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CHAPTER 3

National Bureau Measures of Cyclical Behavior

This study uses extensively the National Bureau technique of describing and measuring the cyclical behavior of economic data. When we wish to know, for example, how regularly inventories rise during business expansions and fall during contractions we use the Bureau's measure of 'conformity'. When we wish to know whether cycles in manufacturers' inventories generally reach their peaks before or after general business activity, or before or after manufacturing production or sales we use its measure of 'timing'. When we wish to know how wide the cyclical swings of inventories are compared with those of production or shipments we compute measures of 'amplitude' according to the Bureau's method. And so on.

The National Bureau measures of cyclical behavior, together with elaborate tests, are described in detail in *Measuring Business Cycles*. Close students of business cycles are referred to that volume. Other readers will need a brief description of the Bureau's statistical techniques if they are to understand the methods and conclusions of this study. This chapter attempts to meet that need.[1] It relies heavily on Chapter 2 of *Measuring Business Cycles*. Indeed, entire pages of that chapter and all the illustrative tables are reprinted below. Verbal alterations have been made in some sections because of the difference in context, and some material has been added.

The description in Chapter 2 of *Measuring Business Cycles* applies in detail only to the measures made from data reported by

[1] The measures used by the Bureau are not complicated, but they are numerous. The reader would probably do well to read this chapter once, then refer back to relevant sections as the results of particular measurements are set forth.

months. In the absence of monthly data, we often have to use quarterly or annual data, and this is especially true of this study. Annual data, moreover, come in various forms: as aggregates or averages for calendar or fiscal years, and as values for a certain month or day, the latter notably in financial data based on end of year balance sheets of corporations. We therefore supplement the description of the procedures applied to monthly data with an explanation of the methods followed when the figures are for calendar years or single dates. Fiscal year data are not treated, since the procedures are identical with those applied to calendar year series, except that the chronology of business cycle turns is for a fiscal instead of a calendar year. Nor are the measures applied to quarterly data described, since they closely resemble the methods used for monthly data. Readers interested in the minor differences will find them described in *Measuring Business Cycles,* pp. 197–202.

The results from annual data are not nearly as accurate as those from monthly or quarterly data. Yet annual data can yield very useful information. But if they are to be more helpful than misleading, their limitations must be known and respected. The latter part of this chapter is, therefore, devoted to a brief discussion of the differences to be expected when the figures are annual instead of monthly or quarterly.

1 Description of the Measures[2]

REFERENCE DATES, REFERENCE CYCLES, AND SPECIFIC CYCLES

To learn how different economic processes behave in respect of business cycles, their movements must be observed during the revivals, expansions, recessions, and contractions in general business activity. Before we can begin observing we must mark off these periods. To that end we constructed a table of 'reference dates', showing the months and years when business cycles reached troughs and peaks. These dates were based first upon the business annals compiled for the National Bureau by Willard L. Thorp; then we refined, tested, and at need amended the dates by studying statistical series. These turning points of the cyclical movements in

[2] This section largely, though not entirely, duplicates Chapter 2 of *Measuring Business Cycles.*

general business activity can be made more precise as the field covered by statistics expands. Hence we have more confidence in the later than in the earlier dates. Table 4 sets forth the National Bureau standard reference dates for the United States since 1853.

TABLE 4
Reference Dates, United States, 1853-1939

MONTHLY		QUARTERLY		CALENDAR YEAR		FISCAL YEAR (ENDING JUNE 30)	
Peak	Trough	Peak	Trough	Peak	Trough	Peak	Trough
	Dec. 1854		4Q 1854	1853	1855		
June 1857	Dec. 1858	2Q 1857	4Q 1858	1856	1858		
Oct. 1860	June 1861	3Q 1860	3Q 1861	1860	1861		
Apr. 1865	Dec. 1867	1Q 1865	1Q 1868	1864	1867		1868
June 1869	Dec. 1870	2Q 1869	4Q 1870	1869	1870	1869	1871
Oct. 1873	Mar. 1879	3Q 1873	1Q 1879	1873	1878	1873	1878
Mar. 1882	May 1885	1Q 1882	2Q 1885	1882	1885	1882	1885
Mar. 1887	Apr. 1888	2Q 1887	1Q 1888	1887	1888	1887	1888
July 1890	May 1891	3Q 1890	2Q 1891	1890	1891	1890	1891
Jan. 1893	June 1894	1Q 1893	2Q 1894	1892	1894	1893	1894
Dec. 1895	June 1897	4Q 1895	2Q 1897	1895	1896	1896	1897
June 1899	Dec. 1900	3Q 1899	4Q 1900	1899	1900	1900	1901
Sept. 1902	Aug. 1904	4Q 1902	3Q 1904	1903	1904	1903	1904
May 1907	June 1908	2Q 1907	2Q 1908	1907	1908	1907	1908
Jan. 1910	Jan. 1912	1Q 1910	4Q 1911	1910	1911	1910	1911
Jan. 1913	Dec. 1914	1Q 1913	4Q 1914	1913	1914	1913	1915
Aug. 1918	Apr. 1919	3Q 1918	2Q 1919	1918	1919	1918	1919
Jan. 1920	Sept. 1921[a]	1Q 1920	3Q 1921	1920	1921	1920	1922
May 1923	July 1924	2Q 1923	3Q 1924	1923	1924	1923	1924
Oct. 1926	Dec. 1927[a]	3Q 1926	4Q 1927	1926	1927	1927	1928
June 1929	Mar. 1933	2Q 1929	1Q 1933	1929	1932	1929	1933
May 1937	May 1938[a]	2Q 1937	2Q 1938	1937	1938	1937	1939

