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of economic time series and more specifically in the adjustment of series for seasonal variations, but only to show that the present electronic computer methods generally yield results of at least the same order of quality as the best clerical methods. There is little doubt, however, that the use of electronic computers, by forcing us to make explicit our assumptions at each stage of the work and enabling us to make comprehensive tests of the results, already has thrown considerable light on these problems and led to some improvements over the techniques previously used.

This paper describes the two methods developed at the Bureau of the Census and compares the results. The first method is a mechanical version of the familiar and widely used ratio-to-moving-average method and the second a refinement of the first. In the newer method the trend-cycle curve is traced out by a weighted fifteen-month moving average which provides a flexible yet smooth graduation. Smooth curves are also fitted to the seasonal-irregular ratios to provide seasonal adjustment factors, and follow the ratios for the full period of the data. Extreme values among the ratios are isolated automatically by a built-in system of control charts and are replaced by averages of the extreme ratio and surrounding ratios. Series as short as six years and as long as thirty years can be seasonally adjusted, and quarterly as well as monthly data can be handled.

Comparisons for a large number of different types of series show the second method to be superior. Comparisons with adjustments carefully made clerically by three different statistical organizations indicate that the results are at least as good as manual adjustments of the same series. These comparisons indicate that this electronic computer program has brought us fairly close to providing on a mass basis a fully mechanical method of making seasonal adjustments as good as those previously prepared for only a small number of series by a combination of laborious hand computations and professional judgments. For the few series where this is not the case, the electronic computer program provides data which can be converted to satisfactory seasonal adjustments with only a small amount of additional hand manipulations. Some of the kinds of series for which Method II is likely to yield inadequate adjustments are described, also.

Continuing studies are being made to find ways of reducing the number of unsatisfactory adjustments, and the resulting refinements of the method will improve it still further. Nevertheless, professional review of the results, particularly for the initial and terminal years of series, still is, and probably always will be, necessary.

II. SEASONAL ADJUSTMENTS BY METHODS I AND II

The first seasonal method programmed for the Census Bureau work, Method I, is an adaptation and elaboration of the familiar ratio-to-moving-average method at its most advanced stage of development.[1] A series reflecting the

[1] See, for example, F. C. Mills, *Statistical Methods* (New York, 1955), pp. 360–375; F. E. Croxton and D. J. Cowden, *Applied General Statistics* (New York, 1955), pp. 320–363; W. A. Wallis and H. V. Roberts, *Statistics: A New Approach* (Glencoe, Illinois, 1956), pp. 580–586; A. F. Burns and W. C. Mitchell, *Measuring Business Cycles* (New York, 1946), pp. 43–55; H. C. Barton, Jr., "Adjustment for Seasonal Variation," *Federal Reserve Bulletin*, v. 27 (1941), pp. 518–528.

trend-cycle components is estimated by a twelve-month moving average of the original observations. This estimate is then divided into the original observations to obtain a series reflecting the seasonal and irregular components. For each month, a moving average curve is next fitted to the time series representing the seasonal-irregular component for that month in successive years in order to obtain estimates of the seasonal factors alone. This last step yields twelve sets of moving seasonal factors, one for each month. The seasonal factors for each year are then "centered" so that their sum equals 1,200.

An iterative procedure is used: first, the seasonal factors obtained as above are divided into the original observations to obtain a preliminary seasonally adjusted series, representing the trend-cycle-irregular components. This series is, in turn, smoothed by a five-month moving average to provide a trend-cycle curve that is more flexible than the twelve-month moving average; that is, a five-month moving average can change direction over a short interval, so that it follows fairly sharp peaks smoothly, as well as shallow ones. The sequence of computations first made on the twelve-month moving average is then repeated on the five-month average to yield the final seasonally-adjusted series.

Altogether, the method yields nineteen tables which show the successive stages of the computations from the original observations to the final seasonally adjusted series.[2] Included are five different moving averages, two sets of ratios to moving averages, two centered and two uncentered sets of moving seasonal factors, two seasonally adjusted series, and five tests of the work. Method I is described more fully below (Section III) in the course of the explanation of the changes made for Method II.

The present writers studied the results of this method as applied to many series and also discussed it with other time series analysts who made similar studies. There is general agreement that this method is very good; that while it is sometimes possible to make a better adjustment for a single series or a few series, up to now it has not been possible to make adjustments of such high quality for large numbers of series. Nevertheless, a number of weaknesses have become evident. The possibilities of correcting these weaknesses depend partly upon the ingenuity of statisticians, but also upon the availability of a facility for carrying out masses of computations rapidly at low cost. The electronic computer comprises such a facility. The writers, therefore, carefully examined each one of these faults and proceeded to develop methods of overcoming them. These improvements have been incorporated in a revised seasonal method—Method II.

