach, while the series experienced a contraction (expansion) according to the other approach. Extra turns, found by an approach at either end of a series, imply counterphases; these are included in the numbers given above.

In order to avoid the quadruple counting, Table 3 is introduced. This table reports only counterphases, that is, contractions (or expansions) that are found by one approach during expansion (or contraction) phases found by the other. In the fluctuations of the average workweek between 1949 and 1953, only one counterphase occurs—the extra contraction found by the program during 1951. The summary shows that the program found only forty counterphases. Moreover, eight of these correspond to concomitant business cycle phases and nineteen to the major retardations in business activity that occurred during 1950–51, 1962–63, and 1966–67.[19] Thus, most of the counterphases found by the program are economically plausible. The counterphases found by the nonprogrammed approach amounted to only fourteen, with eight phases conforming to corresponding business cycle phases and one to the retardation of 1950–51. This means that,

[19] These neighborhoods were singled out since many leading and a fair number of coinciding indicators showed declines, or at least retardations.

with only a few exceptions, the National Bureau staff agreed with the cyclical direction implied in the programmed determination of specific cycle phases.

When additional phases, such as the specific contraction from 1952 to 1953 in manufacturers' inventories of finished goods (series 48), are recognized by the program, the basic reason is simply that the twelve-month moving average went down long enough to establish a high and a low, each in the center of an eleven-month period. When a contraction recognized by inspection is not chosen by the program, as is the case in the specific decline from 1960 to 1961 in the same series, the reason is that the twelve-month moving average did not go down or did not go down long enough to qualify the decline as a cyclical contraction under the adopted criteria. It is true that other rules (alternation of peaks and troughs, minimum cycle length, minimum phase length, etc.) affect the final selection of turns, but the behavior of the twelve-month moving average controls basic eligibility. One case where the program omitted a phase selected by the National Bureau staff—because of insufficient duration, although the twelve-month moving average shows cycles—is the 1952 expansion in vendor performance (series 27).

The cited examples of differences in cycle recognition, and others that could be easily adduced, raise the question whether the programmed or the previously determined cycles are analytically preferable. This question is hard to answer without formal standards or at least some guiding considerations. In the case of manufacturers' inventories (series 48), the program-selected extra contraction of 1952–53 exceeds the extra contraction of 1960–61 selected by the Bureau staff in length and in amplitude and thus seems a better choice. The Bureau staff's recognition of the 1960–61 movement as a cyclical decline was presumably influenced by the fact that it corresponds to a business cycle contraction. On the other hand, the program's recognition of an extra contraction during 1956–57 in the layoff rate (series 4) seems inferior to the judgment of the staff member who regarded 1955–58 as one long specific expansion.[20]

[20] The program's recognition of the additional contraction was partly a consequence of unsatisfactory dating of turns—a point which will be discussed later on. Proper dating of the trough of the (inverted) layoff rate in November 1955 would have ruled out recognition of the ensuing increase as an expansion because the period of increase would have been below minimum phase duration.

Only five of the forty counterphases found by the program must be characterized as incompatible with a reasonable interpretation of the basic rules. The counterphases shown by series 1 in 1962–63, series 15 in 1963–63, series 33 in 1956–57, series 42 in 1948–49, and series 50 in 1961–62 are minor movements in comparison with the typical cyclical variations exhibited by these activities. All other extra-phases consist of mild fluctuations with fairly clear cyclical characteristics. The acceptability of such mild movements as cyclical phases depends on research goals and perhaps on the economic characteristics of experiences during the historical period analyzed. If one is interested in the timing and the degree of synchronization of fluctuations in economic activities during recent years, one may have to recognize mild fluctuations since they are the only ones present. In fact, analytical interest is shifting to the timing of changes in growth rates, so that analysis of fluctuations is not limited to actual declines in the level of activities. On the other hand, recognition of mild fluctuations may well be less desirable—or less important—for research concerned with economic fluctuations during the period before World War II. In principle, the program could be modified to accommodate these differences in objectives and historical context. However, such modification would diminish the procedural stability necessary for a uniform derivation of cyclical turning points and would thus be undesirable.

