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V. THE ELECTRONIC COMPUTER PROGRAM

An electronic computer program for adjusting seasonal and irregular time series to a form that shows primarily the cyclical movements has been developed and tested. This program also reveals the seasonal pattern of the series, describes the course of its irregular fluctuations, and computes many summary measures. It can be applied to any kind of time series—for important economic indicators, for employment in a geographic area, for the sales of a company—whatever the degree of irregularity and seasonality. The program is designed for monthly data but can readily be applied to quarterly data.

The program first corrects the original observations for differences in the number of working or trading days in each month. It next adjusts the series for seasonal variations by an improved version of a familiar method. Then it irons out the irregular movements so that all series are equally smooth and so that their month-to-month movements are primarily cyclical. In the process, some familiar and some new measures of economic fluctuations are computed.

to taking a 12-months moving total of the data and using the first differences of this moving total instead of the raw data. The procedure which consists of *dividing* the quotation for the present month by the quotation for the same month last year amounts to using the antilogarithms of the first differences of a 12-months moving total of the logarithms of the data—instead of the raw data.

"In either case the results are based upon month to month changes (first differences) of a crude graduation, namely, a 12-months moving average. . . . Moreover, as the 12-months moving average does not extend to the end of the data, its first differences do not tell whether, at the present time, the underlying curve of the data is high or low or whether it is rising or falling, but simply *whether it was rising or falling six months ago*" (see Frederick R. Macaulay, *The Smoothing of Time Series* [New York: National Bureau of Economic Research, 1931], pp. 134–35).

This program has been used by many government agencies during the past few years—for about three thousand economic series altogether. It has been thoroughly tested experimentally and in practice.[5] Improvements can be and are continually being introduced as methods of making them become clear. A full run of this program, for a ten-year monthly series, requires less than 5 minutes on a large-scale computer of the Univac class. A detailed listing of all the computational steps in this program and a sample print-out of the final tables are given in Appendix A. In what follows we shall describe the program in general terms and show how it helps in analyzing selected business indicators.

a) ELIMINATING SEASONAL VARIATIONS

Cyclical movements are shown more accurately and stand out more clearly in data that are seasonally adjusted. As we have seen, seasonally adjusted data not only avoid some of the biases to which same-month-year-ago comparisons are subject but also often reveal cyclical changes several months earlier. Seasonal adjustments, therefore, help the business statistician to make more accurate and more prompt diagnoses of the current economic situation. A businessman who uses seasonally adjusted series in lieu of same-month-year-ago comparisons will be in a position to note changing trends in his industry months before his less

[5] These tests are described in two more technical reports: Julius Shiskin and Harry Eisenpress, "Seasonal Adjustments by Electronic Computer Methods," to be published in the December, 1957, issue of the *Journal of the American Statistical Association* and as Technical Paper No. 12 in the National Bureau series; and Shiskin, "Problems in the Seasonal Adjustment of Economic Indicators—a Progress Report," paper presented at a meeting of the American Statistical Association, in Atlantic City, September 10, 1957. Other tests are also under way; these will be described in later reports.

statistically sophisticated competitor will. As a general-purpose aid both in historical studies of the business cycle and in studies of current economic trends, seasonal adjustments rank second only to the provision of the raw observations themselves.

The third panel of Chart IV shows the five economic indicators in seasonally adjusted form. Although the fluctuations are still marked by irregular movements and the curves do not follow patterns that can be neatly described by mathematical equations, the cyclical movements are relatively clear. The series all rose more or less steadily throughout 1936, they reached peaks late in 1936 or in 1937, they then declined for about a year and then rose throughout 1939. Furthermore, the timing relations among these series are fairly clear; the turning points in residential building contracts and business failures precede those in unemployment and freight carloadings, and these in turn led retail sales at the peak, though not at the trough. Similar observations can be made about their movements during the milder 1953–54 contraction. Irregular fluctuations still becloud the course of the business cycle, but much of the mist has been swept away.[6]

There are many different methods of adjusting time series for seasonal variations. All are, however, based on the fundamental idea that seasonal fluctuations can be measured and separated from the trend, cyclical, and irregular fluctuations. The task is to estimate the seasonal factor and to eliminate it from the original observations by either subtraction or division or some combination of the two.

All common methods of seasonal adjustment follow this simple logic, including such familiar methods as the monthly-means, the link-relative, and the ratio-to-moving-average methods. The monthly-means and the link-relative methods were among the first developed; they are simple to compute, but they give crude results. The ratio-to-moving-average method has the advantages of more precise measurement of the components and greater flexibility. In addition, it permits analysis of each of the successive stages in the seasonal adjustment process. For these reasons it has been adopted by almost all groups engaged in large-scale seasonal adjustment work, despite the fact that it is relatively laborious.

The ratio-to-moving-average method first obtains an estimate of the trend and cyclical factors by the use of a simple moving average which combines twelve successive monthly figures, thereby eliminating the seasonal fluctuations. Such a moving average is known as a "trend-cycle curve," since it contains virtually all the trend and cycle and little or none of the seasonal and irregular movements in the data. Division of the raw data by the moving average yields a series of seasonal-irregular ratios. An estimate of the seasonal adjustment factors is then secured by averaging the seasonal-irregular ratios, month by month, and assuming that the irregular factor will be canceled out in the averaging process. Finally, the original observations are seasonally adjusted by dividing them by the seasonal adjustment factors.

Important improvements introduced in the ratio-to-moving-average method have included moving seasonal adjustment factors and smoother and more

[6] For other illustrations of how seasonal adjustments are helpful in studying cyclical movements and for an instructive discussion of this problem see Arthur F. Burns and Wesley C. Mitchell, *Measuring Business Cycles* (New York: National Bureau of Economic Research, 1946), pp. 43–55.

flexible trend-cycle curves. Moving seasonal adjustment factors have generally been approximated by smooth curves fitted freehand to the seasonal-irregular ratios for each month. Improved trend-cycle curves have been obtained by fitting smoother curves, also freehand, to preliminary seasonally adjusted series, using their twelve-month moving averages as guides.

A new and improved version of the ratio-to-moving-average method of seasonal adjustment has been included as part of the electronic computer program. The new method, Census Method II, takes advantage of the electronic computer's high-speed, low-cost computations; it utilizes more powerful and refined techniques than widely used clerical methods do and produces more information about each series. The principal features are summarized below, not with the expectation that the reader will follow them in detail, but to indicate the power and generality of the new method, as well as its limitations.

The new method computes a preliminary seasonally adjusted series following primarily the conventional ratio-to-moving-average technique. It starts in the usual way: ratios are computed by dividing the original observations by a twelve-month moving average; moving seasonal adjustment factors are computed from these ratios; and a preliminary seasonally adjusted series is obtained by dividing these preliminary seasonal adjustment factors into the original observations.

