Volume Title: The Frontiers of Economic Knowledge

Volume Author/Editor: Arthur F. Burns

Volume Publisher: Princeton University Press

Volume ISBN: 0-87014-056-6

Volume URL: http://www.nber.org/books/burn54-1

Publication Date: 1954

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Chapter URL: http://www.nber.org/chapters/c0395

Chapter pages in book: (p. 277 - 297)

Frickey on the Decomposition of Time Series

I. The Conventional Technique

The Review of Economic Statistics came to life with the publication of two remarkable papers by Professor Warren M. Persons on the nature and measurement of time-series fluctuations. Persons conceived of an economic time series as a composite of four types of movements—secular, seasonal, cyclical, and irregular. His main interest was in the problem of analyzing business conditions, and his hope was to develop, on the basis of historical records, a system of forecasting cyclical sequences in business life. Hence he eliminated secular trends and seasonal variations from time series, expressed the adjusted data in units of their standard deviation, and used coefficients of correlation to sort series according to their time sequence. This novel technique of handling economic data instantly attracted wide attention. Before long it was adopted by numerous investigators in this country and abroad; within a few years of its inception, it became the 'customary' or 'conventional' method of handling time series.

But as its use spread, there came criticism and dissent. Some questioned the propriety of some of the detailed methods employed by Persons and his associates. Others questioned the classification of economic movements, and proceeded to develop hypotheses of structural changes, of secondary versus primary trends, of special cycles in different branches of trade, of the intermittence of cyclical waves, and of the coexistence of several sets of cycles—each perhaps periodic but combining with others to produce the irregular waves of the familiar business indexes. Still others directed criticism at the 'empiricism' of Persons' methods. Will not the conventional technique decompose a series of random numbers as elegantly as an historical series? If movements of a given type are 'eliminated' from a time series, are the effects of a corresponding cause or group of causes likewise eliminated? Do not the forces of development within a capitalistic economy move in waves, cyclical depressions being the incidental wreckage of economic progress? If so, will the conventional technique bury real problems and create false ones? To the charge of empiricism, that of 'narrowness' was added. Is it wise to measure secular trends, seasonal variations, and cyclical amplitudes, only to discard them

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without further ado? Is not even the timing of cyclical fluctuations being handled with excessive simplicity? Is it proper to treat the problem of sequences without regard to the stage of the business cycle?

Criticism along these and similar lines was inevitable as the study of business cycles deepened. But it is worth noting that critics have all too frequently laid at Persons' door and that of his collaborators abuses committed by a host of ill-trained imitators. Today, few economists seem to remember that Persons' technique was originally developed for handling the problem of constructing a set of forecasting indexes of business conditions, or appreciate that, taken as a whole and in the light of the statistical data available at the time, it was well suited to the purpose for which it was designed. But it is also fair to add that while the 'conventional technique' gave a strong stimulus to economic research in general and to business cycle research in particular, it has proved of little aid in advancing the frontiers of our theoretical knowledge. There can be no regret that it is losing its preeminence. If economists are to gain authentic knowledge about business fluctuations, they must steadily test their tools of observation and seek to improve upon them.

Professor Edwin Frickey has worked by this creed. His book on *Economic Fluctuations*[1] makes an outstanding contribution to the methodology of time series. It is an original, painstaking, and scholarly work by an economist who for some years was closely associated with Persons. Frickey's book is directed mainly to the problem of trend-cycle separation. From some points of view, the methods that he presents for decomposing time series may be considered a rehabilitation of the customary technique; but if Frickey is the rehabilitator of Persons, his relation to Persons is much like Marshall's to Ricardo. Frickey sees the problem of time-series decomposition as essentially a problem in economic theory; it can never be solved by statistical procedure alone. Mathematical curve-fitting "enters not as the first step, but as the last in a long analytical process. It has its modest function, but it is in no way fundamental" (p. 335). Quasi-mechanical methods for separating secular and cyclical movements are to be shunned. Indeed, "the author's great misgiving in presenting this study is that there may somehow be supposed to be such a thing as the 'Frickey method' for

[1] Edwin Frickey, *Economic Fluctuations in the United States*, Harvard Economic Studies, No. 73 (Harvard University Press, 1942).

analyzing time series, capable of being applied automatically and universally" (p. 342).

II. The General Plan of Frickey's Work

The conventional method of adjusting data for secular trend involves a series of more or less arbitrary decisions. The statistician must decide upon the form of the mathematical equation that will represent the trend, on the period to which the trend is to be fitted, on the method of fitting the trend, on the time unit in which the data are to be expressed for this purpose, and on the manner in which the trend is to be removed. A similar range of decisions is necessary if moving averages are used instead of mathematical curves. There is thus ample opportunity for whim and judgment. Readers of this *Review* may recall Frickey's 'pig iron production case,' published in the October 1934 issue. Frickey assembled twenty-three mathematical trends fitted by other investigators, counted the number of full swings about each trend line, and ascertained the average duration of the 'cycles.' The results ranged, more or less gradually, from 3 or 4 years to 40 or 45 years.