Source: *Measuring Business Cycles*, Table 16, p. 78.

[a] The following reference dates have been revised by the National Bureau since the computations in this study were completed: Sept. 1921 to July 1921; Dec. 1927 to Nov. 1927; May 1938 to June 1938.

After eliminating seasonal variations we divide the series into segments marked off by reference troughs. Since each segment spans an interval between successive reference troughs we call it a 'reference cycle segment', or 'reference cycle' for brevity.[3] Next we compute the average of the monthly values during each 'reference cycle' and convert the data into percentages of this base; these percentages are called 'reference cycle relatives'. The application of a uniform set of dates to all series, and the reduction of the original data expressed in diverse units to relatives of their average values during the periods thus marked off, put all the materials into com-

[3] We find it convenient to use the term 'reference cycle' in two senses: first, to denote the section of a time series between the dates of successive reference troughs (or peaks); second, to denote the interval between successive troughs (or peaks). The meaning should be obvious from the context.

parable form and enable us to see how different processes behave during successive business cycles.

Next, we look in every series for wavelike movements whose length is of the same order as that of business cycles. We call the cyclical movements peculiar to a series its 'specific cycles'. In most series the dates of the troughs and peaks of the specific cycles are fairly clear, but in some series they are obscured by erratic fluctuations. We mark off the specific cycles by the dates of their turning points as well as we can, compute the average value of the monthly data during each cycle, and convert the monthly data into 'specific cycle relatives' which correspond in every respect to the reference cycle relatives, except that they show movements during the cycles in the series itself.

One complication requires attention at this point. Most series studied in connection with business cycles tend to rise during expansions of general business and to fall during contractions. They have what we call 'positive' cycles. Many series, however, have 'inverted' cycles, that is, they tend to fall during business expansions and rise during contractions. Such 'inverted' series are especially numerous among manufacturers' inventories. The specific cycles in 'positive' series are treated as units running from trough to trough, those in 'inverted' series are treated as units running from peak to peak.

We distinguish between 'positive' and 'inverted' series in the following manner. If a series typically moves in the same direction as general business activity over a larger portion of a reference cycle than it moves in the opposite direction, we treat the series as 'positive'.[4] In the opposite case we treat it as 'inverted'. If a series typically rises from the middle of a reference expansion to the middle of a reference contraction, or from the middle of contraction to the middle of expansion, we call the series 'neutral', but we arbitrarily analyze the specific cycles on a 'positive' basis, that is, as units running from trough to trough. The same procedure is followed in the case of series whose movements have no regular relation to business cycles.

We illustrate our procedure for a positive series. We chose coke

[4] We measure the size of the portion in terms of the 9 'reference stages' into which each reference cycle is divided; see below.

production because it is a relatively short series and presents few of the complications we ordinarily encounter (Table 5). The seasonally adjusted figures are plotted on Chart 1, which shows also the turning points of business cycles and of the cycles in coke production. The average monthly production of coke during its first complete cycle, November 1914 to May 1919, was 4,246,000 short tons. With that figure as a base, the monthly values in Table 5 for the months covered by this cycle are converted into specific cycle relatives. The first reference cycle covered by this series runs from December 1914 to April 1919. Average monthly output was 4,305,000 short tons, and on this base we compute the first set of reference cycle relatives. During the second specific cycle, May 1919 to July 1921, average monthly output was 3,565,000 short tons; during the second reference cycle, April 1919 to September 1921, it was 3,417,000 short tons. These figures are the bases upon which relatives are computed for the second specific and the second reference cycle. The turning points shown on Chart 1 mark off three more specific and three more reference cycles, for each of which we compute cycle relatives. In annual series the cycle bases are computed by striking averages including all the years from one

