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CURRENT PROBLEMS IN RESEARCH

Decomposition of Economic Time Series

Business fluctuations are broken down into seasonal, cyclical, and irregular factors by computers.

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During recent years there has been an increased interest in economic developments on the part of the public, particularly during the 1953–54 and 1957–58 recessions. This interest has further stimulated the collection and dissemination of an already imposing array of current economic statistics. A major factor impeding the organization, analysis, and interpretation of these great quantities of data has been the high cost of the required calculations. Electronic computers, however, opened up the possibility of making such calculations quickly and cheaply. An electronic computer method of analyzing business fluctuations prepared at the United States Bureau of the Census in 1954 served to demonstrate the potentialities of computer analysis of economic data. After improvement and extension, this method is now in widespread use in the analysis of economic time series. These series measure, usually at monthly intervals, such things as the production of steel, the number of unemployed, the average price of wheat, stock prices, and the liabilities of business concerns that have failed. Altogether more than 5000 economic time series have been analyzed by the Bureau of the Census for U.S. Government agencies, foreign governments, universities, and private research organizations. Many business concerns are also using this method to analyze their own performances.

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Types of Economic Fluctuations

A principal purpose of studying business statistics is to determine the stage of the business cycle at which the economy stands. Such knowledge helps in forecasting subsequent cyclical movements and provides a factual basis for taking steps to moderate the amplitude and scope of the business cycle. It is of critical importance around turning points —for example, failure to recognize a downturn in business may lead to the adoption of policies to curb expansion when a recession is already under way. In using business indicators, however, analysts have been perennially troubled by the difficulty of separating the underlying, more meaningful cyclical movements from other types of fluctuations.

Time series make up the most important raw materials for historical studies of economic events. They are statistical records of economic processes for consecutive and equal periods. They are generally compiled monthly and have been cumulated for long periods. Many are available for each month since the beginning of 1919. A few start prior to 1900; thus, a monthly series on pig iron production covers the period since 1877. These monthly series are supplemented by annual and quarterly series. More recently interest has been turning to weekly series, and about 50 weekly series covering broad economic processes are now compiled currently, for example, on steel production, electric power production, and initial claims for unemployment insurance. Thousands of weekly, monthly, and quarterly economic time series have been compiled by statisticians over the years and are available for study.

For many years economic statisticians have found it useful to consider each economic time series as a composite of cyclical, trend, seasonal, and irregular factors. In the analysis of a given series, the series is decomposed, or broken down, into these parts. (Figure 1 shows the decomposition of an economic time series on private, nonfarm dwellings that were started during the period 1947–1958.) The cycle—usually referred to as the business cycle—consists of short-run movements made up of alternating periods of business expansion and contraction. They last from 3 to 4 years, on the average, though the range extends from 2 to 10 years. The trend is made up of the still-longer-run movements of the series and ordinarily has little effect upon month-to-month movements of economic series. For convenience in short-term forecasting it is often combined with the cyclical factor.

The practice of combining the cyclical and trend factors is followed in this article (*1*). This should be borne in mind, because sometimes the trend is important, even over short periods—for example, in series showing airline traffic since 1947. The curves used to delineate the cyclical component also show shorter movements that are not generally recognized as cyclical—for example, in a great many economic series there was a rise from July to October 1932 and a decline from the spring to the fall of 1951. Furthermore, the term *cyclical* is used in other sciences, and especially in mathematics, to mean something different—a curve with a recurrent cycle that has a symmetrical pattern, a standard amplitude, and a fixed period. For these reasons, the use of the word *cyclical* to identify curves in economic studies leaves something to be desired; another word, possibly *systematic* or *oscillatory,* might be preferable if we were starting afresh. But the use of the term *cyclical* to describe alternating periods of business expansion and contraction, with uneven patterns, varying amplitudes, and irregular durations, is so widespread among economists that it would probably be impossible to substitute another term now.

The seasonal factor consists of intrayear movements which are repeated more or less regularly each year. For example, farm income rises steadily each year from early spring to fall and then drops sharply again. Most economic series contain significant seasonal fluctuations, but some (stock prices, for example) contain none. The irregular fluctuations are those that remain after the other types are accounted for. They are occasioned by a wide variety of factors: exceptional events, such as unusual weather, strikes, unexpected political developments, or the failure of a large business concern, and statistical errors, such as sampling errors, response errors, and errors caused by defective seasonal adjustments.

Irregular, seasonal, and cyclical movements all vary a great deal in magnitude from one series to another. The irregular movements are very large in some series, such as the liabilities of business failures series, but are very small in others, such as the grocery sales series. Similarly, the seasonal factor is quite large in construction and retail trade series but small in many manufacturing series. The cyclical amplitude is considerably larger in new orders and construction series than it is in employment series.

Role of Computers

The Census Bureau's electronic computers perform arithmetic computations at a very high rate of speed, and their operations are almost completely automatic. They will 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. The decomposition of time series fits this requirement very well and, moreover, requires only a small number of input operations (punching and card-to-tape conversion). Although the output of data in the time series decomposition program is large relative to the input, it is easily handled by the Census Bureau's high-speed printers. Recent experience with these computers shows that they make possible the massive application of diagnostic and forecasting techniques that could previously be applied only on a small scale. Computers have also opened up possibilities of types of analysis far beyond the capacity of earlier equipment.