This dramatic illustration sets the problem of the book. How are 'cycles' that are merely technical creatures of mathematical processes to be distinguished from economically significant cycles? Is it possible to anchor trend lines to firmly established knowledge, and thus narrow, if not eliminate, the range for discretionary judgment? These questions cannot be handled satisfactorily by analyzing series one at a time. A far more promising method is to "attack the problem as a *unified whole*" (p. 52). Ideally, this will involve a search for "consistencies and uniformities of behavior" (p. 53) over a wide range of economic data; some proximate solution of the puzzle of time-series decomposition; an interpretation of the results as a whole in the light of economic theory and history; finally, a reconsideration of the statistical work done earlier, "with a view to obtaining . . . a systematic and connected composite array of statistical results, accompanied . . . by a systematic . . . theoretical and historical interpretation" (p. 57).

The volume is concerned with the earlier sections of this far-reaching program. Part One poses the problem and the method of attack. Part Two is devoted to a "search for patterns of fluctuation" (p. 63) in economic time series for the United States over the half century between the close of the Civil War and the outbreak of World War I. From this search three major conclusions

emerge. First, in the period covered, "there is a clearly-defined pattern of short-run fluctuation which permeates the whole structure of the nation's industrial and commercial life" (p. 230). Second, the evidence suggests "the presence of one, and only one, definite pattern of fluctuation" (p. 231). Third, in the array of series analyzed, "certain long-run tendencies" are present, "which were gradually . . . overcoming the cohesiveness of these series and driving them away from one another" (p. 233). These conclusions serve as "foundation stones" (p. 20) for the decomposition of time series undertaken in Part Three. They also have considerable significance in their own right, and it is well to ponder them before passing to Frickey's decomposition.

III. A Standard Pattern of Short-Run Fluctuations

For many years Wesley C. Mitchell has worked with the concept that business cycles are not merely fluctuations of a certain order of duration in aggregate economic activity; they are also units of roughly concurrent fluctuations in many economic activities, and it is this feature, more than any other, that distinguishes them from the fluctuations in aggregate activity that occurred prior to the emergence of a business economy, and from other types of fluctuations in modern times. This concept finds striking confirmation in Frickey's entirely independent study.

The conclusion that a "smooth, wave-like fluctuation of particular form" (p. 230) has pervaded the nation's commercial and industrial life is reached by Frickey at the close of an extensive investigation, conducted with meticulous care, and therefore deserves the most serious attention. The investigation starts with an analysis of thirteen important series[2] in quarterly form: bank clearings in New York City, clearings in seven cities outside New York, loans of New York banks, railroad earnings, immigration, imports, exports, sensitive commodity prices, wholesale commodity prices, railroad stock prices, industrial stock prices, bond prices, commercial paper rates. After adjustment for seasonal varations, where needed, the series are converted into link relatives, which are then adjusted for differences in their average level (by taking deviations from geometric means of the relatives, series by series), for differences in amplitude (by expressing the deviations in units of their quartile deviation), and for differences in timing (by shifting the adjusted relatives forward or backward, also by in-

[2] The substance of this part of the study was published in the December 1934 issue of this *Review*.

verting them for two series). These adjusted series, Frickey finds, "exhibit a remarkable degree of correspondence" (p. 95). There is a "close approach to parallelism" among the curves showing quartiles of the adjusted link relatives; this fact "taken in conjunction with the presence of most clearly distinct 'zones of distribution' " of the relatives at successive quarters "affords decisive evidence as to the presence of a common pattern of movement among the series" (p. 96). By taking averages of the seven middle items, quarter by quarter, a "link-relative standard pattern" is obtained. As a final step, this pattern is converted from quartile-deviation units to percentages (by using the mean of the middle seven of an array of the thirteen quartile deviations), and then chained. The result is a "standard pattern" of *original items*, which delineates by quarters the common, pervasive, short-run fluctuation of the entire group of series; its oscillations "may be clearly traced—sometimes, to be sure, exaggerated or minimized; occasionally distorted by irregularities—in the movements of the original series" (p. 99).

I have described the derivation of this pattern in some detail, because it is the general method—modified slightly in some instances, considerably in others—pursued throughout the pattern studies. I must now summarize more boldly, even at the cost of conveying to the reader no more than an inkling of the methodical tests that Frickey employs to guard his results against unconscious bias. On the basis of a sample of about 100 annual production series, he derives patterns for major groups of industries—agriculture, mining, manufactures eventuating in capital equipment, manufactures eventuating in consumption, and transportation and trade. Agriculture aside, a "high degree of intrinsic correspondence" is found among the several groups in "the fundamental form of short-time fluctuation" (p. 167). This suggests the derivation of a pattern for industrial and commercial production as a whole. When the new pattern is compared with the standard pattern for thirteen series earlier described, "the correlation is truly remarkable" (p. 170). The patterns of commodity prices and of a group of miscellaneous series likewise confirm the standard pattern. So too does the form of the short-run fluctuation of various index numbers of production (excluding agriculture), employment, and wholesale commodity prices. Thus, whether a given group of series is examined collectively or combined in an index number, the same basic pattern emerges.