The above comparisons dealt with the recognition of cycle phases. Table 4 deals with the comparison of program-determined and staff-selected cyclical turns for leading, coinciding, and lagging indicators. Altogether, the difference between the results of the two approaches amounts to about 20 per cent of all phases, with a clear tendency of the program to pick more turns.

The program found 483 turns in the series as compared with 435 selected by the Bureau staff, for a net difference of 48 turns, or 11 per cent of the previously selected turns. These figures, however, overstate the agreement of the two selections since the program picked 72 turns where no corresponding turns were recognized by the National Bureau staff, and the staff picked 24 turns where no corresponding turns were found by the program. The resultant sum of 96 discrepancies in turning point recognition is double the size of the net differences. The program tended to recognize more cyclical turns both in leading and coinciding indicators, but particularly in the leading group with its more volatile activities. Altogether, the 411 corresponding

TABLE 4

CYCLICAL TURNING POINTS IN BUSINESS CYCLE INDICATORS, PROGRAMMED AND NONPROGRAMMED APPROACHES, 1947–67

	Indicators			
	29 Leading	*14 Coinciding*	*6 Lagging*	*All Indicators*
1. All turns found by programmed approach	324	103	56	483
2. All turns found by nonprogrammed approach	281	98	56	435
3. Corresponding turns found by both programmed and nonprogrammed approaches	272	92	47	411
a. Identical dates	255	92	47	394
b. Different dates	17	0	0	17
4. Noncorresponding turns				
a. Found by programmed but not by nonprogrammed approach	52	11	9	72
b. Found by nonprogrammed but not by programmed approach	9	6	9	24
5. Corresponding turns as a percentage of those found by nonprogrammed approach				94
6. Identical turns as a percentage of those found by nonprogrammed approach				91
7. Corresponding turns as a percentage of those found by programmed approach				85
8. Identical turns as a percentage of those found by programmed approach				82

turns constitute 94 per cent of all turns found by the nonprogrammed approach and 85 per cent of the more numerous turns found by the programmed approach.

While there are systematic differences between programmed and unprogrammed cycle recognition, differences between the dates of comparable turns selected by the two approaches are of minor importance. This can be seen in Chart 4 and lines 3a and 3b of Table 4. Among 411 cyclical turns that are recognized both by the program and by inspection, the program picked the same date in 394 turns (96 per cent of all corresponding turns); this represents 91 per cent of all staff-selected turns and 82 per cent of all turns found by the programmed approach.

In 12 of the 17 turns with different dates—which all occurred in the leading indicators—the National Bureau staff picked later turns than the program, in keeping with the Bureau's preference for resolving doubtful cases in favor of the later turn. Only four program-established dates are clearly inferior. They occur in the following circumstances:

Series	*Activity*	*Type of Turn*	*Date of Program-Selected Turn*	*Date of Staff-Selected Turn*	*Cause for Program Selection*
2	Accession rate	T	June 1963	Nov. 1963	Lower Spencer curve
4	Layoff rate	T[a]	May 1955	Nov. 1955	Lower Spencer curve
6	Initial claims, state unemployment insurance	P[b]	Aug. 1949	Apr. 1949	Higher peak
27	Vendor performance	T	Mar. 1957	Dec. 1957	Lower Spencer curve

[a] Shown as peak on inverted scale.
[b] Shown as trough on inverted scale.

In three of the four instances the basic cause for the discrepancy was that the Spencer curve was lower in the neighborhood of the program-selected trough; and the staff-selected trough (which was lower and/or later in the unsmoothed series) was beyond the stipulated search range. In series 2, for example, the program picked a turn in the middle of the flat-bottom trough of 1963 although there is a lower point at the end of the year—the turn picked by the National Bureau staff. The reason is that the Spencer curve has its trough in the beginning of the year, which puts the December low of the three-month moving average and the November low of the unsmoothed series beyond the respective search ranges. The search range, from Spencer to short-term average, would have to be greatly increased to catch the late 1963 low. However, such an increase would also result in a recognition of the irregular high in December 1959 as a peak, a clearly undesirable result. The limited range of the search leads to a questionable selection also in case of the peak (shown on the chart as a trough, due to inverted scale) of initial claims (series 6) in 1949. Here the program chooses the middle value of three prongs although the last value is higher and the early value, chosen by the staff, is better supported by adjacent values. The programmed approach did not search as far as the last prong and did not choose the first because it always picks the outlying value of the unsmoothed data without regard to adjacent values.