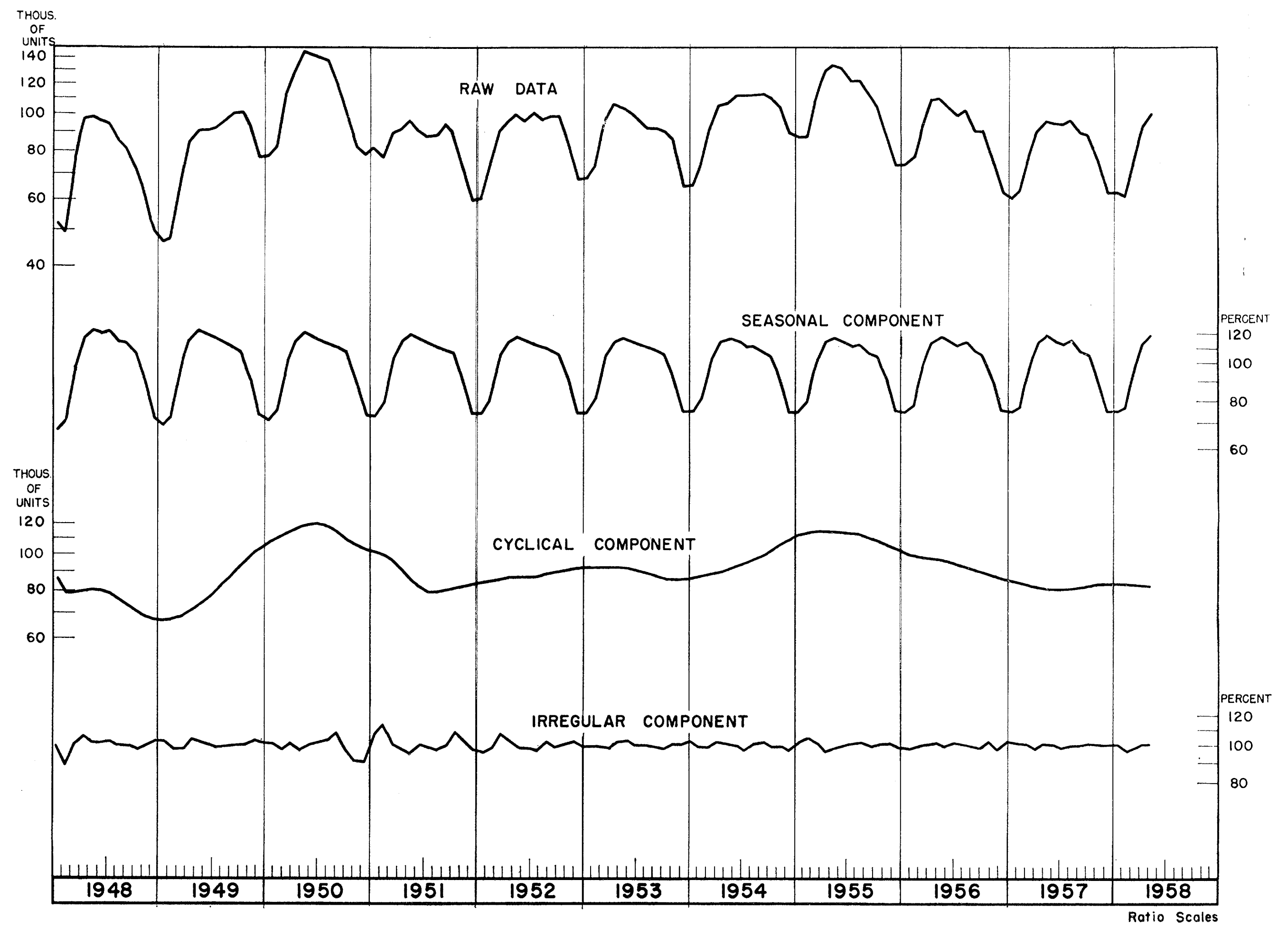

Fig. 1. The Census Bureau time series analysis and adjustment program is designed to separate the seasonal, cyclical, and irregular components of unadjusted economic time series. An example of the raw (unadjusted) data (number of dwelling units started each month) and its derived seasonal, cyclical, and irregular components are represented graphically above. Source of raw data: Bureau of Labor Statistics, U.S. Department of Labor.

The method of time series decomposition developed at the Bureau of the Census eliminates the seasonal factor and irons out the irregular factor so that the cyclical factor stands out more clearly. The application of this method to many economic time series has been helpful in diagnosing current business conditions and forecasting the course of business. Thus, the results were used on a large scale by many Government agencies as an aid in following the course of the 1957–58 recession (*2*). In addition, studies of the results have revealed some important information about the relations among the components of aggregate economic change. For example, they have shown that in most economic time series both the seasonal and irregular factors dominate the month-to-month movements of the underlying, more meaningful cyclical factor; on the other hand, cyclical movements dominate comparisons made over longer spans, usually three months.

The method used, the tests to which it has been put, and some of the new knowledge yielded by its application are described more fully below. While this work has already been fruitful, this article should be considered primarily as an illustration of the new potentialities in economic research made possible by the advent of the electronic computer.

Seasonal Adjustments

An adaptation of a widely used method of measuring seasonal variations (the ratio-to-moving-average method) was programmed for the Census Bureau's electronic computers. There were three principal reasons for selecting this method, rather than some other: (i) It had been thoroughly tested in the past and had proved satisfactory for a large variety of economic series; (ii) it permits checking and analysis at each of the many stages in the seasonal adjustment process; and (iii) it had been almost universally accepted by economists and business analysts, who are the chief users of seasonally adjusted data. It is possible that equally good, or even better, results could have been obtained had we started with another method—for example, a regression method or perhaps the link-relative method—and expanded and developed it in a similar way. The development and testing of alternative methods and comparisons with the present method might also add significantly to our knowledge of economic time series analysis.