In view of the consilience of the evidence, Frickey is fully justi-

fied in drawing the conclusion that the standard pattern for thirteen series represents the form of a fluctuation that has pervaded the nonagricultural sphere of the economy.[3] This does not mean, however, that there are no flaws in the analysis. (1) In designing the sample of thirteen series, Frickey included "only important basic series" (p. 65); "highly inflexible" and "extremely erratic series" (p. 66) were rejected. The sample contains just one series expressed in a physical unit. The rest are price or value series, one of which—the index of sensitive commodity prices—is not only a subdivision of another price index included, but a subdivision deliberately made on account of sensitivity to business cycles. May not such a sample bias the results in the direction of 'consistencies and uniformities'? (2) The method of partition values, in the presence of distinct 'zones of distribution,' is said to yield a decisive test of a common or general pattern of movement. But in order that the test be decisive, the zones of distribution must not merely be distinct; they *must not overlap*—and this condition is obviously not fulfilled by Frickey's data. Under the circumstances either no test is decisive or this distinction belongs to a method not employed by Frickey; namely, a count, simple or weighted, of the rises and declines (allowing, of course, for leads or lags), period by period.[4] (3) Frickey relies on visual readings of charts to describe the degree of correspondence among his numerous curves. I think that he occasionally exaggerates the 'uniformities' and never the 'discrepancies' among the curves. I may, of course, be mistaken. If objective measures of correlation, with all their defects, had been presented, there would be less room for uncertainty on this score.

There are also several questions that Frickey's demonstration of

[3] I may add that this pattern agrees closely with the chronology of business cycles of the National Bureau of Economic Research. Allowing for leads or lags, every movement keeping the same direction for three quarters or longer in Frickey's standard pattern is matched by a corresponding movement in the Bureau's chronology of business cycles. Again, every phase of expansion and contraction in the Bureau's chronology (restricted, of course, to the period covered by Frickey) is reflected in a movement of corresponding direction, lasting three quarters or longer in the standard pattern; so that the two sets of cyclical waves are throughout in one-to-one correspondence. For a fuller comparison, see Chap. 4, Sec. VI of the forthcoming publication on *Measuring Business Cycles*, by Wesley C. Mitchell and the present writer.

[4] Curves of partition values are an extremely powerful device for bringing to the surface any tendencies towards a common rhythm in a mass of time series, but the device is a little too powerful—it can extract false rhythms as well as true ones. If the actual items of a group of series move chaotically between two dates, the partition values may still move uniformly in the same direction. Indeed, it is possible for all partition values to rise, while every series but one falls; or for all partition values to fall, while every series but one rises.

a pervasive, common, wave-like fluctuation leaves unanswered. What is the precise statistical meaning of the standard pattern? Does every wrinkle in this curve depict a movement that is diffused through the economy? That cannot be Frickey's meaning. But what, then, *are* the main movements, in historical time, that are supposed to be diffused? In what degree has each of these unit movements been in fact pervasive? What are the activities whose fluctuations correspond to the standard pattern? And what is the degree of correspondence or noncorrespondence in each instance? There are no answers to these questions in Frickey's book. They either are not considered at all, or are treated in an incidental fashion.

Nor has sufficient attention been given to the fact that the 'pervasiveness' of business cycles is relative to the units of observation. Assume a group of monthly series that cover rather comprehensively the nonagricultural sphere of the economy—say, aggregates or indexes of production, income payments, employment, freight traffic, bank clearings, wholesale prices. The cyclical fluctuations of these series will harmonize closely, though clearings and prices will occasionally fall out of step with the others. Now let each composite be broken down into 'major groups,' and numerous discrepancies of cyclical behavior will begin to appear. Carry the breakdown another step, and the divergencies will again multiply. Imagine this process of breakdown to continue until the 'ultimate' economic units are reached. What will the constellation of time series now look like? The smooth, wave-like fluctuations, keeping in close step with one another, will be gone. Their place will be taken by a confused network of millions or billions of curves, some inflexible, others erratic, perhaps some wave-like, crossing one another in crazy fashion. Hence if one economist 'sees' different branches of the economy moving in harmonious cyclical waves, and another 'sees' divergent fluctuations as dominant, the first is not necessarily right and the second wrong. Each may be essentially right in terms of the 'units' on which his mind's eye is centered; that is, with reference to the 'stage' at which economic behavior is being considered.

The crucial task that faces business cycle theory comes precisely at this point. No student of business fluctuations is, or can be, concerned with the ultimate units into which time series may, in principle, be broken. On the other hand, there are some—their number and influence seem to be growing—who believe, or write as if they believed, that the mechanism whereby business cycles

are generated can be adequately disclosed by analysis of a few broad aggregates. No one can be sure at present how far it is wise to go in breaking down comprehensive aggregates; the issue will be resolved, if at all, by experiment and performance, not by debate. I think, however, that Frickey is on the right track when, in outlining his program of research, he remarks that the search for 'consistencies and uniformities' must be followed by "investigation of inconsistencies and departures from uniformity" (p. 53). In other words, if we are to explain business cycles, we must know in some detail what activities participate in the general rhythm, what activities do not, what activities participate by rising and falling in harmony with the general tide, and what activities participate by rising throughout but more moderately during general contractions than during general expansions, what activities move early and what late in the general progression, what activities swing over a wide range and what have narrow amplitudes, and the changing relations of different activities in these respects from one business cycle to the next.