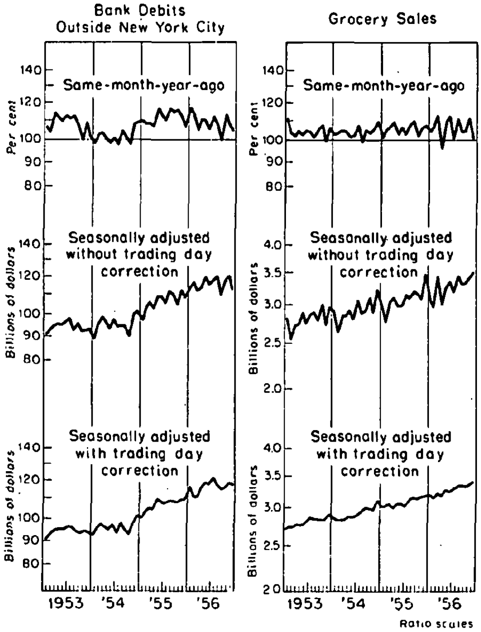
Method II then goes on to refine these results. It utilizes a complex graduation formula—a weighted fifteen-month moving average—as the estimate of the trend-cycle curve used to obtain the final seasonally adjusted series. For most series this formula yields a curve that is flexible, follows the data closely, and gives a smooth representation of the trend-cycle components. The method then utilizes a control-chart procedure to identify extreme items among the seasonal-irregular ratios and systematically reduces their weight for the subsequent computations. For each month, control limits of two standard errors are determined above and below a five-term moving average fitted to the seasonal-irregular ratios. Any ratio falling outside the limits is designated as "extreme" and is replaced by the average of the "extreme" ratio and the ratios immediately preceding and following. The new method employs weighted moving averages of the seasonal-irregular ratios for each month to obtain the seasonal adjustment factors —for example, a three-term moving average of a three-term moving average, which is equivalent to a five-term moving average with the weights 1, 2, 3, 2, 1.

Census Method II utilizes a measure of the irregular component of each series to determine the type of moving average to fit to the seasonal-irregular ratios. The larger the irregular component, the larger the amount of smoothing that is required. Alternative graduation formulas, appropriate for the different magnitudes of the irregular component in various series, are placed in the computer "memory" and automatically selected according to the average monthly amplitude of the irregular fluctuations.

The new method takes into account changing trends in calculating seasonal adjustment factors for the first and last few years of each series. Instead of following the usual procedure of extrapolating the seasonal adjustment factor curve to the end of the series, this method takes an average of the last two seasonal-irregular ratios for a given month as the estimated value of each of the following two or three ratios. These estimates are then used in computing the two seasonal factors that would otherwise be missing at the end of the series. A similar procedure is used to obtain missing values for computing the ends of the trend-cycle curve.[7] This program also computes seasonal factors for each of the twelve months ahead. Suppose the program is run for a series ending in December, 1957. Then seasonal factors for each of the twelve

CHART V

THE EFFECT OF TRADING-DAY ADJUSTMENTS
1953–56



months of 1958 would also be shown (see Appendix A, Table 12). These factors are computed by adding to the factors for the last year one-half the trend between the previous year and that year.[8] Tests indicate that this method is better than the use of the seasonal factors for the last year without a trend allowance.[9] Such factors may be helpful in keeping seasonally adjusted series up to date as new raw data become available each month; periodically, however, the seasonal factors should be revised on the basis of the new data.

The seasonal adjustments shown in the third panel of Chart IV were all made on an electronic computer by this method.

b) WORKING- AND TRADING-DAY ADJUSTMENTS

Variations in levels of activity between the same months of different years take place in part because of differences in the number of working or trading days in the same months. For example, there were five Saturdays and five Sundays in September, 1956, and only four each in September, 1955. Many types of economic activity are affected by such variations, particularly those in which there is a disproportionately large volume of activity on Saturdays, such as retail trade and personal services.

The effect of such calendrical variations is illustrated in Chart V, which shows bank debits and sales of grocery stores in various forms: (1) same-month-year-ago comparisons of the original observations, (2) seasonally adjusted data, and (3) seasonally adjusted data with a simple adjustment for the number of trading days. The trading-day adjustment is made by dividing the original series by the number of trading days, month by month.[10] Note that the same-

[7] For a detailed description of the seasonal methods referred to here see Julius Shiskin, "Seasonal Computations on Univac," *American Statistician*, February, 1955, pp. 19–23, and Shiskin and Eisenpress, *op. cit.* The summary given here is adapted from these papers.

[8] Here we follow a suggestion by W. A. Beckett, of the Department of Trade and Commerce of Canada.

[9] For a description of these tests see Shiskin, "Problems in the Seasonal Adjustment of Economic Indicators—a Progress Report."

[10] Where the volume of activity cannot be assumed to be directly proportional to the number of

month-year-ago comparisons of the original observations for bank debits in September, 1956, indicate a decline from the preceding year, the first such decline since 1954. The seasonally adjusted data also show a moderate decline, sufficient to bring the September figure down to the level of the preceding September. But when adjustment is made both for seasonal variations and for the extra Saturday and Sunday in September, 1956, the figure turns out to be substantially higher than in the preceding year and much more nearly in line with preceding and following months.

The effects of a trading-day adjustment are even more strikingly illustrated by the series on sales of grocery stores from 1953 to 1956. The seasonally adjusted series makes up a very choppy line with an underlying upward trend. The choppiness is almost entirely eliminated by the trading-day adjustment, which yields a fairly smooth curve. It becomes clear that the purchase of groceries has been rising steadily, with most of the apparent variation due to differences in the number of days the stores were open each month and in the consumers' preferences for buying more during certain days of the week.

The electronic computer program provides for working- or trading-day corrections where they are needed. These correction factors must be made available, however, along with the raw data; there is no technique built into the electronic computer program for estimating such factors.

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working days (e.g., retail sales), a special adjustment technique must be used. Similar adjustments can be made for holidays which occur on different days of the week (e.g., Independence Day) or different periods of the month (e.g., Easter) (see Harry Eisenpress, "Regression Techniques Applied to Seasonal Corrections and Adjustments for Calendar Shifts," *Journal of the American Statistical Association*, LI, No. 276 [December, 1956], 615–20).

c) IRONING OUT IRREGULAR FLUCTUATIONS

Now what kind of allowance can we make, implicit or explicit, for the irregular factor? Since it is irregular, a technique similar to that adopted for seasonal fluctuations cannot be followed.