The first step in the ratio-to-moving-average method is to compute a 12-month moving average—that is, a series of averages for sucessive 12-month periods (January to December, February to January, March to February, and so on). These annual averages eliminate the seasonal fluctuations and trace out, approximately, a "trend-cycle curve." Division of the raw data by this moving average yields a series of seasonal-irregular ratios. Since both the raw data and the moving average contain the trend-cycle component, it is canceled out (approximately) by division, leaving only the seasonal and irregular components. Estimates of the seasonal adjustment factors are then secured by averaging the seasonal-irregular ratios for successive Januaries, successive Februaries, and so on, in such a way that the irregular factor will be largely canceled out in the averaging process. Finally, the seasonal variations are eliminated from the original observations by dividing these observations by the seasonal adjustment factors. The resulting (seasonally adjusted) series contain the trend, cycle, and irregular factors, but not the seasonal factor.

The adaptation of the ratio-to-moving-average method programmed at the Census Bureau takes advantage of the electronic computer's high-speed, low-cost computations; it utilizes more powerful and refined techniques than clerical methods widely used in the past, so it is likely to produce satisfactory results more frequently. It also produces more information about each series—information that can be used for checking the adequacy of the results, for forecasting seasonal and other movements, and for other purposes. The principal features of the method (*3*) 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 electronic computer first computes a preliminary seasonally adjusted series and then goes on to refine it. It utilizes a complex graduation formula—a weighted 15-month moving average applied to the preliminary adjusted series —to obtain the estimate of the trend-cycle curve. This average provides a smoother and more flexible curve than the simple 12-month moving average. A control-chart procedure is employed to identify extreme seasonal-irregular ratios, and the weight of these extreme ratios is systematically reduced in the subsequent computations. Weighted moving averages of the seasonal-irregular ratios for each month are employed to obtain a set of moving seasonal adjustment factors. A measure of the irregular component of each series is used to determine which of two moving averages to fit to the seasonal-irregular ratios. If the irregular component is relatively small, the machine selects a three-term moving average of a three-term moving average; if the irregular component is relatively large, it selects a three-term moving average of a five-term moving average for greater smoothing. Changing trends are taken into account in calculating seasonal adjustment factors for the full period of the series, including the first and last few years. For each month an average of the seasonal-irregular ratios for the last two years available is taken as the estimated value of each of the ratios for the two or three additional years required for the computations. These estimates provide the full amount of data required to compute the seasonal factors for the end years of the series. A similar procedure is used to obtain missing values for the beginning years of series and for computing the beginnings and ends of the trend-cycle curve.

Measures of Cyclical-Trend and Irregular Factors

After the program computes seasonal factors—that is, a series estimating the seasonal component of the aggregate series and a seasonally adjusted series—it calculates a curve estimating the cyclical and trend factors in combination. This is accomplished by taking a weighted 15-term moving average of the final seasonally adjusted series. Finally, an irregular series is obtained by dividing the seasonally adjusted series by the cycle-trend curve. Thus, the time series representing the original observations is broken down into three separate series representing the seasonal, cyclical-trend, and irregular components of the aggregate series (see Fig. 1).

A group of summary measures of the seasonal, cyclical, and irregular components and the relations among them are also computed. The average monthly amplitude of the seasonal factor, $\overline{S}$, is obtained by averaging the month-to-month percentage changes in the seasonal factor curve without regard to sign. Similarly, the average monthly amplitude of the cyclical factor, $\overline{C}$, is obtained by averaging the month-to-month percentage changes in a weighted 15-month moving average of the seasonally adjusted series without regard to sign.