IV. The Problem of Long and Short Cycles

When economists discuss the dating of business cycles, they are apt to differ endlessly from one another. But when they get down to the task of measurement, their results are surprisingly similar. There is some disagreement over whether there was a contraction in 1918-1919 or 1926-1927; but practically everyone who has worked extensively with American data will agree that a contraction occurred in 1903-1904, 1907-1908, 1910-1911, 1913-1914, 1920-1921, 1923-1924, 1929-1933, and 1937-1938—to mention only the declines in business since the turn of the century. At this point agreement stops. Some believe that there is a single cyclical wave only; others believe that the 'short cycles' are subdivisions of 'long cycles,' and this group is divided into numerous sects, each devoted to its own brand of 'long cycles.'

The analyst who seeks to 'decompose' a time series must take a position on this question. If a time series is affected by just a single cyclical wave, one kind of statistical operation will be in order; if several sets of cyclical waves are simultaneously running their course, a more complex technique will be necessary. It is natural, therefore, that Frickey should seek to determine whether, in addition to the pattern of short-run fluctuation that stands out so clearly in his materials, patterns of long-run fluctuation are also present. His conclusion, already given, does not imply that long

cycles do not exist. What Frickey means is, simply, that cogent evidence in favor of the hypothesis of long cycles has failed to turn up in the course of his work; consequently, for the time being, he deems it best to take an agnostic position.

This judgment is based on an analysis of the thirteen quarterly series from which the standard pattern was originally derived. Frickey begins the search for new patterns by transforming the series into annual averages, and applying to them the technique used with such striking success on quarterly data. The results are negative: "we have merely in effect derived the old pattern over again" (p. 107). Next, this technique is applied to biennial averages, with the same results; to triennial averages, and again the same results; to sextennial averages—and once again "we see that the basic pattern of fluctuation first discerned in the quarterly analysis persists in practically unmodified form" (p. 123). Finally, the technique is tried on nine-year averages; the intercorrelation of the series is now weaker and the amplitude of the pattern narrower, but "so far as a pattern of movement does still remain in the nine-year results, it is altogether consistent with the patterns previously derived from quarterly data" (p. 127). Since the methodology has now "reached almost the point of technical breakdown" (p. 130) and the results remain negative, Frickey brings this phase of the investigation to a close.

Is Frickey's interpretation of the results correct? Imagine the standard pattern—I shall call it a quarterly index of business conditions for the present purpose—converted into annual form, then biennial form, triennial, etc. Since each wave of the index lasts several years, and since the successive waves vary considerably in duration and still more in intensity, it will not be surprising if the annual curve bears a good resemblance to the quarterly curve, and if the same is true, up to a point, of curves based on progressively coarser time units. Given such results, we may say that the wave-like form of the quarterly index is merely being reproduced by the curves based on broader time units. But will it not seem a little strange if wave-like fluctuations appear in six-year averages, even in nine-year averages, and analysis discloses that these fluctuations (though less pronounced than was the case when a finer time unit was used) are diffused among the constituents of the index? Can these fluctuations be dismissed on the mere ground that they trace out a curve that has a resemblance to the original curve of the quarterly index?

That, in essence, is what Frickey does. But the evidence may

be read differently. Insofar as full waves can be marked off in his patterns of six- and nine-year averages, their duration is eighteen years. If six- or nine-year *moving* averages had been used instead of straight averages, the waves would probably stand out more clearly than they do. These waves may be a genuine and distinct species of fluctuations, that is, 'long cycles.' On the other hand, they may be merely an illusion, resulting from the failure of the short waves, which vary in duration and intensity, to cancel out even in the six- or nine-year averages. That possibility could be tested by recognizing the long waves provisionally as higher units of fluctuation, and then seeing whether the short waves that occur during the upswing of the long waves differ from the short waves during the downswing of the long waves in a manner consistent with the long-cycle hypothesis.[5] If this test should be met, the provisional long cycles might still be suspect; for example, because they are not uniform multiples of short cycles, or because they are so few in number, or because they are not confirmed by evidence—statistical or historical—outside the thirteen-series sample, or on all these grounds. Frickey has not tracked down any of these possibilities. He does note that the results of the pattern studies are "at least consistent" (p. 132, n.) with the Kondratieff hypothesis, but it would seem that they are more nearly consistent with certain other long-cycle hypotheses than that of Kondratieff.

At the close of the book Frickey reasserts his agnosticism on the perplexing subject of long cycles. He notes, however, one interesting relationship suggested by a group of twelve series subjected to intensive trend analysis. "While our time period of analysis is . . . too short to afford any decisive test of the Kondratieff long-wave hypothesis, we may nevertheless note in passing that the showing of the trend-indication lines . . . , and especially the behavior of these lines around the turn of the century, is at least consistent with this hypothesis . . . ; and the array of evidence . . . can be made to fit into his statistical scheme" (p. 340). This comment seems to overlook the fact that the Kondratieff hypothesis posits *general* long waves—that is, long waves in both the production and price spheres—and that its significance for business cycle theory turns on this point. If Frickey's representations of the trends of the employment and production indexes (the former is an exponential, the latter a logarithmic parabola, showing retardation) are valid, they seem to argue against Kondratieff. Nine other series relate to prices or values; their behavior is consistent

[5] See *Measuring Business Cycles*, cited above, Chap. XI.

with Kondratieff's hypothesis, but also with the simpler and older hypothesis of long waves in prices. The behavior of immigration, the one remaining series, is again consistent with Kondratieff's hypothesis; but the most striking feature of this series is its tendency to move in waves that are about a third of the Kondratieff period—waves found also in railroad construction and, among Frickey's series, in railroad stock prices. I do not think, therefore, that the Kondratieff hypothesis gains much support from Frickey's trend analysis.[6]

These doubts arise solely in regard to some of the methods used by Frickey and the interpretation that he has placed on the results. They are not directed at his conclusion concerning "the presence of one, and only one, definite pattern of fluctuation." On the contrary, agnosticism on the subject of general long cycles seems, at the present time, definitely the better half of wisdom.