Method II follows the general procedure of Method I but takes advantage of the great capacities of electronic computers for statistical computations, by utilizing more powerful and refined techniques and producing more information about each series. Thus, it substitutes weighted for simple moving averages and isolates and reduces the weight of extreme items more selectively. It computes measures of the relative significance of the trend-cycle, seasonal, and irregular components of each series and uses these relations automatically to guide the course of subsequent computations. It adds a new basis for judging the validity of the seasonal adjustment to those provided by Method I. It

[2] See Julius Shiskin, "Seasonal Computations on Univac," *American Statistician*, February 1955, pp. 19–23.

provides optionally a constant seasonal index for special uses. It computes month-to-month percentage changes in the series and its components. It also produces point charts for the convenience of its users.[3] The full array of data now provided by this electronic computer program is shown for an illustrative series in Table 1.

The principal features of Method II are:

1. It computes a preliminary seasonally adjusted series which follows primarily the conventional ratio-to-moving-average technique. It starts with ratios computed by dividing the original observations by a twelve-month moving average; it computes moving seasonal adjustment factors from these ratios; and it obtains a seasonally adjusted series by dividing these preliminary seasonal adjustment factors into the original observations.

2. 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 which is flexible, follows the data closely, and gives a smooth representation of the trend-cycle components.

3. It utilizes a control chart procedure to identify extreme items among the seasonal-irregular ratios and systematically reduces the weight of these extremes 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 ratios immediately preceding and following.

4. It utilizes 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.

5. It 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 carried out. Alternative graduation formulas, each appropriate for series with irregular components of different magnitude, are placed in the computer memory and automatically selected according to the average month-to-month amplitude of the irregular fluctuations.

6. It 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 new 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.

The electronic computer programs for Methods I and II provide for working or trading day corrections where they are needed. The working or trading day

[3] For a description of how these charts are prepared, see Harry Eisenpress, James L. McPherson, and Julius Shiskin, "Charting on Automatic Data Processing Systems," *Computers and Automation*, August 1955.

correction factors must, however, be available, for punching or taping, along with the original observations; there is no technique built into the electronic computer program for estimating such factors. The working day correction is accomplished by the modification of the original observations, in the electronic computer routine, before they are started through the seasonal adjustment process.

The faults in Method I and the methods for overcoming them which have been adopted in Method II are described below and comparisons of the seasonal adjustments made by Methods I and II are shown and analyzed for several economic series. A detailed description of each of the steps in these seasonal methods can be obtained by writing to the authors.

III. FAULTS OF METHOD I AND THEIR IMPROVEMENT IN METHOD II

1. *Improvements in the Trend-Cycle Curves*

(a) *Smoothing the trend-cycle curves:* The five-month moving average of the preliminary seasonally-adjusted series, which has been used in Method I as the underlying trend-cycle curve, occasionally yields a somewhat irregular curve, although for most series it produces better results than earlier methods based on a 12-month moving average of the original series. Nevertheless, for series with large irregular components, the 5-month moving average does not result in a smooth delineation of the trend-cycle components of the series. (See, for example, Chart 1.)

With the burden of computations no longer a factor, the writers were able to turn to the large array of complex graduation formulas previously developed by others to select a curve which is as flexible as, yet smoother than the five-month moving average.

It seems fairly clear to students of this problem that there is no single graduation formula which best delineates the underlying cyclical movements of all economic series.[4] Perhaps it may be possible eventually to develop criteria for selecting a particular graduation formula for each series according to the types of cyclical and irregular fluctuations characteristic of that series. Then with electronic computer programs for a large number of different graduation formulas available, the computer would calculate measures of the cyclical and irregular components in each series, and on the basis of these select the smoothing formula most suited to each particular series. The writers have tried to make such a start; however, its development is for the future. For the present, because of the time that will be required to develop a conceptual basis for this idea and to prepare the electronic computer programs, the writers have selected a single graduation formula to measure the trend-cycle factors.

Graduation formulas are available which provide smooth and flexible curves and also eliminate seasonal fluctuations; for example, Macaulay's 43-term formula. But such formulas involve the loss of a relatively large number of points at the beginnings and ends of series. Graduation formulas which provide similarly smooth and flexible curves and involve the loss of relatively few points do not also eliminate seasonal variations. The computation for a preliminary seasonally adjusted series is now easy mechanically; on the other hand, the

[4] See, for example, Arthur F. Burns and Wesley C. Mitchell, *op. cit.* Chapter 8, esp. p. 320.