Eventually, the irregular fluctuations in economic data may be less troublesome than at present. First, there will probably be a gradual reduction in the errors of measurement. Second, we may be able to measure and make statistical adjustments for some of the factors that create irregular movements—for example, unusual variations in the weather. While present methods for treating the irregular factor are less satisfactory than for the seasonal factor, some useful things can be done. We can compute measures of the average month-to-month amplitude of the irregular component and the ratio of this amplitude to the corresponding amplitude of the cyclical component, and we can determine the number of months that must go by before the cyclical factor, which is cumulative in the short run, dominates the irregular factor, which is not cumulative. These measures provide a notion of the extent to which month-to-month movements in seasonally adjusted series can be taken to reflect cyclical movements and about when it is safe to say that a change is cyclical.

We have already described how the seasonal factor is isolated and how the raw data are adjusted for this factor. The smooth curve used to obtain the estimate of the cyclical factor in the seasonal adjustment technique (a weighted fifteen-term graduation formula) is also fitted to the final seasonally adjusted series. This curve smooths out the irregular fluctuations and is taken as the estimate of the cyclical factor. When it is divided into the seasonally adjusted series, the resulting series represents the irregular factor alone.

1. *Summary measures.*—A group of summary measures of the irregular, seasonal, and cyclical components and the relations among them is then computed. The first measure is the average month-to-month amplitude in the irregular factor, $\bar{I}$. It is computed by averaging the monthly percentage changes in the irregular factor without regard to sign. Similarly, the average monthly amplitude of the cyclical factor, $\bar{C}$, is obtained by averaging the month-to-month percentage change in the cyclical factor without regard to sign. And the average monthly amplitude of the seasonal factor, $\bar{S}$, is obtained by averaging the month-to-month percentage changes without regard to sign in the seasonal factor curve. These measures and the relations among them are shown for eighteen important monthly economic indicators in Table 2.[11]

Ratios of the average amplitudes of the irregular to the cyclical factors are computed for one-, two-, three-month, and longer spans. For the one-month span the computation is based on the percentage changes January to February, February to March, etc.; for the two-month span the percentage changes are computed for January to March, February to April, etc.; for the three-month span, the percentage changes are computed for January to April, February to May, etc.; and so on. Tests show that the magnitude of the irregular amplitude remains about the same regardless of the span, while the cyclical amplitude cumulates uninterruptedly as the span increases.[12] The number of months necessary for this ratio to fall below 1 may, therefore, be taken as an index of the months required for cyclical dominance, on the average. This index is identified by the symbol *MCD* (Months for Cyclical Dominance); thus *MCD* is 3 for the manufacturers' new-orders series and 1 for the index of industrial production. These measures are shown for the eighteen monthly indicators in Table 3.

These measures show that cyclical movements are typically smaller on a month-to-month basis than seasonal and irregular movements. Table 2 indicates clearly that on this basis the seasonal factor has been dominant in many important series during the postwar period,

[11] The raw data, the seasonally adjusted data, the *MCD* span moving averages, and the Univac seasonal adjustment factors for these eighteen series are given in Appendix B for 1956. The official seasonal factors, estimated seasonal factors 1 year ahead, and the sources of the raw data are also given. These series are eighteen of twenty-one selected by Geoffrey H. Moore as consistent indicators of cyclical revivals and recessions. Three series (corporate profits, gross national product, and bank interest rates) are omitted because they are quarterly (see Geoffrey H. Moore, *Statistical Indicators of Cyclical Revivals and Recessions* ["National Bureau of Economic Research, Occasional Papers," No. 31 (1950)], esp. pp. 63–77).

[12] If this were precisely true, one would expect the two-month span computation to yield an $\bar{I}/\bar{C}$ ratio half as large as that for the one-month span; the three-month span to yield a ratio one-third as large; etc. Inspection of Table 3 shows that this holds true approximately. The average $\bar{I}/\bar{C}$ ratios for all eighteen indicators, and the expected ratios estimated from the average for the one-month span are as follows:

	Actual	Expected
One-month span	1.98	....
Two-month span	1.04	0.99
Three-month span	0.61	.63
Four-month span	0.52	.49
Five-month span	0.39	.39
Six-month span	0.31	.33
Nine-month span	0.22	.22
Twelve-month span	0.21	0.16

Hence one can estimate fairly closely the span required to reduce the $\bar{I}/\bar{C}$ ratio to any desired level from the value of the ratio for any given span. Moreover, since the electronic computer program does not calculate $\bar{I}/\bar{C}$ ratios for spans greater than five months, this relationship may be used to estimate average $\bar{I}/\bar{C}$ values beyond this range and hence to determine *MCD* spans for highly irregular series.

and similar data show its dominance during earlier periods. In thirteen of the eighteen economic indicators, the average monthly change of the seasonal factor is larger than that of the cyclical factor. Only in the price indexes does the cyclical factor generally dominate the seasonal. Next in magnitude is the irregular factor, which is larger than the month-to-month basis, we are very often most interested in the behavior of the smallest in a composite of three variables. For this reason, especially great care is required to isolate the cyclical movements.

Let us consider these measures for two key economic indicators. The average month-to-month irregular amplitude in

TABLE 2

AVERAGE MONTHLY AMPLITUDES OF THE IRREGULAR, CYCLICAL, AND SEASONAL COMPONENTS AND THEIR RELATIONS, EIGHTEEN MONTHLY ECONOMIC INDICATORS, 1947–56*

Series	Seasonally Adjusted ($\overline{CI}$)	Irregular ($\bar{I}$)	Cyclical ($\bar{C}$)	Seasonal ($\bar{S}$)	$\bar{I}/\bar{C}$	$\bar{I}/\bar{S}$	$\bar{S}/\bar{C}$
Leading:							
Business failures, liabilities	16.2	15.3	3.2	9.6	4.8	1.6	3.0
Industrial stock prices	2.0	1.5	1.2	1.1	1.2	1.4	0.9
New orders, durable manufactures	5.3	4.6	2.1	6.3	2.2	0.7	3.0
Residential building contracts	8.3	7.8	2.7	11.3	2.9	0.7	4.2
Com. and indus. building contracts	13.7	13.0	3.0	10.8	4.3	1.2	3.6
Hours worked, manufacturing	0.4	0.3	0.2	0.6	1.7	0.6	2.7
New incorporations, number	4.3	4.0	1.3	8.4	3.2	0.5	6.7
Wholesale prices, basic commodities	2.2	1.4	1.3	1.2	1.1	1.1	1.0
Coincident:							
Non-agricultural employment	0.4	0.2	0.3	0.8	0.8	0.3	2.7
Unemployment, total	5.4	3.9	3.0	9.3	1.3	0.4	3.1
Bank debits, outside New York City	3.1	3.0	0.8	6.1	3.8	0.5	7.7
Freight carloadings	3.5	3.2	1.2	5.0	2.7	0.6	4.2
Industrial production	1.1	0.7	0.7	2.3	0.9	0.3	3.0
Non-farm wholesale prices, excl. foods	0.5	0.2	0.4	0.2	0.4	0.7	0.6
Lagging:							
Personal income	0.8	0.6	0.6	4.5	1.0	0.1	7.8
Retail sales	1.9	1.7	0.6	6.5	2.9	0.3	11.3
Instalment credit outstanding	1.8	0.3	1.7	0.8	0.2	0.4	0.5
Inventories of manufacturers	0.9	0.3	0.9	0.4	0.3	0.7	0.4

* $\bar{I}$ = Average month-to-month percentage change without regard to sign in irregular component; $\bar{C}$ = The same for the cycle-trend component, and $\bar{S}$ = The same for the seasonal component.