V. The Nature of Time-Series Variations

It is only after the extensive search for patterns and certain supplementary investigations have been completed that Frickey feels prepared to define the nature of time-series variations, and even then does it merely to a first approximation. This procedure is in decided contrast to that followed by Persons in his basic memoir on time series. Why does not Frickey follow Persons' example —make common sense his ally at the start, define forthwith the movements in time series, and get down to the business of segregating them? Why are so many elaborate preparations necessary? The answer is simple. Frickey is concerned with fundamentals. His aim is to "build from the bottom," to carry through the analysis of time series in such a manner "that in the end the results shall portray only relationships inherent in the original data" (p. 50). This explains the avoidance of the conventional technique, even of moving averages and other smoothing devices, in the pattern studies.[7] If the task of time-series decomposition is to isolate variations that are "inherent in the material" (p. 254), these varia-

[6] See George Garvy, "Kondratieff's Theory of Long Cycles," this *Review*, Vol. xxv (1943), pp. 203-220.

[7] Of course, it is impossible to avoid elements of these techniques completely. In deriving the standard pattern, Frickey in effect eliminates exponential trends, passed through the first and last data points of the individual series. Again, annual figures, on which he is forced to rely heavily, may be considered a degenerate form of a twelve-month moving average, one term being used and eleven dropped, in repetitive sequence.

tions must disclose something of their true economic nature before refined methods can be justified.

And that is precisely what the pattern studies have accomplished. If a smooth, wave-like, short-run fluctuation pervades the industrial and commercial life of the nation, if there is definite evidence of only one such pattern, and if the mutual attachment of the series tends to weaken as successively longer periods are analyzed, then it is plain "that elements of short-run and of long-run movement are present" (p. 241) in the statistical material. But what is the precise nature of these two elements and the relationship between them? To throw light on this question, Frickey subjects twelve important series to further analysis—an index of production, an index of employment, and ten of the original thirteen-series sample.[8] The series are broken into subperiods according to several different plans, and differences in amplitude and timing in each subperiod are eliminated, in order to see how the "form of short-run fluctuation . . . is affected by the long-run tendencies" (p. 244). Within each subperiod "distinct differences" emerge "with respect to general direction of movement" (p. 245). There is a "strong and ubiquitous tendency for the various curves . . . to drift apart from one another in a comparatively smooth and gradual way. . . ." On the other hand, "setting aside . . . relatively minor and incidental features" of the curves, "the general impression is one of striking congruence in the contours of short-run movement" (p. 247).

In view of these findings Frickey concludes that "it is a good first approximation to the truth to say that the time-series variations (setting aside seasonal and irregular fluctuations) are resolvable into smooth, continuous, gradually-changing long-time movements which may appropriately be designated 'secular trends,' and wave-like short-time oscillations which may appropriately be designated 'cyclical variations.' " Further, since investigation had disclosed a tendency towards a simple proportionate relationship between the short-run absolute fluctuations of time series and the size of original items, it is also "a good first approximation to assert that the relationship" between secular trends and cyclical variations "is that of being logarithmetically additive" (p. 253). These are, of course, familiar propositions; the novelty lies in their demonstration.

Frickey is careful to explain that this demonstration has been

[8] Loans of New York banks, exports, and bond prices are dropped because of their irregular conformity to the standard pattern.

carried through for only a small group—though a highly important group—of time series. He also recognizes that since the demonstration is limited to a fifty-year period, the movements designated as secular trends may, in fact, be segments of long-wave movements, and that the movements designated as cyclical variations may, in fact, be a composite of major and minor cycles. Nor can we assume that secular trends and cyclical variations are due to independent causes; "we should think here, not in terms of distinct sets of causal forces, but in terms of *lines of causal influence*" (p. 256). By this Frickey means, apparently, that 'economic forces' produce divergent trends in different activities, while they simultaneously produce cyclical movements which, apart from variations in timing and amplitude, have substantially the same contours in one activity and the next over a considerable part of the economic system.

This interesting interpretation of the nature of time series is bound to excite the reader to raise some questions. For example, what happens to the postulate that secular trends and cyclical variations are logarithmetically additive, in the case of series that conform well to the short-term general rhythm but that consist of plus or minus values—series like net incomes of business firms or net additions to inventories? Is it proper to assert, even as a first approximation, that certain causal impulses impinge with substantial uniformity on the short-run fluctuations of different parts of the economic system? Do not the very developments that produce variations in timing and amplitude among different activities also produce variations in the contours of their fluctuations? For example, pig iron production, as a rule, has registered its maximum rate of advance early in cyclical expansions, and its maximum rate of decline late in cyclical contractions. Commercial paper rates, on the other hand, have tended to register their maximum advance late in expansions and their maximum decline early in contractions. Such differences have been essential parts of the business cycle mechanism. They cannot be disregarded by economic theorists or statisticians. It is only proper to add, however, that Frickey's neglect of this feature of time series is not of serious moment in connection with his method of decomposing time series.