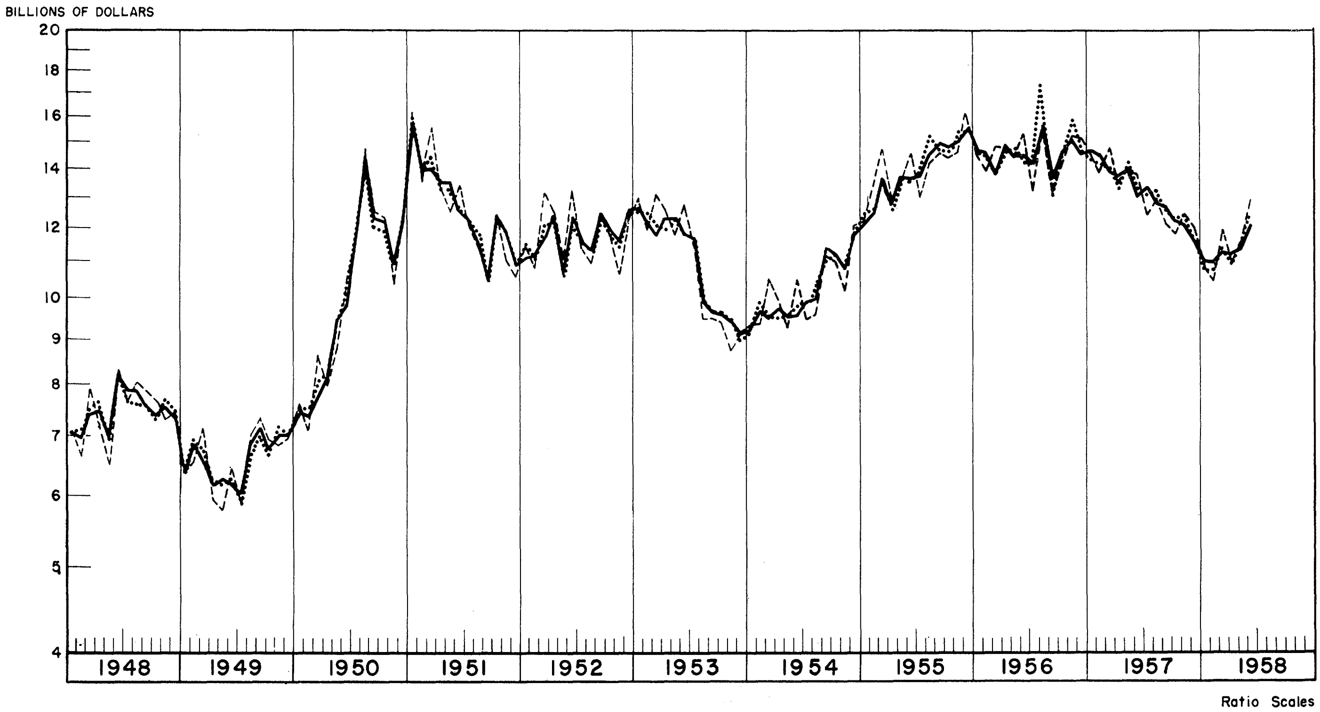

Fig. 2. A variety of manual methods of seasonal adjustment have been in use for many years. This chart shows an unadjusted time series (original observations for manufacturers' new orders of durable goods) (dash line) and compares seasonal adjustments resulting from the computer method (solid line) described in this article and a typical manual method (dotted line). Many such charts for other series have been prepared and show about the same kind of similarities and differences. Source of original observations and manually seasonally adjusted data: Office of Business Economics, U.S. Department of Commerce.

Finally, the average amplitude of the irregular factor, $\bar{I}$, is computed by averaging the monthly percentage changes in the ratio of the seasonally adjusted series to the cyclical curve without regard to sign. The machine then uses these measures to compute various ratios of these amplitudes—for example, the ratio of the average amplitude of the irregular factor to the average amplitude of the cyclical factor.

Ratios of the average amplitudes of the irregular to the cyclical factors are computed for 1-, 2,- 3-month, and longer spans (up to 6 months). For the 1-month span the computation is based on the percentage changes for the periods January to February, February to March, and so on; for the 2-month span the percentage changes are computed for the periods January to March, February to April, 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 as the span increases. The number of months required for the irregular-cyclical ratio to fall below unity may, therefore, be taken as an index of the months required for the cyclical factor to dominate the irregular factor. This index is identified by the symbol MCD ("months for cyclical dominance"); thus, MCD is 3 for manufacturers' new orders of durable goods and 1 for the index of industrial production. This indicates that comparisons of the industrial production indexes for consecutive months usually show significant economic changes, but that comparisons in manufacturers' new orders usually show significant economic changes only over 3-month or longer spans. The MCD index has proved to be one of the most useful measures yielded by the electronic computer program.

Since the first differences of simple moving totals are equivalent to differences between figures for months separated by an interval equal to the period of the moving average, it follows that a moving average of a seasonally adjusted series calculated for a period equal to MCD would show primarily changes in the cyclical factor. A moving average of this period is automatically computed in the program.

Tests of the Electronic Computer Method

Many tests of the accuracy of the time series decomposition method described above have now been made; the two most important are described here (*4*). A comparison was made of the seasonal adjustments determined by electronic computer with some of the adjustments prepared clerically at the National Bureau of Economic Research, the Office of Business Economics of the Department of Commerce, and the Department of Agriculture. The National Bureau of Economic Research adjustments used in this test employ stable seasonal factors, with two short periods selected for each series; the Office of Business Economics and the Department of Agriculture employ changing seasonal adjustment factors for the series selected. The results for one of these series, manufacturers' new orders of durable goods, are shown in Fig. 2 (*5*).

Figure 2 shows that the differences in the results are small. Where they occur, the computer method usually yields the smoother seasonally adjusted series, although this does not necessarily mean that the series is better. It is clear, however, from these and other comparisons, that the computer method can ordinarily be counted upon to yield a seasonal adjustment of as good quality as the best manual methods. Furthermore, this method seems to be versatile enough to make stable and moving adjustments about equally well, though it will not handle abrupt (discontinuous) changes in seasonal patterns such as may arise from legal or other types of institutional change.

In a second kind of test the irregular, cyclical, and seasonal components computed from different real economic series by the electronic computer program were combined into artificial series, and the method was applied to these artificial aggregates. That is, the seasonal factor from one series, the cyclical-trend from a second series, and the irregular factor from a third series were combined multiplicatively into an artificial composite. Each of the actual components that had been combined to make up the artificial aggregate (the input) was then compared with the corresponding component yielded by the electronic computer decomposition (the output). Some of the results are shown in Table 1 and Fig. 3.

The artificial series were constructed in such a way as to test the method of extracting each factor (irregular, cyclical, and seasonal) under both favorable and unfavorable conditions. This was accomplished by making up an artificial series in which one factor showed small movements relative to the other two, and another in which the same component had large movements relative to the other two. Altogether ten different artificial series were constructed; for five of these the test was made with the use of both constant and changing seasonal factors.

In most instances the "estimated" components trace a course similar to that of the "true" components. Moreover the monthly amplitudes of the "estimated" components usually closely approximate those of the "true" components. Clearly, the electronic computer program has considerable power to rediscover the different types of fluctuations that were built into the series and does not generate arbitrary fluctuations that have no relationship to the original observations.