Neither all the values of the average amplitudes nor all the deviations from 1 in the ratios are statistically significant. For example, there is probably no seasonal pattern in stock prices, yet the average seasonal amplitude is shown as 1.1 per cent. Statistically significant values for these measures have not yet been determined.

cyclical factor in twelve of the eighteen series. The measures shown in Table 3 suggest that it often takes three or more months for the cyclical factor to cumulate to a magnitude greater than the irregular; this is true in eight of the eighteen series. Furthermore, the average changes of these three factors are highly correlated; that is, in series for which the cycle is large, the seasonal and irregular factors are also large. Thus, in making judgments about the business cycle on a manufacturers' new orders of durable goods is 4.6 per cent, the average cyclical amplitude is 2.1, and their ratio is 2.2 (Table 2). The corresponding ratio for a two-month comparison is 1.2 and for a three-month comparison 0.7 (Table 3). Thus comparisons in seasonally adjusted data over a three-month period are required for the cyclical component to dominate the irregular, and in this interval the cyclical changes exceed the irregular by almost 40 per cent, on the average. This information suggests that we should not give much weight to the month-to-month percentage changes for this series but that comparisons made over three-month periods are substantially more reliable for current business-cycle studies. On the other hand, the corresponding figures for the Federal Reserve index of industrial production (irregular, 0.69; cyclical, 0.74; percentage ratio of irregular to cyclical, 0.93; and *MCD*, 1) suggest that in this series even month-to-month movements are dominated by the cyclical factor, on the average.

2. *MCD span moving averages.*—Comparisons of the differences between figures a specified number of months apart are also shown by simple moving averages. For example, an unweighted three-month moving average is calculated by summing the figures for the first three months, then adding the fourth month and dropping the first, adding the fifth month and dropping the second, and so on (in each case the sum is, of course,

TABLE 3*

IRREGULAR-CYCLICAL RATIOS FOR DIFFERENT MONTHLY SPANS, NUMBER OF MONTHS REQUIRED FOR CYCLICAL DOMINANCE, AND AVERAGE LEADS AND LAGS, EIGHTEEN MONTHLY ECONOMIC INDICATORS, 1947–56

Series	Months Span 1	2	3	4	5	Months Required for Cyclical Dominance (*MCD*)	Average Lead (−) or Lag (+) in Months: At Peaks	At Troughs
Leading:								
Business failures, liabilities	4.78	2.39	1.59	1.21	1.04	6	−10.5	−7.5
Industrial stock prices	1.24	0.73	0.46	0.32	0.22	2	− 6.0	−7.2
New orders, durable manufactures	2.19	1.21	0.73	0.57	0.39	3	− 6.9	−4.7
Residential building contracts	2.87	1.47	0.90	0.76	0.64	3	− 6.2	−4.5
Com. and indus. building contracts	4.31	1.99	1.40	1.06	0.82	5	− 5.2	−1.7
Hours worked, manufacturing	1.70	0.88	0.58	0.43	0.38	2	− 3.8	−2.6
New business incorporations, number	3.18	1.58	0.69	0.87	0.55	3	− 2.5	−3.5
Wholesale prices, basic commodities	1.07	0.69	0.47	0.33	0.23	2	− 2.6	−3.2
Coincident:								
Non-agricultural employment	0.76	0.46	0.27	0.17	0.15	1	− 0.2	−3.3
Unemployment, total	1.30	0.76	0.50	0.39	0.27	2	n.a.†	n.a.
Bank debits, outside New York City	3.76	1.72	0.79	0.90	0.56	3	+ 2.0	−4.3
Freight carloadings	2.73	1.42	0.85	0.69	0.63	3	− 0.3	−1.3
Industrial production	0.93	0.51	0.35	0.24	0.21	1	+ 0.6	−2.2
Non-farm wholesale prices, excl. foods	0.40	0.27	0.17	0.11	0.09	1	− 3.5	+3.7
Lagging:								
Personal income	0.97	0.55	0.36	0.23	0.20	1	+ 4.0	−0.2
Retail sales	2.88	1.56	0.98	0.82	0.54	3	+ 3.8	+1.8
Instalment credit outstanding	0.18	0.12	0.09	0.07	0.05	1	+ 5.0	+3.5
Inventories of manufacturers	0.30	0.20	0.14	0.11	0.08	1	+ 6.5	+7.5

* Percentage ratios of the average monthly amplitudes of the irregular and cyclical factors are computed for consecutive months (January–February, February–March, etc.), two-month spans (January–March, February–April, etc.), three-month spans (January–April, February–May, etc.), and so on. "Months Required for Cyclical Dominance" is the first interval of months for which the average amplitude of the cyclical factor is less than that of the irregular factor and remains so. Amplitudes are not routinely computed for spans exceeding five months.

For an explanation of the average leads and lags for these series see Geoffrey H. Moore, *Statistical Indicators of Cyclical Revivals and Recessions* ("National Bureau of Economic Research Occasional Papers," No. 31 [1950]), pp. 64–65. These measures are not computed as part of the electronic computer program.

† Not available.

divided by 3). Therefore, a three-month moving average will change according to the differences between the figures separated by three months (counting from mid-month to mid-month), e.g., January–April, February–May, etc. Similarly, a four-month moving average will change with the differences between the figures separated by four months, a five-month moving average by figures separated by five months, and so on. Thus changes in simple moving averages are equivalent to differences between figures for months separated by an interval equal to the period of the moving average. These relations suggest that a moving average of a seasonally adjusted series calculated for the period equal to *MCD* would show primarily changes in the cyclical factor.