VI. The Decomposition of Time Series

The method devised by Frickey to separate secular trends and cyclical variations is highly ingenious. Putting qualifications aside, he removes the cyclical variations from a series and gets its secu-

lar trend as a residual—which is the very opposite of the conventional technique. The method is a logical sequel to the findings reached earlier in the book. For if a time series is resolvable into a secular trend and cyclical variations,[9] and the standard pattern delineates the cyclical variations that permeate economic life, then it should be possible to derive the trend of a series by dividing its successive values by corresponding values of the standard pattern. The actual statistical operations, however, must be more elaborate, partly because the standard pattern is an imperfect gauge of the cyclical variations, partly because the observable fluctuations of individual series—even after allowing for differences in cyclical timing and amplitude—are not precisely congruent with the standard pattern.

The first task is to refine the standard pattern. In deriving this pattern, link relatives were used in the form of deviations from their geometric mean—an operation that implies exponential trends. In fact, there is very great diversity in the relationships of the secular trends over successive decades; but this very fact makes it probable that the diverse trends have largely offset one another in the standard pattern. Frickey therefore proceeds to eliminate from the twelve series selected for experimentation the particular form of variation traced out by the standard pattern. Once modified, the series are broken into several subperiods and a logarithmic straight line fitted to each. With these 'trend indications' as a guide, tentative trend lines are drawn. The standard pattern[10] is now recomputed, the adjustments for trend being made on the basis of the tentative trend lines instead of the crude corrections originally applied. But the revised pattern makes it possible to derive secular trend lines more accurately than before; hence the whole round of operations is repeated. The new tentative trend lines, in their turn, make it possible to revise the standard pattern once again. Since this revision turns out to be almost an exact replica of the first revision, "the logical stopping place in the present line of procedure" has manifestly been reached. "The process of gradual attenuation of the secular elements in the standard pattern" has been practically completed; in other words, the second revision constitutes "a rather faithful picture of *the cyclical element in isolation*" (p. 329).

With this objective realized, the remaining operations are straightforward. In general, they follow the model just sketched.

[9] Setting aside, of course, seasonal and irregular fluctuations.
[10] Based on ten series. See note 8.

The full period is broken into seven subperiods, each corresponding approximately to a full fluctuation of the standard pattern about its base line. The logarithms of the standard pattern are then adjusted for differences between their amplitude and that of the series during each subperiod. Next, the figures thus derived are subtracted from the logarithms of the original items—which are first shifted a little, here and there, to allow for leads or lags. The resulting modified series are "primarily and essentially representative of secular variations" (p. 290). To remove minor errors and irregularities from the modified series, straight lines are fitted for each subperiod, and these 'trend indications' serve as a guide—followed closely but not slavishly—for drawing up a final schedule of trend lines.

Two series—the production index and the employment index—are fitted by simple mathematical curves, the first by a logarithmic parabola, the second by an exponential curve. Of the remaining ten series there are "few, if any, for which the secular variations are capable of satisfactory representation by a single simple mathematical curve" (p. 292). Hence the series are split into subperiods, and a trend line fitted separately to the logarithms of the data in each subperiod. For example, the secular trend of industrial stock prices is represented by a straight line during 1866-1904 and a parabola during 1904-1914. Other series are broken into three or even four subperiods, the interval varying from four to thirty-nine years.[11] The trend lines involve, of course, a certain degree of

11 Frickey believes that "wide diversity and decided individuality as regards the form of secular variation" (p. 315) are by no means peculiar to his sample. Although simple mathematical curves fit a few broad aggregates admirably for half a century, they cannot be generally trusted to represent secular trends. True, individual industries predominantly grow at a declining rate, but their "long-time tendencies . . . are much less simple than has commonly been supposed" (p. 151). The logarithmic parabola is satisfactory for pig iron production in the period studied, but few individual production series "can be suitably represented" (p. 340, n.) by this function. A broad range of evidence "strongly suggests that the secular movements of economic series over long periods do not in general tend to proceed in accordance with 'laws' embodied in simple mathematical functions" (p. 292). I think all these broad observations are well founded, though here and there a special interpretation clause may be desirable.

A few of Frickey's detailed observations concerning secular trends seem a little careless. I shall restrict comment to one point, which is of some significance. Frickey compares (a) the median of average rates of retardation for individual production series ending in 1929 with (b) the average rate of retardation of a chained median of link relatives for the same series ending in 1914. Such comparisons are made for several groups of series. The results show that (a) is consistently and appreciably higher than (b), which leads Frickey to state that the evidence strongly suggests that the "predominant general tendency *is not simply for the pre-war retardation rate to continue into the post-war years 1915-29, but rather is for the retardation to become*

discretionary judgment; but the difference in this respect between the new method and the conventional technique is "great enough to constitute a difference in kind" (p. 340). The trend lines and curves of cyclical variations[12] are presented as "first approximations to the truth" (p. 339).