Application of the process to other series than those used in the present study revealed a potential weakness. In excluding turns associated with "short" phases (less than 5 months), the alternative peak selected by the program may be lower than the eliminated one, or the alternative trough may be higher. This result would be justified if the eliminated turn were randomly high or low but not if it reflected a cyclical reversal. Further experience may lead to program modification; in the meantime the user should be aware of the problem.

On the whole, our experience suggests that programmed turning point determination will prove useful for many research purposes. While the program-determined turns may be inferior to those established by experienced research workers, they may well be superior to those found by nonspecialists. The program is objective with regard to procedure; thus, the same turns will be found by every investigator who relies upon the program.

One research result that would not be significantly altered, whether the programmed or staff-selected turns are used, is the classification of economic indicators according to timing characteristics. Also, since program-determined and staff-selected dates are identical for all coinciding indicators, it must be presumed that the dating of reference cycles (which depends heavily on specific cycle turns in the coincident series) would not be substantially modified by the adoption of a programmed selection of turning points. However, the propensity of the program to pick up the relatively mild fluctuations, which characterize recent experience, affects measures of average cycle durations, overall amplitudes, and so forth.

APPLICATION TO REFERENCE TURNS

In the preceding section it was established that the classification of individual indicators into groups of leading, lagging, and coinciding measures would not be affected if turns were established by the programmed approach rather than by inspection. This, of course, does not imply that identical turns are selected by the two methods.

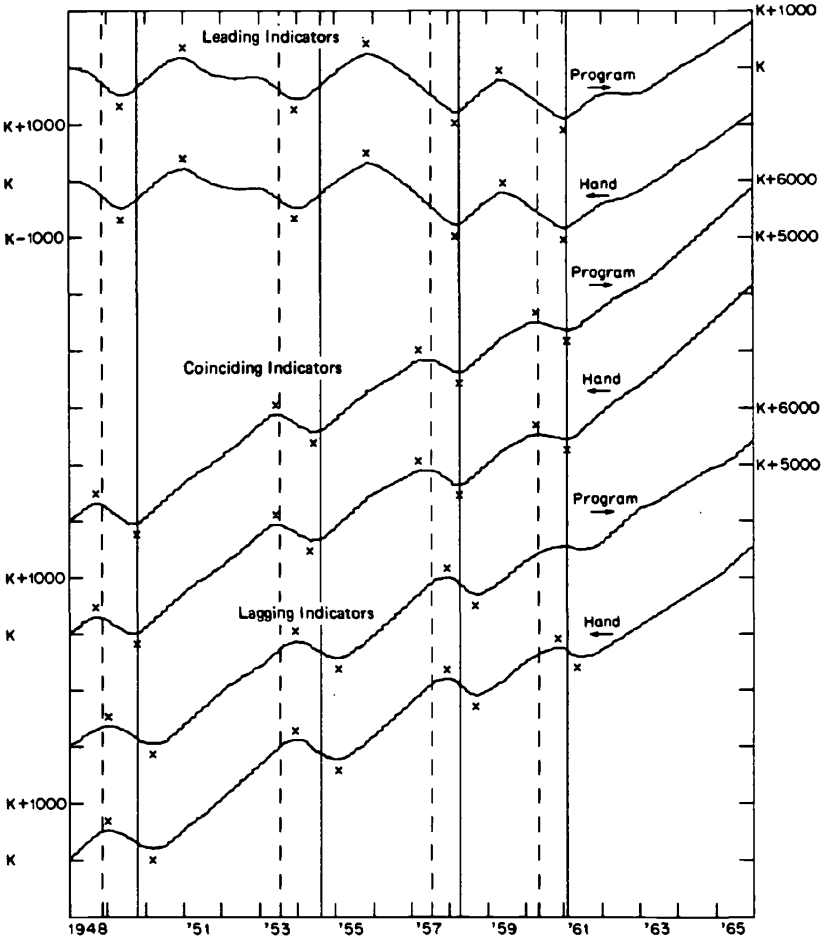
In this section we wish to establish whether and to what extent measures, such as cumulative historical diffusion indexes,[21] are affected by the substitution of program-determined turning points for staff-selected ones. A particularly important aspect of this question relates to summary measures of coinciding indicators, since their turns are strategic determinants of reference turning points, i.e., of the benchmark dates chosen to identify peaks and troughs in business activity at large. If it should turn out that cyclical turning points in cumulative diffusion indexes of coinciding indicators, based on program-determined specific turns, conform well with turns established by inspection, then the programmed approach may become a tool for reference turn determination. Finally, since the program tends to select more cycles than does the previous Bureau approach it would be interesting to establish whether these additional cycles—similar to cycles corresponding to those selected by inspection—are sufficiently synchronized to lead to recognizable swings in the cumulative diffusion indexes; and if so, whether these extra swings are related to known periods of business retardation.