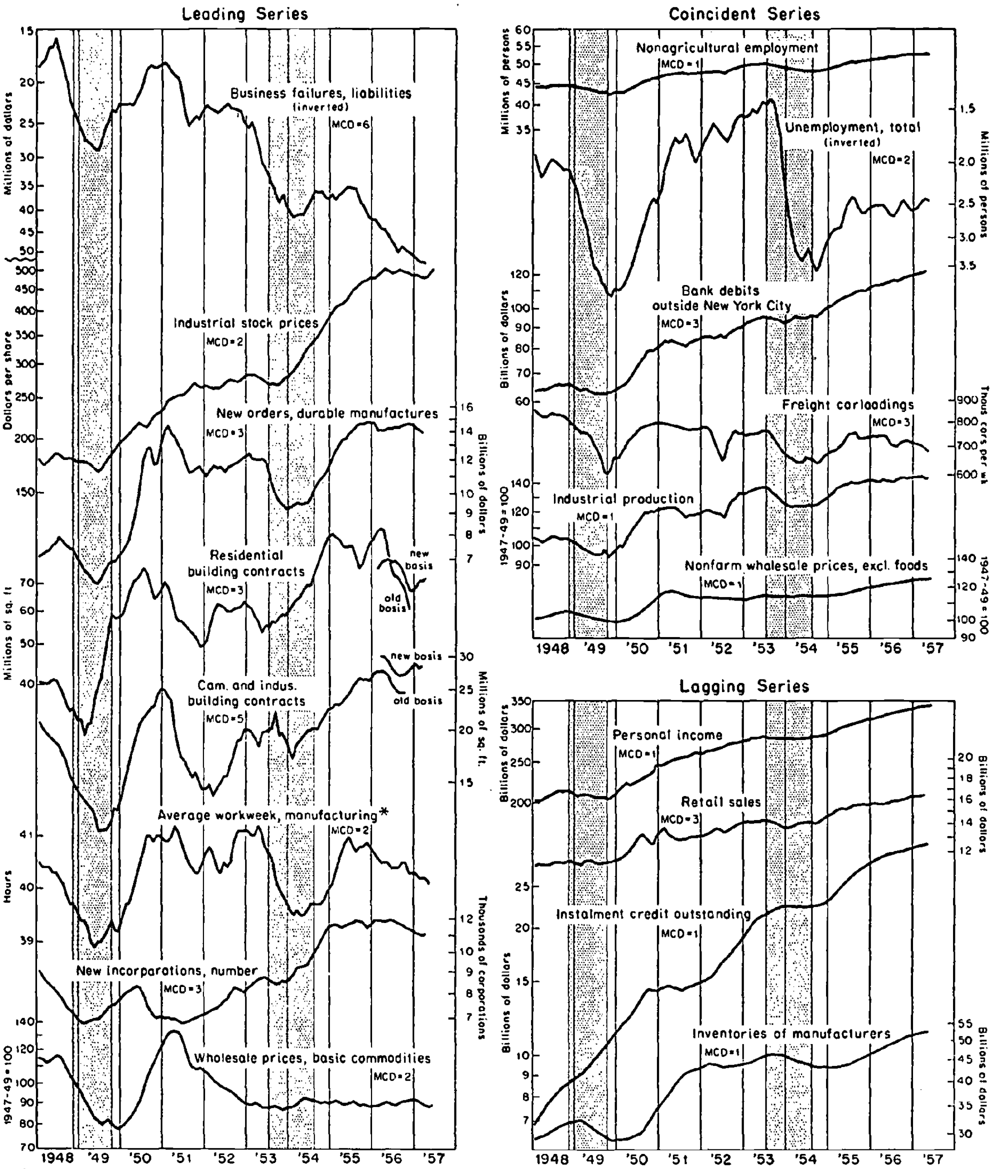
The month-to-month movements of many economic indicators in their seasonally adjusted form contain a fairly large irregular factor, as pointed out earlier. Our measure, $\bar{I}/\bar{C}$, the irregular factor divided by the cyclical factor, shows that the irregular factor is usually larger than the cyclical factor on a month to-month basis. In the eight leading series, those that are particularly useful as early indicators of cyclical revivals and recessions, the irregular factor is relatively largest; in every series it is larger than the cyclical factor, and it is usually more than twice as large. The dominance of the irregular factor makes it difficult to trace the cyclical movements in the seasonally adjusted series and especially to date turning points.

The relative magnitudes of the irregular factor and the cyclical factor are reversed in the short-term moving averages automatically selected and computed by the electronic computer program. These short-term moving averages are of varying periods; in each the period is equal to the number of months required for the cyclical factor to dominate the irregular factor, and the $\bar{I}/\bar{C}$ ratios for the spans measured by these moving averages show this to be true: they are all less than 1 (Table 4, seventh col.). Thus the month-to-month movements in these moving averages are primarily cyclical, in contrast to the primarily irregular month-to-month movements of the seasonally adjusted series. When the general sweep of these moving average series is considered, then the dominance of the cyclical movements is overwhelming, and the cycles stand out clearly, as can be seen in Chart VI.

Longer-period moving averages might show the cyclical factor even more clearly, and from this point of view the weighted fifteen-term moving average used earlier in the electronic computer program as the estimate of the cyclical factor would usually be satisfactory. But all moving averages suffer from the handicap that they do not reach to the current month. Since they are centered at the middle month of the interval covered by the average, there are no values for the last month(s). Long-term moving averages lose so many months that their usefulness in current economic analysis is greatly diminished, as we observed in connection with the same-month-year-ago comparisons, which are equivalent to changes in twelve-month moving averages. Thus our weighted fifteen-term moving average is always seven months behind the current date. Furthermore, changes over a span of months may skip over a cyclical turn in the series and hence show a rise when the series is currently declining, or vice versa. The longer the span, the more likely is this possible error in identifying the current trend.

CHART VI

Short-Term Moving Averages of Eighteen Business Indicators, 1948–57



* Arithmetic scale

Shaded areas represent contractions of business cycles, according to NBER chronology

Ratio scales

On the other hand, short spans may lead to errors of another type, as when an irregular turn is identified as cyclical and is shortly reversed. Use of a span equal to *MCD* appears to be a reasonable compromise that avoids many errors of either type.[13]

This point may be stated somewhat more precisely. *MCD* is taken for the first comparison for which the $\bar{I}/\bar{C}$ ratio is less than 1 and remains so. This is, to some extent, arbitrary. To begin with, when this ratio falls below 1, it will not always be significantly below 1 in the statistical sense. An advance will have been made when levels of significance have been determined for $\bar{I}$, $\bar{C}$, $\bar{S}$, and their ratios. But, in addition, it might be better to use a lower critical value for the $\bar{I}/\bar{C}$ ratio, say 0.75 or 0.50 instead of 1.00. These lower values would certainly imply longer moving averages and hence smoother curves; indeed, almost any degree of smoothness can be obtained by appropriate selection of the critical value for $\bar{I}/\bar{C}$. Lower critical values, however, would entail comparisons over longer periods and the loss of more moving average values for the current period. The present choice of a critical value for the $\bar{I}/\bar{C}$ ratio is based upon the idea that it yields a series dominated, on the average, by the cyclical rather than the irregular factor, with the smallest loss of current figures. Future experience with this problem, however, may lead us to change this critical value.