Frickey's method of decomposing time series is the product of careful reasoning, searching, and testing. The most attractive feature of the technique is that both secular trends and cyclical variations are determined in a series of successive approximations, the entire group of series being handled as a unit to facilitate consistent judgments. In contrast to the conventional technique, which can be applied to any series whatever, Frickey's method can be properly used only in the case of series whose fluctuations bear a close correspondence to the standard pattern. "The application of our present procedure to a series not possessing this property of correspondence . . . would be unjustified, and the results would in all probability be absurd and meaningless. We must . . . enter an emphatic caveat against any such perversion of the methodology" (p. 288). But what series and how many series will meet the criterion of close correspondence? That depends, of course, on how strictly the criterion is applied. Between series like sugar meltings, which move in virtual independence of business cycles, and series like pig iron production, which move in almost perfect harmony, there is a continuous gradation. The criterion of close correspondence could be applied so strictly as to disqualify one of Frickey's mainstays—the index of wholesale prices, which suffers some notable lapses from conformity. On the other hand, it could be applied so liberally as to admit bond prices, which Frickey excludes. If the standard pattern were extended into the thirties, commercial paper rates would become a somewhat doubtful case, while exports might beckon for reinclusion. These difficulties must not, however, be exaggerated. Frickey's method is likely to prove satisfactory even if a series shows serious lapses from conformity during some periods. If that is true, the method can be applied rather extensively.

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more severe in these later years" (p. 166). No degree of qualification can make this anything but a very dubious statement. The question of fact involved here is difficult to handle even by explicit calculation for the shorter period on plan (a). It surely cannot be handled by a mere process of inference from (a) and (b), for there is no fixed or simple relationship between (a) and (b). For example, it is mathematically possible for (b) to show a zero rate of retardation or even acceleration, although every series but one shows definite retardation.

[12] The latter, as in the conventional technique, are considered as percentages of corresponding trend ordinates.

But is not the method far more expensive than the conventional technique? It is difficult to answer this question, because in practice the 'conventional technique' means different things to different investigators. Some statisticians fit and remove trend lines with speed and authority; others need to make many experimental calculations before they 'hit upon' a curve they are willing to accept even tentatively. In any case, the elaborateness of Frickey's technique is not likely to prove a deterrent for long. Practical statisticians who may wish to use the method are sure to discover, sooner or later, how to 'cut corners' and yet get results that do not differ seriously from those obtained by a literal application. For example, satisfactory approximations of Frickey's results might possibly be obtained by (1) passing a moving average through a series so as to remove approximately the cyclical variations, (2) fitting freehand straight lines to the moving averages for subperiods such as Frickey's, and (3) using these trend indications as a guide to the final trend line—which may again be a freehand curve.

Frickey's method clearly has a scientific foundation; its superiority over the conventional procedure of treating series one at a time, with only vague ideas tying the operations together, is beyond question. This does not mean, however, that the actual statistical results will necessarily be very different from those yielded by the conventional technique. If a statistician fits a line of secular trend to pig iron production in a mechanical manner, without specifying in advance his conception of the secular trend or of cyclical fluctuations, he may get 'cycles' averaging four years in duration, or ten times as long. But a judicious and informed investigator who is seriously studying cycles of a given order of duration will examine the series closely before choosing the trend line; he will seek to mark off the cycles observable in the original data or their first differences, and then fit a trend line that cuts through and exposes the cycles in which his interest centers. Discretionary judgment will enter into the operation, but the scope for its wanderings will be comparatively narrow—though perhaps not so narrow as in Frickey's method. What chiefly distinguishes Frickey's method is its explicit and thorough foundation, not the shapes of the curves finally derived by its use.

These shapes, as Frickey carefully notes, still involve *some* discretionary judgment. Let the reader examine Frickey's results closely. Is he not tempted to draw the trend line a little differently here, and a little differently there? But how tell whether the

one drawing is better than the other? "We are confronted here with a problem in probabilities" (p. 333); but there is no mathematical technique for rendering the probabilities. Granting that the trend lines are 'approximations to the truth,' how can we test the goodness of the approximations? If some indeterminacy persists, should we recognize that fact explicitly, by giving up trend *lines* and drawing trend *zones* instead? One way, perhaps the only way, of making any headway with these difficult questions is to check 'decomposed' time series against historical information. Thus, if we accept Frickey's trend lines provisionally, we must also accept each full swing about the trend lines as a cycle, and we can then inquire how well these cycles check against historical evidence of business fluctuations. To cite an example, it seems rather clear that a general contraction in American business activity occurred in 1869-1870, 1890-1891, 1895-1897, and 1899-1900. Each of these contractions is reflected in Frickey's production index, but the first two appear in their entirety above the trend line and the last two are sunk below the trend line. If the historical validity of these cyclical movements is accepted, the trend line of the production index requires some adjustment. On the basis of the criterion just suggested, I should be inclined to modify most of Frickey's trend lines, but the modifications would in most instances be slight. I am, of course, anticipating here the next stage of Frickey's program of research—which, it should be recalled, requires an interpretation and reconsideration of the statistical results in the light of economic theory and history.