While the results appear to be generally good, some limitations are also clear: (i) The magnitude of the largest of the three components is almost always reduced, with offsetting increases in one or both of the other factors. (ii) Where one or both of the factors are large rela-

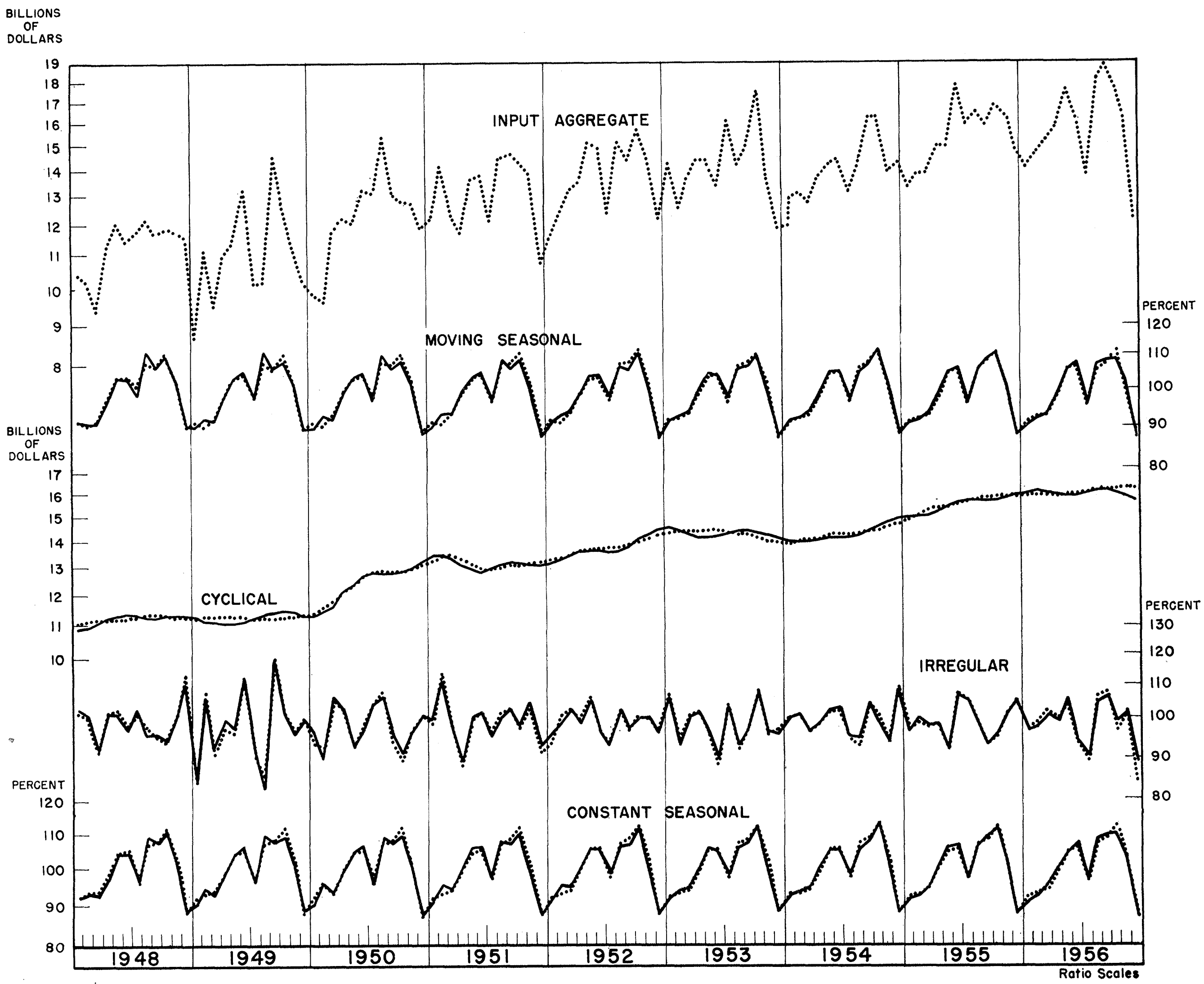

Fig. 3. A number of artificial series were constructed by combining components from various sources as a test of the quality of the Census Bureau method of decomposing economic time series. The series shown above as the input aggregate was made up of (i) an irregular component from the residential building contracts series, Y (ii) a cyclical component from the retail sales series, Z, and (iii) a seasonal component from the freight car loadings series, W. These components are shown as input series (dotted lines). The input aggregate was then decomposed by the computer. The resulting components are shown as solid lines (output). The moving seasonal lines compare a moving seasonal input with a moving seasonal output. The constant seasonal lines compare a constant seasonal input with a moving seasonal output. The same test was applied to nine other artificial series with the results summarized in Table 1.

tive to the third, the smallest factor can be significantly affected. (iii) The amplitudes of the cyclical and seasonal factors tend to be overestimated more (or underestimated less) when relatively large irregular factors are present. The analysis indicates, however, that these deficiencies are important only in kinds of series that occur infrequently at the national level (see Tables 2 and 3). They may be more serious for individual firm data, however. The results also strongly suggest that the program could be improved by using more powerful smoothing formulae for series with large irregular components. The procedure for choosing among such formulae could be written into the program and thus be made completely automatic. Further tests are planned. In one, the component series would be combined additively, or partly additively and partly multiplicatively. In another, series built up from mathematical components would be decomposed, and the results would be studied.