While the loss of data for a few current months entailed by the use of moving averages of period equal to the *MCD* span is regrettable, it is not crucial, so far as the use of leading indicators is concerned. This can be seen by comparing the period of the moving average equal to *MCD* and the average lead or lag for each of the eighteen monthly economic indicators. Such comparisons, shown in Table 3, indicate that in only two of the lead series are more than one month's data lost (business failures and commercial and industrial building contracts), and in these the average lead is substantially longer than the loss due to centering the moving average (except for commercial building at troughs). In the case of the series with short leads, the loss of data is only one month or less, as is also the case for the coincident and lagging series.

Simple moving averages of period equal to *MCD* would appear to trace out the cyclical pattern better than the seasonally adjusted series, but they are not quite up to date. They therefore appear to be useful supplements to, but not replacements for, seasonally adjusted series in current economic analysis.[14] To maintain the currency and flexibility of the moving average, the maximum period is limited to six months when *MCD* is 6 or more. Such moving averages are plotted for five series in the fourth panel of Chart IV and for all eighteen indicators in Chart VI. Here we see that a substantial degree of similarity in smoothness has been achieved among series that differ widely in this respect in the raw and seasonally adjusted data.

These relations among the different forms of monthly series and other sig-

[13] The fact that two different cyclical curves are computed for each series stresses the point that the cyclical curves (as well as the seasonal and irregular curves) are only *estimates* of the phenomenon we are trying to measure and cannot be depended on in any absolute or certain sense.

[14] A similar use of short-term moving averages is made by Geoffrey H. Moore in the construction of diffusion indexes (see his *Statistical Indicators of Cyclical Revivals and Recessions*, Appendix A, pp. 78–91, especially p. 79, and "Analyzing Business Cycles," *American Statistician*, April–May, 1954). The moving average periods used by Moore average about one and one-half months longer than the *MCD* spans.

nificant relations are also shown by a simple measure, the average duration of run[15] (see Table 4). This measure equals the average number of consecutive monthly changes in the same direction; it takes into account only the signs of the changes and not their amplitudes. For a random series, short runs occur much more frequently than long runs, and the expected average duration of run is only 1.5 (months, quarters, or whatever the time unit in which the series is expressed). For random series with 120 observations (i.e., ten years of monthly data), the average duration of run falls within the range 1.36 and 1.75 about 95 per cent of the time. This measure provides a basis for determining whether the month-to-month movements of an economic series depart significantly from randomness. Thus it shows that the month-to-month movement of the irregular component extracted by our method for most of the eighteen economic indicators is essentially random. This is true for all for which *MCD* is greater than 1. This measure also makes it possible to test quantitatively our procedure for reducing all series to the same degree of smoothness.

TABLE 4*

AVERAGE DURATIONS OF RUN FOR SEASONALLY ADJUSTED SERIES, IRREGULAR AND CYCLICAL COMPONENTS, AND SHORT-TERM MOVING AVERAGES, EIGHTEEN MONTHLY ECONOMIC INDICATORS, 1947–56

Series	Average Duration of Run (Months): Seasonally Adjusted (*CI*)	Irregular (*I*)	Cyclical (*C*)	Moving Av.	*MCD* Period of Moving Av. (Months)	*I/C* Ratio for *MCD* Span
Leading:						
Business failures, liabilities	1.6	1.4	5.8	3.0	6	0.88
Industrial stock prices	2.3	1.8	9.8	3.6	2	.73
New orders, durable manufactures	1.9	1.5	10.4	4.3	3	.73
Residential building contracts	1.8	1.5	7.7	3.9	3	.90
Com. and indus. building contracts	1.6	1.4	8.9	3.4	5	.82
Hours worked, manufacturing	2.5	1.8	7.7	3.7	2	.88
New incorporations, number	1.5	1.5	9.5	4.0	3	.69
Wholesale prices, basic commodities	3.2	1.8	9.0	3.6	2	.69
Coincident:						
Non-agricultural employment	3.6	1.8	12.9	3.6	1	.76
Unemployment, total	2.6	1.7	7.2	3.5	2	.76
Bank debits, outside New York City	1.4	1.4	16.4	3.2	3	.79
Freight carloadings	1.8	1.5	7.7	3.0	3	.85
Industrial production	3.5	2.8	10.6	3.5	1	.93
Non-farm wholesale prices, excl. foods	8.8	2.0	12.8	8.8	1	.40
Lagging:						
Personal income	2.8	1.6	18.8	2.8	1	.97
Retail sales	1.7	1.5	8.8	3.6	3	.98
Instalment credit outstanding	16.4	2.2	23.0	16.4	1	.18
Inventories of manufacturers	10.4	2.3	16.3	10.4	1	0.30

* The average duration of run is equal to the average number of consecutive monthly changes in the same direction in seasonally adjusted data (*CI*), in irregular component (*I*), in cyclical component (*C*), and in moving average of seasonally adjusted series, with period equal to *MCD* (*MA*). The expected average duration of run for a random series is 1.5, with two standard error limits of 1.36 and 1.75 for a series of 120 observations; for a simple moving average of a random series the expected average duration of run is 2.0, regardless of the period of the moving average.

Table 5 separates from the greater detail shown in the preceding tables the

[15] For an explanation of the average duration of run, its significance and uses, see W. Allen Wallis and Geoffrey H. Moore, *A Significance Test for Time Series* ("National Bureau of Economic Research Technical Papers," No. 1 [1941]); see also Wesley C. Mitchell and Arthur F. Burns, *Statistical Indicators of Cyclical Revivals* (National Bureau of Economic Research Bull. 69 [1938]), Table 2, col. 14.

average durations of run, *MCD*, and the $\bar{I}/\bar{C}$ ratio for the span at which *MCD* falls below 1 for our five illustrative series. The average durations of run for the seasonally adjusted series in four of the five cases are only slightly higher than for the irregular component and close to the figure for a random series. This does not mean that the seasonally adjusted series are random but rather that the irregular factor is so large in the seasonally adjusted series that it dominates the month-to-month movements. When the irregular factor is reduced by smoothing the data with short-term moving averages, the cyclical (non-random) character of the series emerges. The moving average of a random series has an expected average duration of run of 2.0, regardless of the period of the moving average. The average durations of run for the moving averages of period equal to *MCD* are all between 3.0 and 4.0. They thus exceed beyond reasonable limits the figure expected for a random series and therefore represent the cyclical (non-random) movements of the series.[16]

The average durations of run for the moving averages of these five series are not only close to one another but are also close to those for the seasonally adjusted form of the two smooth series—nonagricultural employment and industrial production—selected earlier in this paper to introduce the problem. The average durations of run for these series are 3.6 and 3.5, respectively. The $\bar{I}/\bar{C}$ measures for the spans equal to *MCD* are also all about the same and less than 1; they fall between 0.76 and 0.98. Series with relatively large and varying seasonal and irregular factors have been reduced to a form that is primarily cyclical and of a comparable degree of smoothness. This method appears to offer a workable solution to a problem posed at the beginning of this paper: How can series like business failures and retail sales be made to show their cyclical movements as clearly as those for factory employment and industrial production?