VII. The Problem Ahead

It will be interesting to see what use Frickey makes of the segregated trends and cycles in the next stage of his research. The secular trend lines that he has developed are 'real' in the sense that they delineate, to a first approximation, certain tendencies in time series conforming to business cycles; that is, the direction and rate of change of the series, when cyclical variations and still shorter movements are put out of sight. The cyclical variations are 'real' in the sense of being diffused over a considerable part of the economic system. An array of trend lines and curves of cyclical variations—especially when the latter are left without adjustment for differences in amplitude—yields a highly useful description of the paths of change followed by different business factors. But how will activities that conform irregularly or badly to the general cyclical rhythm—for example, agricultural produc-

tion, most food manufactures, some branches of textile output, public construction—be brought into the statistical picture? Frickey is fully aware of this problem, and undoubtedly will find some solution.

But too much must not be expected from trend-cycle separations, no matter how that problem may be solved. By eliminating cyclical variations (and still shorter movements) it is possible to isolate for scrutiny relationships among basic economic factors that persist over periods longer than business cycles. By eliminating secular trends, it is possible to isolate approximately the cyclical path of economic change, and demonstrate the imprint of business cycles on the economy. That much is clear. But what else can the separation of secular trends and cyclical variations accomplish? Specifically, is it likely to contribute materially to knowledge of causal relationships? Will time series adjusted for secular trend by Frickey's technique add more to an understanding of the mechanism of business cycles than have time series adjusted for secular trend by the conventional technique?

There is room for skepticism on these matters. Let us recall the history of electric power production during recent decades—its amazing growth, its resistance to moderate business depressions. Does it seem at all likely that this activity, and others correlated with it, have played a role in business recoveries similar to that of, say, the beehive coke industry? Yet when the secular trends are removed, whether by Frickey's method or the conventional method, electric power production becomes merely another 'index of business conditions'; there is little to distinguish it, except for a difference in amplitude, from the output of beehive coke or a dozen other industries. That which is most characteristic of the industry, most suggestive of its part in economic development, has been put out of sight. Or take another example, railroad investment. If the secular trend is left in the data, it soon becomes apparent that during the seventies and eighties this process tended to lead American recoveries by a substantial interval; but as the decades rolled on, the leads became shorter, and now have disappeared. This fact suggests that the industry shifted from an 'active' to a 'passive' role in business cycles, and raises the question whether the same may not be true generally of industries as they pass through successive stages of development. All this is lost or blurred when the secular trend is removed from the data; for the characteristic effect of this statistical operation is to standardize cyclical movements.

These observations are not directed against the decomposition of time series in general, or even against trend-cycle separations. No one who has seen seasonal variations fairly step out of charts, or watched important series climb rapidly during business cycle expansions and hesitantly during contractions, can question the value of even crude attempts to decompose some time series. The separation of secular trends and cyclical variations—especially by Frickey's technique—is sure to prove highly useful in tracing the imprint of business cycles on economic life. It seems unlikely, however, that trend-cycle separations will prove of equal advantage when effort shifts from statistical description to the explanation of business cycles. If these comments are valid in their general drift, the student of business cycles will want to remove secular trends at one stage of his work and leave them in at another stage.[13]

Frickey has kept his own counsel on the specific methods he intends to pursue in carrying his investigation to the next stage. But he remarks that "it is precisely in the course of the investigation of inconsistencies and departures from uniformity that we may hope to find those clues which, traced back, will enable us to surprise basic economic forces in the course of their operation" (p. 53). This attitude, combined with the fact that Frickey has lavished considerable attention on secular trends as matters of curiosity in their own right, indicates that he has broken with the tradition built up by the conventional technique and promises well for his future studies.

VIII. Concluding Comments

To give emphasis to some of the points covered in this review as well as make partial amends for its omissions, I conclude by listing what seem to me to be the leading contributions of Frickey's book. These include:

1. Elaboration of a technique for searching for 'consistencies and uniformities' in time series, capable of wide application.

2. Demonstration, on the basis of an extensive sample, of a rhythmic fluctuation pervading the economic life of the United States during the period from 1866 to 1914.

3. Delineation of the cyclical pattern of economic change by a quarterly index covering this period.

[13] Cf. *Measuring Business Cycles*, cited above, especially Chap. 3, and Joseph A. Schumpeter, *Business Cycles* (McGraw-Hill, 1939), Vol. I, Chaps. 3-5.

4. Careful formulation, and partial test, of a hypothesis concerning the nature of time-series variations.

5. A new and improved technique for separating secular trends and cyclical variations.

6. An improved technique for fitting secular trend lines.

7. Development of some new statistical series, the most important being an index of manufacturing employment, of manufacturing production, of the output of the transportation and communications industry, and a composite of the two preceding indexes.[14]

8. Presentation of a large body of significant economic measurements.

A good craftsman knows how to make a chain that will be stronger than its weakest link. He does it by doubling and tripling the links, especially when he suspects a link may be weak, and also when he believes it to be strong, so that the chain may stay firm even if some of the links break. This basic methodological principle has been observed by Frickey on a scale rarely equaled in economic research. The result is a book that, beside making substantial contributions to knowledge, bids fair to become a significant educational instrument.

[14] Only a brief description and graphs of the indexes are now given. The full record will be presented by Frickey in a later publication.