The evidence is presented in Chart 5 and Table 5. The chart shows that, with the exception of one contraction, the two sets of cumulative

[21] Broadly defined, "diffusion" indexes for a group of time series consist of the percentage of these series which are increasing over a specified time span: they measure the degree to which the increases are diffused among the components. In "historical" diffusion indexes, all changes between the troughs and peaks of the component series are regarded as increases, all changes between peaks and troughs as decreases. This means that historical diffusion indexes describe the degree to which cyclical expansion phases prevail among components. For "cumulative" diffusion indexes the differences between the percentage of increasing series and 50 per cent are cumulated, on the theory that these differences reflect the degree of concomitance of upward movements and thus of upward thrust in the group as a whole. If the component series can be aggregated, turns of the simple diffusion indexes lead the corresponding turns of the aggregate and those of cumulative diffusing indexes tend to coincide with them. A basic discussion of the construction and behavior of diffusion indexes can be found in Chapters 2 and 8 of *Business Cycle Indicators*, Geoffrey H. Moore, ed., New York, Princeton University Press for NBER, 1961.

CHART 5

CUMULATIVE HISTORICAL DIFFUSION INDEXES BASED ON PROGRAM-SELECTED AND STAFF-SELECTED CYCLICAL TURNS IN THE COMPONENTS, 1948–65



Note: Broken vertical lines denote business cycle peaks; solid vertical lines denote business cycle troughs. Origin of vertical scale is arbitrary, since K may be any constant.

TABLE 5

TURNING POINTS IN CUMULATIVE HISTORICAL DIFFUSION INDEXES, BASED ON PROGRAM-SELECTED AND STAFF-SELECTED CYCLICAL TURNS OF COMPONENTS, 1948–65

Type of Turn	Business Cycle Dates	29 Leading Indicators		15 Roughly Coincident Indicators		7 Lagging Indicators	
		Staff-Selected	Program-Selected	Staff-Selected	Program-Selected	Staff-Selected	Program-Selected
P	Nov. 1948	—	—	Sept. 1948	Sept. 1948	Jan. 1949	Jan. 1949
T	Oct. 1949	May 1949	May 1949	Oct. 1949	Oct. 1949	Mar. 1950	Mar. 1950
P	July 1953	Jan. 1951	Jan. 1951	June 1953	June 1953	Dec. 1953	Dec. 1953
T	Aug. 1954	Dec. 1953	Dec. 1953	May 1954 *	June 1954 *	Feb. 1955	Feb. 1955
P	July 1957	Nov. 1955	Nov. 1955	Mar. 1957	Mar. 1957	Dec. 1957	Dec. 1957
T	Apr. 1958	Mar. 1958	Mar. 1958	Apr. 1958	Apr. 1958	Sept. 1958	Sept. 1958
P	May 1960	June 1959 *	May 1959 *	Apr. 1960	Apr. 1960	Nov. 1960	—
T	Feb. 1961	Jan. 1961	Jan. 1961	Feb. 1961	Feb. 1961	May 1961	—
LEADS (−), COINCIDENCES (0), AND LAGS (+), IN MONTHS, RELATIVE TO BUSINESS CYCLE TURNS							
P	Nov. 1948	—	—	−2	−2	+2	+2
T	Oct. 1949	−5	−5	0	0	+5	+5
P	July 1953	−30	−30	−1	−1	+5	+5
T	Aug. 1954	−8	−8	−3	−2	+6	+6
P	July 1957	−20	−20	−4	−4	+5	+5
T	Apr. 1958	−1	−1	0	0	+5	+5
P	May 1960	−11	−12	−1	−1	+6	—
T	Feb. 1961	−1	−1	0	0	+3	—