Table 1. Comparisons of the average monthly amplitudes of the components of artificial aggregates (input) with those yielded by the decomposition of these aggregates (output). In column 1, the first letter indicates the series supplying the irregular factor; the second, that supplying the cyclical factor; the third, that supplying the seasonal factor: *W*, freight-car loadings; *X*, business failures; *Y*, residential building contracts; *Z*, retail sales. The symbols $\overline{I}$, $\overline{C}$, and $\overline{S}$ represent average month-to-month change, without regard to sign, in irregular component, cyclical component, and seasonal component, respectively.

Time series components	Input				Output			
	$\overline{I}$	$\overline{C}$	$\overline{S}$	$\overline{I}/\overline{C}$	$\overline{I}'$	$\overline{C}'$	$\overline{S}'$	$\overline{I}'/\overline{C}'$
Test 1: Moderate irregular and cyclical, large seasonal, factors								
ZZY, moving seasonal	1.7	0.6	11.3	2.8	1.5	0.6	10.6	2.5
ZZY, constant seasonal			9.6				9.6	
Test 2: Moderate irregular and seasonal, large cyclical, factors								
ZXW, moving seasonal	1.7	3.2	5.0	0.5	2.2	2.6	5.1	0.8
ZXW, constant seasonal			5.4				5.5	
Test 3: Moderate irregular, large cyclical and seasonal, factors								
ZXY, moving seasonal	1.7	3.2	11.3	0.5	3.1	2.7	10.3	1.1
Test 4: Large irregular, moderate cyclical and seasonal, factors								
YZW, moving seasonal	7.8	0.6	5.0	13.0	7.6	0.8	5.3	9.5
Test 5: Large irregular and cyclical, moderate seasonal, factors								
YYW, moving seasonal	7.8	2.7	5.0	2.9	7.4	2.6	5.5	2.8
Test 6: Large irregular, moderate cyclical and seasonal, factors								
XZW, moving seasonal	15.3	0.6	5.0	25.5	14.8	1.3	5.9	11.4
Test 7: Large irregular and seasonal, moderate cyclical, factors								
XZY, moving seasonal	15.3	0.6	11.3	25.5	14.8	1.3	10.7	11.4
XZY, constant seasonal			9.6				9.9	
Test 8: Large irregular and cyclical, moderate seasonal, factors								
XXW, moving seasonal	15.3	3.2	5.0	4.8	14.8	3.2	5.8	4.6
XXW, constant seasonal			5.4				6.0	
Test 9: Large irregular and cyclical, moderate seasonal, factors								
XYZ, moving seasonal	15.3	2.7	6.5	5.7	14.7	2.6	7.0	5.7
XYZ, constant seasonal			6.8				6.8	
Test 10: Large irregular, cyclical, and seasonal, factors								
XXY, moving seasonal	15.3	3.2	11.3	4.8	13.8	3.1	11.1	4.5

Table 2. Relative magnitude of seasonal, irregular, and cyclical factors in 149 economic series, 1947–1956. The symbols $\overline{S}$, $\overline{C}$, $\overline{I}$, and $\overline{CI}$ represent average month-to-month percentage change, without regard to sign, in seasonal component, cyclical component, irregular component, and seasonally adjusted data, respectively.

Class interval (%)	Percentage distribution of series, according to			
	$\overline{S}/\overline{CI}$	$\overline{S}/\overline{I}$	$\overline{S}/\overline{C}$	$\overline{I}/\overline{C}$
0–0.19	1	1	0	0
0.20–0.39	1	1	0	3
0.40–0.59	15	4	5	5
0.60–0.79	21	10	5	10
0.80–0.99	17	18	12	7
1.00	0	1	0	1
1.01–1.19	9	17	5	10
1.20–1.39	8	9	5	5
1.40–1.59	3	6	1	2
1.60–1.79	3	4	4	5
1.80–1.99	2	3	3	5
2.00–2.99	9	10	15	18
3.00–3.99	4	5	11	14
4.00–4.99	5	6	11	7
5.00 and over	2	5	23	8
Totals	100	100	100	100

Findings: Relations among Types of Economic Fluctuations

A sample of about 150 series, selected as broadly representative of the different activities of the United States economy, has been decomposed and studied. The cyclical, seasonal, and irregular amplitudes are summarized in Table 2 and shown in detail for 18 important monthly business indicators in Table 3. These tables reveal that, for the post-World War II period, seasonal movements dominate other kinds of month-to-month movements in most current economic series. Seasonal movements are almost always larger than either the irregular or cyclical movements, and they are often larger than both of the other types combined. More specifically, the average monthly amplitude of the seasonal fluctuations exceeds that of the cyclical factor in 78 percent of the series, exceeds the irregular in 65 percent of the series, and exceeds the cycle-trend and irregular in combination in 45 percent of the series. Furthermore, where the seasonal factor is larger, it is often much larger. The seasonal factor is 3 or more times as large as the cyclical factor in 45 percent of the series, 3 or more times as large as the irregular factor in 16 percent of the series, and 3 or more times as large as the cyclical and irregular fluctuations together in 11 percent of the series. The relative magnitude of the seasonal factor is also very great in many of the 18 monthly business indicators (Table 3) which are used widely in interpreting current business trends.