TABLE 5

AVERAGE DURATIONS OF RUN AND RELATED MEASURES FOR FIVE ILLUSTRATIVE SERIES, 1947–56

Series	Average Duration of Run (Months): Irregular Component	Seasonally Adjusted Series	Moving Av. with Period Equal to *MCD*	Months for Cyclical Dominance (*MCD*)	$\bar{I}/\bar{C}$ for Span Equal to *MCD*
Business failures, liabilities	1.4	1.6	3.0	6	0.88
Residential building contracts	1.5	1.8	3.9	3	.90
Freight carloadings	1.5	1.8	3.0	3	.85
Unemployment, total	1.7	2.6	3.5	2	.76
Retail sales	1.5	1.7	3.6	3	0.98

The sequence of adjustments is further illustrated in Charts VII and VIII, in which different forms of data for a single series are plotted one below the other. The series are for residential building contracts during two periods, 1936–39 and 1953–56, and for the sales of a major chemical company, 1948–56.

[16] Using moving averages of somewhat longer periods, Geoffrey H. Moore has applied this test to a large number of economic series. He concluded: "Although a few of the series might, in terms of the average duration of run in the seasonally adjusted data, be deemed to behave like random series, this hypothesis is not consistent with the behavior of the moving averages. All the smoothed series exhibit average durations of run far in excess of the value (2.0) expected on the random series hypothesis" (unpublished manuscript, "A Note on Serial Correlation in Economic Data").

VI. PRESENT AND PROSPECTIVE APPLICATIONS

The importance of seasonal and other adjustments of raw economic series for current business analysis has long been recognized. However, all satisfactory methods are laborious to compute, and, in general, the better the method, the greater the computing burden. Consider, for instance, the well-established method, used in the Federal Reserve System in 1954: for a ten-year monthly series (for example, the number of shoes produced each month from January, 1946, to December, 1955) about 2,500 computations would be required to compute moving seasonal adjustment factors and to adjust the series. If the checking were counted, about 5,000 computations would be required. It would take a clerk about a week to make and check these calculations and to record the results. The labor cost alone would be about $75, and, in addition, there would be the supervisory costs associated with a complicated assignment of this kind.

CHART VII

Different Forms of the Series on Residential Building Contracts

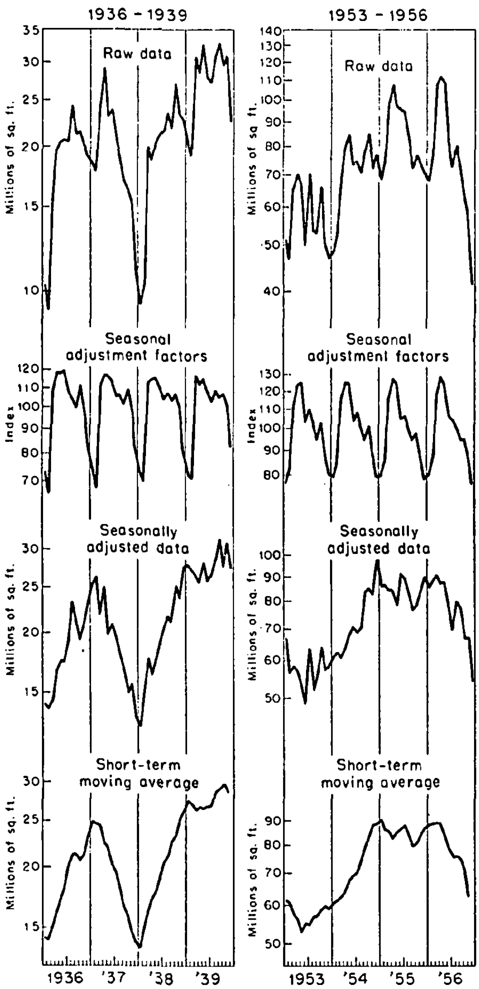
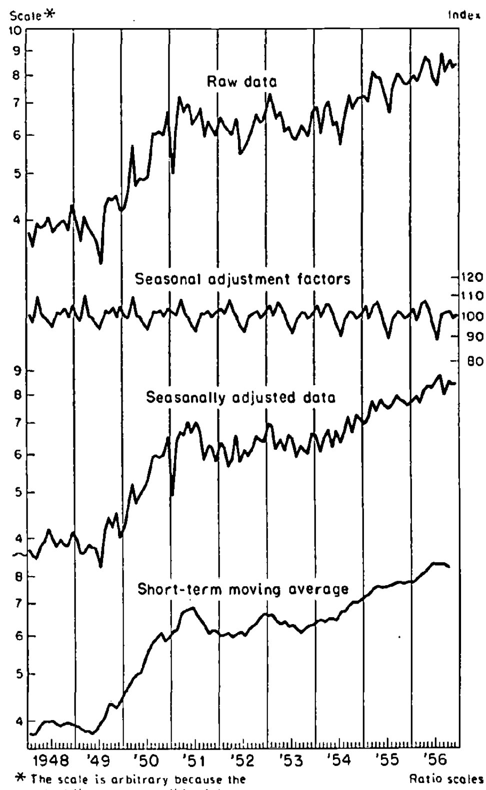


CHART VIII

Different Forms of the Series for the Sales of a Major Chemical Company 1948–56



Experience has shown that many series are needed for a reliable, comprehensive view of current business conditions, and there are many special industry and regional interests. Thousands of series need seasonal adjustment. *Economic Indicators*, prepared for the Congressional Joint Committee on the Economic Report by the Council of Economic Advisers, shows only the most important national series; yet it includes more than 125 monthly series. The *Survey of Current Business*, issued by the Department of Commerce, carries several thousand monthly economic series. And this is to say nothing of the numberless series compiled by individual business firms, banks, government agencies, etc. Nearly all these series require seasonal adjustment for effective use in current analysis. Furthermore, it is desirable to bring the seasonal adjustments up to date each year.