Note: For an explanation of the nature of cumulative historical diffusion indexes, see footnote 21. Asterisks denote a difference between the turning point dates chosen by the two methods.

diffusion indexes move closely together, exhibiting corresponding swings, similar amplitudes, and practically simultaneous timing. The one exception is the 1960–61 contraction in the lagging indicators, which is shown in the index based on staff-selected turns but is omitted in the index based on program-selected turns. Reference to Chart 4 shows that the difference is entirely due to turning point determination in two series (48 and 49). In these series the program does not select turns in 1960 and 1961. The declines during these years are minute and scarcely detectable on our chart.

Table 5 quantifies the relationship of cyclical turns in the two sets of indexes to those in general business activity. The upper panel contains the dates of these turns: only two out of twenty-one comparable turns occurred at different dates (see asterisks), and the differences never exceeded one month. The lower panel focuses on the timing relation of the diffusion index turns to those in business cycles. Note the consistency of signs for both sets of leading and of lagging indexes; most important, note the "practical coincidence" of the turns of cumulative diffusion indexes of coinciding indicators, whether computer based or not, with business cycle turns. That is, with one exception the peaks and troughs of the index either coincide exactly (three out of eight) or occur within three months of business cycle turns. The exception, a lead of four months, occurs at the July 1957 peak. This performance bolsters the hope that program-based cumulative diffusion indexes of coinciding indicators—though not necessarily of the fifteen indicators used above—may play an increasing, and perhaps decisive, role in the determination of business cycle turning points.

One question is whether it is possible to dispense with other evidence, such as amplitudes of cyclical swings and the economic importance of the activities reaching turns at particular dates. Also, the programmed method lends itself better to the identification of past business cycle turns than to the identification of current turns, since it requires evidence for four or more months after the occurrence of a cyclical turn in the component series. Nonprogrammed identification of current business cycle turns may possibly be more prompt. It can more readily make use of other evidence, such as the behavior of leading indicators, the sharpness of the turns, the character and comprehensiveness of specific activities, and the effect of impending events and policies.

There are other applications. The program permits, for example, turning point determination and construction of historical diffusion indexes for large groups of time series, such as sales and profits data of individual companies, or indicators of various economic activities in each of the fifty states. The program can also be used to measure cyclical divisions in levels and changes for business cycle analysis, trend analysis, and other purposes. In short, programmed determination of turning points opens the way for a variety of imaginative experiments.

SUGGESTIONS FOR FURTHER DEVELOPMENT

Experimentation with the programmed turning point selection raises certain issues that should be considered in the further development of the approach.

1. The program is sensitive to the accuracy with which the basic data are reported, that is, rounded data may yield fewer and different turns than do unrounded data. It should be feasible to standardize the input so that the number of digits used does not affect the number and location of specific cycles.

2. The twelve-month moving average, used as the basis for the determination of the presence of cycles, may obliterate shallow but cyclically significant phases in certain series. Conversely, it may transform irregular movements into cyclical patterns. If these tendencies are to be avoided, the smoothing term of the basic trend-cycle representation should bear some relation to the relative importance of irregular, as compared to systematic, movements.

3. The Spencer curve, with its graduated 15-point weight pattern (and negative weights at the ends) is not necessarily the most effective tool for present purposes. It may be fruitful to experiment with other weighting systems and perhaps with flexible weights.

4. The turning points near the ends of the series are frequently more uncertain than others. Some modifications of the approach may be considered. The span (now six months from each end) within which turns are not recognized could be extended. This type of constraint, which now operates only on the turning points of the final (unsmoothed) series, could also be imposed on some of the smoothed curves. Also, the present sequence of tests (first for acceptability of end values, then for cycle and phase durations) might be reversed, so that those turns that become first or last turns only through the re-

jection of end turns would not be subjected to tests designed for turns close to the ends of the series.

5. Present search ranges sometimes exclude values worthy of consideration as cyclical peaks or troughs. While extension of the ranges increases the danger of selecting noncyclical extremes as turns, there is no assurance that the present ranges are optimal. Experiments with alternative ranges might be desirable.