For the same sample of about 150 series, ratios of the average irregular change to the average cyclical change were computed for 1-, 2-, 3-, 4-, 5-, and 6-month spans. Separate computations were made for the interwar period, 1919–1939, and the postwar period, 1947–1956. The distribution of the measure showing the months required for cyclical dominance (MCD), given in Table 4, provides a broad view of the relations between the irregular and the cyclical factors in U.S. economic series. This table shows that on a month-to-month basis, the average change in the irregular factor is larger than that in the cyclical factor in about 75 percent of the series; over 3-month intervals it is larger in about 25 percent of the series; over 6-month intervals it is larger in less than 10 percent of the series.

These results emphasize the advantages of seasonally adjusted series for studying cyclical movements over those not so adjusted. Where the seasonal fluctuations are large, a difference in the unadjusted data for two months may be due largely or solely to normal seasonal fluctuations; if the data are seasonally adjusted, the difference can be assumed to be caused chiefly by cyclical or irregular factors. The results also emphasize the importance of knowledge of the relative magnitudes of irregular and cyclical factors in interpreting current movements in economic series. They indicate that the month-to-month movements of most seasonally adjusted series are not "cyclically significant"; for most series, meaningful economic trends are revealed only by comparisons over three-month or longer spans. For many series, of course, month-to-month changes are significant, and this group includes such important series as total industrial production and total nonagricultural employment. The measure MCD provides a useful guide for interpreting the short-term fluctuations of each series.

It should be noted that more frequent observations make more current comparisons possible. Consider a series in which the cyclical factor does not dominate until comparisons are made over 3-month periods. If this series is available quarterly, only one comparison a quarter can be made. If it is available monthly, then three comparisons a quarter can be made: the first month of each quarter with the first month of the preceding quarter, the second month of each quarter with the second month of the preceding quarter, and the third month of each quarter with the third month of the preceding quarter. Thus, seasonally adjusted weekly series may add to the currency of economic information, even though the week-to-week fluctuations are not significant.

Table 4. Months required for cyclical factor to dominate the irregular factor in 150 important economic series, 1919–1939 and 1947–1956.

Months required for cyclical factor dominance	Percentage distribution of 150 series according to measure, MCD	
	1919–1939	1947–1956
1	23	27
2	29	21
3	25	23
4	14	11
5	5	10
6 or more	4	8
Total	100	100

Table 3. Relative magnitude of the seasonal, irregular, and cyclical factors in 18 monthly business indicators, 1947–1956. The symbols $\overline{S}$, $\overline{I}$, $\overline{C}$, and $\overline{CI}$ represent average month-to-month percentage change, without regard to sign, in seasonal component, irregular component, cycle-trend component, and seasonally adjusted data, respectively. The "leading series" usually anticipate changes in general business conditions; the "coincident series" usually delineate changes in general business conditions; the "lagging series" usually follow changes in general business conditions [see G. H. Moore, "Statistical indicators of cyclical revivals and recessions," *Natl. Bur. Econ. Research Occasional Paper No. 31* (1950)].

Series	$\overline{CI}$	$\overline{I}$	$\overline{C}$	$\overline{S}$	$\overline{S}/\overline{CI}$	$\overline{S}/\overline{I}$	$\overline{S}/\overline{C}$	$\overline{I}/\overline{C}$
Leading series								
1. Business failures, liabilities	16.6	15.7	3.2	10.0	0.6	0.6	3.1	4.9
2. Industrial stock prices	2.0	1.5	1.2	1.0	0.5	0.7	0.9	1.2
3. New orders, durable manufactures	5.3	4.8	2.0	6.2	1.2	1.3	3.0	2.3
4. Residential building contracts	8.6	8.0	2.8	11.2	1.3	1.4	4.0	2.9
5. Commercial and industrial building contracts	13.5	12.8	3.0	10.6	0.8	0.8	3.6	4.3
6. Hours worked, manufacturing	0.4	0.3	0.2	0.5	1.4	1.8	2.8	1.6
7. New incorporations	4.3	4.0	1.3	8.4	2.0	2.1	6.7	3.2
8. Wholesale prices, basic commodities	2.2	1.4	1.3	1.2	0.6	0.9	1.0	1.1
Coincident series								
9. Nonagricultural employment	0.4	0.2	0.3	0.8	2.0	3.8	2.6	0.7
10. Unemployment, total	5.4	4.0	3.0	9.4	1.7	2.4	3.2	1.3
11. Bank debits outside New York City	3.1	3.0	0.8	6.1	2.0	2.0	7.7	3.8
12. Freight carloadings	3.4	3.0	1.2	5.1	1.5	1.7	4.4	2.6
13. Industrial production	1.1	0.7	0.8	2.3	2.1	3.4	3.0	0.9
14. Nonfarm wholesale prices, exclusive of foods	0.4	0.2	0.4	0.2	0.5	1.3	0.6	0.4
Lagging series								
15. Personal income	0.8	0.6	0.6	4.5	5.5	8.1	7.8	1.0
16. Retail sales	1.9	1.7	0.6	6.5	3.4	3.8	11.6	3.1
17. Instalment credit outstanding	1.7	0.3	1.7	0.8	0.4	2.3	0.4	0.2
18. Inventories of manufacturers	0.9	0.2	0.9	0.4	0.4	1.5	0.4	0.3

Other important findings can be discerned from these tables and from the listing (not given here) of the measures for each series in the sample. There is a high correlation between the magnitude of the amplitudes of the irregular, seasonal, and cyclical factors: Series with large irregular movements generally also have large cyclical and large seasonal movements. This implies some systematic relationship among the month-to-month forces represented by the irregular series, the annual forces represented by the seasonal series, and the longer-term forces represented by the cyclical-trend series. Furthermore, series which usually lead at business-cycle turning points usually have large irregular, seasonal, and cyclical fluctuations; series that are usually coincident at cyclical turning points usually have moderate fluctuations; and series that usually lag at turning points usually have small fluctuations (see especially Table 3). That is, series which respond promptly to prospective changes in business conditions also respond vigorously, and series which respond sluggishly also respond mildly.