In the summer of 1954 a congressional committee held hearings on the adequacy of the economic statistics compiled by the federal government. Principal users of current economic series—for example, the chairman of the Council of Economic Advisers and the chief economist of the National Industrial Conference Board—complained that many of the monthly series published by the government were not adjusted for seasonal variations at all; that many others were adjusted by crude methods; and that for still others the seasonal adjustments did not reflect the most recent experience. As a result, they pointed out, it is difficult to make judgments on the state of current business. This situation is not due to the unwillingness or inability of the government statisticians to make such adjustments; it is attributable primarily to the huge amount of computation required and to the large costs involved. The use by business concerns of the crude same-month-year-ago comparison is due to similar factors.

The isolation of the irregular factor by the technique described above also requires a large amount of computation and can be considered only after a seasonally adjusted series is available. Furthermore, the trend-cycle curve that is divided into the seasonally adjusted series to yield the estimate of the irregular component must be smooth and fit the data closely. A simple unweighted moving average will not do, because imperfections in the measurement of the cycle will give rise to larger irregular fluctuations, on the average. Consequently, complex graduation formulas must be used. Such laborious computations were in the past made only for a limited number of series on an experimental basis. Summary measures, such as those described here, were not computed at all.

The large-scale digital electronic computer has brought an end to this situation. These machines record, store, transfer, calculate, and compare numbers and letters. They compute on the binary scale and convert automatically from and to the decimal scale. Such computers perform arithmetic computations at a very high speed; their checking circuits prevent the propagation of errors; and their operations are almost completely automatic. They can be programed to select the appropriate one of several series of computations according to the results of earlier computations.

Computers of this class are at their best in performing operations involving long series of sequential or iterative computations on relatively small numbers of original observations. They are particularly useful in the computation of seasonally adjusted series and moving averages, requiring only a small amount of input (e.g., card-punching and card-totape conversion). Although the output of data in our electronic computer program is large relative to the input (the ratio of output to input is about 30 to 1), it is easily handled by a high-speed printer. A high-speed printer not only can print the results but also can make charts adequate to serve as visual aids in interpreting them, all at the speed of the electronic computations.

This present program is essentially a modification of conventional methods, which combine laborious hand computations and professional judgments, to meet the requirements of electronic programing. The approach is intuitive and not aided by rigorous mathematical analysis; it does not even take advantage of existing mathematical techniques, such as regression and correlegram analysis, which might be adapted to economic time-series analysis. Fairly obvious measures, such as confidence limits, which are useful in judging the significance of month-to-month changes in the seasonally adjusted series are left out. Furthermore, defects in some of the measures in the program have already been observed in tests of the results and the experience of users. Thus the method of estimating the trend-cycle curve is not satisfactory in very smooth or highly irregular series; a more variable type of graduation formula should be substituted in the very smooth series and a less variable formula in the highly irregular series. The technique for obtaining seasonal factors for the initial and terminal years of each series must be improved. Troublesome questions arise regarding the relations of the *MCD* approach and the confidence-limits approach in judging the cyclical significance of month-to-month movements of seasonally adjusted series. Tests of significance have not yet been developed for the measures of the average monthly amplitude of the irregular, cyclical, and seasonal movements and the relations among them. Similarly, we pay a price for our measures of the cyclical factor—the loss of a few months' data at the ends. This is to list but a few of the limitations of this program that we know about already: no doubt more will be uncovered as further experience is gained with the results.

For these reasons the present program provides only a glimpse of what can be accomplished, if electronic computers are fully exploited for business and economic analysis. It is to be hoped that the application of fresh young minds, not shackled to the methods of the past, will bring a modification of this program beyond recognition and, perhaps more important, the development of completely new and more fruitful approaches to the analysis of economic problems. Nevertheless, the present program appears to represent a real improvement over widely used clerical methods in terms of the speed, the cost, and the results. And, since it is based upon methods that have, for the most part, met the test of experience and usefulness, it would appear desirable to use this program until the day comes that newer and better approaches have been developed and have passed similar tests. In the meantime, improvements will continue to be introduced into this program as the need for them becomes clear and techniques for making them are developed.

Almost all federal statistical agencies are now using the government's electronic computers and the program described in this article. About three thousand government series have been processed on the Census Bureau's Univacs by the present and earlier versions of this method. The method is being used for many of the Census Bureau's own series and by the Bureau of the Budget, the Bureau of Labor Statistics, the Council of Economic Advisers, the Federal Reserve System, the Department of Agriculture, the National Office of Vital Statistics, and the Office of Business Economics. Other users include private research groups, such as the National Bureau of Economic Research and the National Industrial Conference Board. In addition, groups in Canada, Australia, and Norway have sent their series to the United States Bureau of the Census for such processing.

Several of the large commercial computer centers also have this program available for the general public, and business organizations have started to use it. The cost is far less than that of cruder adjustments by clerical methods, and trivial compared to the cost of compiling the raw data.[17] Students of business conditions can therefore expect to have currently all important economic indicators in seasonally adjusted and smoothed form and to have measures of the cyclical behavior of these series. Business concerns can shift away from the crude same-month-year-ago comparisons to more useful measures of the fluctuations in their own activities.

In the light of the recent advances made in our understanding of the processes of economic change and the availability of electronic computers to prepare measures of these changes promptly and cheaply, it seems reasonable to expect better diagnoses of the current state of the business cycle and improvement in businessmen's forecasts of their own companies' activities.[18]

[17] Note, however, that substantial costs, human as well as financial, went into this program before it became a reality. These included costs of developing explicit criteria to enable the machine to make appropriate choices among alternatives in a long series of computations; of writing the computer instructions and "proving in" the program; and of training personnel in new skills. These are no longer factors for the present program; it can now be used at little more than the cost of operating the computer. But such costs must be taken into account in planning new programs.

[18] Other electronic computer programs for analyzing economic series have also been completed or are approaching completion as part of the National Bureau project on the use of electronic computers in economic analysis. One program, already completed for the Univac, embodies and expands the National Bureau's techniques for measuring the behavior of components in relation to aggregates. It supplies measures of the dispersion of changes between any two periods for components of aggregates or for members of a family of time series. Among the measures included are (1) frequency distributions of percentage rates of change, both absolute and relative; (2) arithmetic means of all rates of change, the rises alone and the falls alone; (3) deciles of the rates of change; and (4) diffusion indexes, both total and net percentage rising. Another program—the standard National Bureau business-cycle measures of cyclical timing, amplitude, duration, pattern, and conformity, as well as the accompanying measures of secular trend, for any monthly, quarterly, or annual time series, such as steel production for the industry or any of the steel companies—is now being programed for the IBM 704.

These programs will be described more fully in later National Bureau publications. Summaries appear in the National Bureau's *Thirty-seventh Annual Report*, May, 1957, pp. 65–72.