6. Since amplitude considerations are only implicit in the present procedure and in some of the above suggestions, the amplitude effects of these procedures and of contemplated changes should be kept under close review. An explicit amplitude criterion might also be devised and tested.

7. In view of the bias inherent in the use of a collection of well-conforming indicators as a test sample, it is desirable to test the approach on series that present special problems of turning point determination. This will improve our judgment regarding the effectiveness of the approach for economic activities at large.

It is not proposed that all of these suggestions should be evaluated on the basis of present experience. The effects of any specific change, and the interaction of several changes, are hard to foresee. What is needed is some well-organized accounting of the results of the present procedure after it has been more widely used and an evaluation of these results, based on well-defined criteria. When substantial additional knowledge has accumulated, major changes in the current approach might be contemplated.

APPENDIX TO CHAPTER 2

SAMPLE RUN, SELECTION OF CYCLICAL TURNING POINTS, BITUMINOUS COAL PRODUCTION

BITUMINOUS COAL PRODUCTION
100,000 NET TONS 1914 - 1938 01118

NBER TURNING POINT DETERMINATION FOR SERIES 01118

NUMBER OF MONTHS = 300

FIRST MONTH = 1914 1

MCD = 0 CONTROL LIMIT = 3.500

Output Table 2-1

BITUMINOUS COAL PRODUCTION
100,000 NET TONS 1914 - 1938

TIME SERIES DATA 01118

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1914	383.0	359.0	382.0	347.0	340.0	345.0	361.0	363.0	371.0	325.0	312.0	336.0
1915	351.0	329.0	324.0	349.0	325.0	347.0	356.0	359.0	387.0	384.0	430.0	463.0
1916	440.0	508.0	447.0	391.0	408.0	385.0	381.0	403.0	397.0	390.0	432.0	445.0
1917	453.0	465.0	489.0	487.0	496.0	478.0	463.0	447.0	425.0	420.0	459.0	444.0
1918	398.0	492.0	491.0	535.0	531.0	521.0	550.0	520.0	483.0	455.0	422.0	406.0
1938	270.0	261.0	252.0	280.0	254.0	262.0	269.0	296.0	317.0	299.0	329.0	329.0

Output Table 2-2

SPENCER CURVE, NO SUBSTITUTIONS 01118

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1914	370.3	367.0	361.9	357.3	354.6	353.6	353.3	351.7	347.3	341.6	336.3	332.5
1915	331.4	332.0	333.2	334.9	338.1	343.7	352.5	365.7	383.7	405.4	427.9	446.9
1916	456.9	454.8	442.7	424.6	406.2	393.2	387.9	389.4	396.9	409.0	423.3	439.5
1917	456.2	470.8	481.5	486.2	483.6	475.1	462.6	449.1	438.1	431.7	431.3	438.4
1918	452.7	472.1	494.7	515.5	520.9	534.4	527.9	511.3	487.1	459.0	430.5	405.0
1938	291.8	274.0	262.4	258.0	260.3	267.4	278.1	290.4	302.5	312.7	319.3	322.4

MEAN OF RATIOS TO SPENCER CURVE= 99.91 STD.DEV. = 7.853

EXTREME OBSERVATIONS AND THEIR SUBSTITUTES

71	1919	11	183.0	387.4
99	1922	3	490.0	336.8
100	1922	4	201.0	305.1

Output Table 2-3

BITUMINOUS COAL PRODUCTION
100.000 NET TONS 1914 - 1938

12 MONTHS MOVING AVERAGE 01118

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1914	359.3	359.5	360.0	361.2	357.6	353.4	352.0	349.3	346.8	342.0	342.1	340.9
1915	341.0	340.6	340.3	341.6	346.5	356.4	367.0	374.4	389.3	399.5	403.0	410.0
1916	413.1	415.2	418.9	419.7	420.2	420.4	418.9	420.0	416.4	419.9	427.9	435.2
1917	443.0	449.C	453.5	455.8	458.3	460.5	460.5	455.9	458.1	458.3	462.3	465.2
1918	468.8	476.0	482.1	487.0	489.9	486.8	483.6	483.6	472.7	461.0	448.0	437.3
1938	309.4	300.9	296.2	290.4	286.1	285.4	284.8	286.1	288.6	292.7	294.3	300.1