These findings raise interesting new questions about the relations among the causes of economic fluctuations.

References and Notes

1. This article is an adaptation of more detailed statements appearing in economic and statistics journals, as follows: (i) J. Shiskin, "Electronic computers and business indicators," *J. Business* (Oct. 1957), republished as *Occasional Paper No. 57* by the National Bureau of Economic Research, New York, N.Y.; (ii) J. Shiskin and H.

Eisenpress, "Seasonal adjustments by electronic computer methods," *J. Am. Statist. Assoc.* (Dec. 1957), reprinted as *Technical Paper No. 12* by the National Bureau of Economic Research, New York, N.Y.; and (iii) J. Shiskin, "Seasonal adjustments of economic indicators," *Proc. Business and Econ. Sect. Am. Statist. Assoc.* (1957). The project described in this article has been carried on at the Bureau of the Census since the spring of 1954. During the academic year 1956–57, however, I extended and refined the electronic computer program during a year's leave of absence spent at the National Bureau of Economic Research. The tests of the program and the analysis of the relations among different types of economic fluctuations described were both made during this academic year. This work was financed by National Science Foundation and Rockefeller grants. Important contributions to this project have been made by Henry Eisenpress and Geoffrey H. Moore. Michael J. Conlon provided valuable assistance in the preparation of this article.

2. J. Shiskin, "New measures of recession and recovery," in preparation.
3. The method of time series decomposition described here follows the general plan formulated by early analysts of economic time series, particularly Warren M. Persons [see W. M. Persons, "Indices of business conditions," *Rev. Econ. and Statistics* (Jan. 1919); "An index of general business conditions," *ibid.* (Apr. 1919)].
4. For other tests, see the sources cited in (*1*).
5. The results for six additional series are shown in J. Shiskin and H. Eisenpress, "Seasonal adjustments by electronic computer methods," *J. Am. Statist. Assoc.* (Dec. 1957), pp. 432–433, chart 6.

Radiation Dose Rate and Mutation Frequency

The frequency of radiation-induced mutations is not, as the classical view holds, independent of dose rate.

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It is usually considered to be one of the basic tenets of radiation genetics that variation in radiation intensity—that is, dose rate—does not affect mutation rate. However, the experimental results upon which this conclusion is based were obtained only from certain cell stages, particularly *Drosophila* spermatozoa. The bulk of the radiation dose causing genetic hazards in man will be accumulated not in spermatozoa but in spermatogonia and oocytes. It was therefore of both practical and fundamental importance to question whether mutation rates observed following irradiation of these cell stages would also prove to be independent of radiation intensity.

Two major considerations that prompted such a question, in the face of the general acceptance of the absence of a radiation intensity effect on induced mutation rate, may be outlined. First, there has been increasing evidence that induction of mutation may not be as direct an action as had often been supposed, and that the mutation process in the gene may not be entirely independent of variation in its cellular environment. Consequently, there was room for speculation that even though the mutation process in spermatozoa is apparently independent of dose rate, it might not be so in metabolically active cells like spermatogonia. Second, it was reasoned that even if the actual mutation process in spermatogonia should prove to be, as in spermatozoa, independent of radiation intensity, nevertheless the mutation rate, as measured by mutations transmitted to the offspring, might still be dependent on dose rate, because of cell selection due to killing or other interference with the dynamics of the cycle of the seminiferous epithelium (*1, 2*).

With these two considerations in mind, experiments to determine mutation rates induced by chronic gamma irradiation in spermatogonia in mice were started. The first data from these experiments, and a comparison of them with mutation rates obtained earlier with acute x-irradiation, were presented at the April 1958 annual meeting of the National Academy of Sciences (*1*). They had been submitted earlier for a publication still in press (*2*), and they have also been discussed briefly elsewhere (*3*). The results showed a much lower mutation rate from chronic gamma than from acute x-irradiation. It was pointed out that, without further analysis, it could not be definitely decided whether the difference was attributable to intensity or to quality of radiation (although the latter seemed unlikely in view of the magnitude of the effect), and whether it was the mutation process itself that was involved or some secondary process, such as cell selection.

Since the time of the early reports, the data have been approximately doubled. Also, a number of new experiments, undertaken specifically for the purpose of analyzing the observed effect, have already thrown additional light on the problem. Because of the wide interest in this field, the present interim report has been prepared, bringing tabulation of the spermatogonia results up to date and presenting preliminary results from the new experiments.

Chronic Gamma Irradiation of Spermatogonia

Young mature male mice were exposed, in polystyrene cages of 3.0 to 3.5-millimeter wall thickness (more than adequate for secondary electron equilibrium), to a 5-curie Cs^{137} source. Dose rate was regulated by distance. Exposure was continuous (except for occasional interruptions of a few minutes) until the total dose had been accumulated (*4*). The males were mated to test females (see below) immediately following removal from the radiation field. However, only mutations induced in spermatogonia are considered in this section of this article. Unirradiated males were tested simultaneously with the irradiated.

Mutation rates were determined by the specific locus method. Irradiated and control males are mated to females homozygous for seven autosomal recessive visibles. The offspring are then examined for mutations at the seven loci. Details of the experimental procedure have been described earlier (*5*).

The results from the chronic gamma irradiation experiments are given in

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