Output Table 2-4

4 MONTHS MOVING AVERAGE 01118

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1914	367.7	367.7	367.7	357.0	353.5	348.2	352.2	360.0	355.0	342.7	336.0	331.0
1915	332.0	335.0	338.2	331.7	336.2	344.2	346.7	362.2	371.5	390.0	416.0	429.2
1916	460.2	464.5	446.5	438.5	407.7	391.2	394.2	391.5	392.7	405.5	416.0	430.0
1917	448.7	463.0	473.5	484.2	487.5	481.0	471.0	453.2	438.7	437.7	437.0	430.2
1918	448.2	456.2	479.0	512.2	519.5	534.2	530.5	518.5	502.0	470.0	441.5	420.2
1938	301.2	280.0	265.7	261.7	262.0	266.2	270.2	286.0	295.2	310.2		

Output Table 2-5

TENTATIVE TURNING POINTS. 12 MONTHS MOVING AVERAGE
TENTATIVE PEAKS

	OBS	YEAR	MO	VALUE
1	4	1914	4	361.2
2	53	1918	5	489.9
3	79	1920	7	472.7
4	113	1923	5	484.0
5	154	1926	10	496.6
6	187	1929	7	447.5
7	241	1934	1	308.4
8	280	1937	4	383.7

TENTATIVE TROUGHS

	OBS	YEAR	MO	VALUE
1	15	1915	3	340.3
2	33	1916	9	416.4
3	67	1919	7	403.0
4	99	1922	3	315.1
5	130	1924	10	390.3
6	167	1927	11	399.9
7	227	1932	11	247.4
8	244	1934	4	296.5
9	256	1935	4	300.6
10	295	1938	7	284.8

REJECTIONS

	PEAKS	TROUGHS
MULTIPLE PEAKS OR TROUGHS		33 1916 9 416.4
MULTIPLE PEAKS OR TROUGHS		256 1935 4 300.6

Output Table 2-6

BITUMINOUS COAL PRODUCTION
100.000 NET TONS 1914 - 1938 01118

TENTATIVE TURNING POINTS. SPENCER CURVE B

TROUGHS			PEAKS		
			1914	3	362.
1915	1	331.	1918	6	534.
1919	3	370.	1920	10	486.
1922	6	263.	1923	6	543.
1924	6	377.	1927	1	513.
1927	11	381.	1929	7	464.
1932	6	227.	1934	4	321.
1934	9	279.	1937	1	403.
1938	4	258.			

TEST FOR MINIMUM DURATION OF 15 MONTHS

NO EXCLUSIONS

Output Table 2-7

TURNING POINTS. 4 MONTHS MOVING AVERAGE

TROUGHS			PEAKS		
			1914	3	368.
1914	12	331.	1918	6	534.
1919	3	372.	1920	11	495.
1922	6	230.	1923	6	549.
1924	7	376.	1927	2	518.
1927	12	376.	1929	6	469.
1932	7	218.	1934	4	326.
1934	10	281.	1937	2	418.
1938	4	261.			

Output Table 2-8

BITUMINOUS COAL PRODUCTION
100.000 NET TONS 1914 - 1938 01118

TENTATIVE TURNING POINTS. TIME SERIES

TROUGHS			PEAKS		
			1914	3	382.
1914	11	312.	1918	7	550.
1919	3	350.	1920	12	538.
1922	4	201.	1923	5	568.
1924	6	366.	1927	3	565.
1927	12	370.	1929	5	487.
1932	7	208.	1934	3	363.
1934	9	274.	1937	3	490.
1938	3	252.			

1914 3 382.0 1914 1 383.0 ELIMINATE TURN

TEST FOR MINIMUM DURATION OF 15 MONTHS

NO EXCLUSIONS

FINAL TURNING POINTS. TIME SERIES

TROUGHS			PEAKS		
1914	11	312.	1918	7	550.
1919	3	350.	1920	12	538.
1922	4	201.	1923	5	568.
1924	6	366.	1927	3	565.
1927	12	370.	1929	5	487.
1932	7	208.	1934	3	363.
1934	9	274.	1937	3	490.
1938	3	252.			