TABLE 5

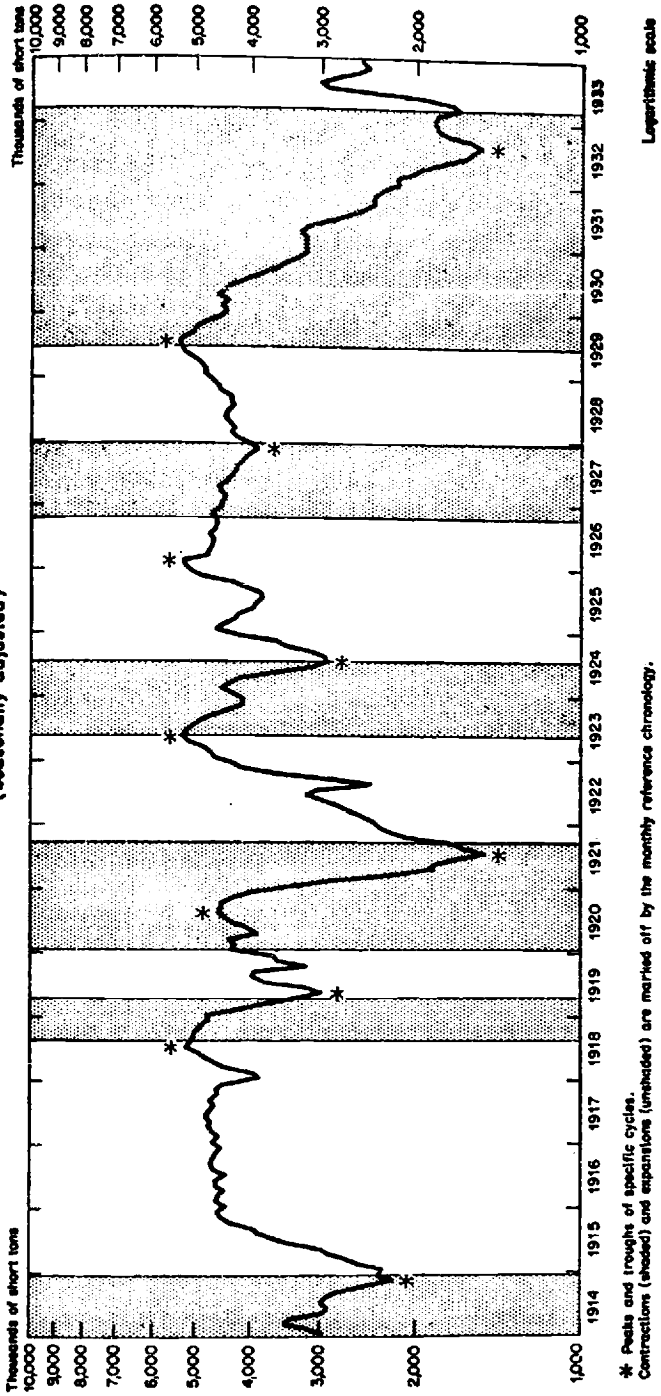
Coke Production

(thousands of short tons)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1914	2973	3147	3476	3364	2940	2897	2991	2927	2797	2531	2193	2348
1915	2281	2555	2675	2897	2990	3410	3613	3873	3959	4320	4475	4553
1916	4381	4564	4554	4425	4581	4581	4392	4667	4684	4655	4593	4499
1917	4664	4523	4672	4720	4693	4778	4731	4611	4693	4542	4577	4452
1918	3855	3957	4415	4639	4801	4941	5228	5067	5033	5017	4844	4780
1919	4763	4126	3773	3335	2977	3173	3777	3987	3943	3157	3600	3624
1920	4329	4261	4360	3885	4031	4299	4412	4536	4520	4496	4284	3971
1921	3314	2886	2203	1855	1860	1679	1497	1637	1719	2076	2231	2338
1922	2391	2512	2658	2798	2979	3180	3038	2413	2927	3638	4145	4342
1923	4650	4695	4853	5174	5250	5216	5076	4901	4641	4362	4132	4107
1924	4278	4493	4386	4199	3581	3108	2923	2936	3132	3466	3596	4182
1925	4599	4458	4259	4204	3950	3900	3804	3838	4102	4333	4836	5087
1926	5244	5280	4746	4719	4643	4635	4721	4606	4578	4604	4665	4495
1927	4471	4426	4521	4553	4389	4320	4219	4219	4112	4027	3887	3991
1928	4249	4348	4276	4365	4450	4413	4286	4344	4332	4524	4569	4688
1929	4822	4798	4889	5005	5250	5311	5361	5295	5000	4961	4761	4502
1930	4441	4480	4387	4562	4460	4316	4041	3817	3579	3480	3280	3193
1931	3195	3193	3187	3266	3167	2870	2682	2522	2396	2403	2356	2277
1932	2150	2174	2037	1948	1761	1619	1586	1522	1598	1741	1817	1846
1933	1853	1819	1664	1720	1948	2363	2928	3029	2803	2553	2443	2523

Adjusted for seasonal variations. The original data come from *Mineral Resources of the United States* (Bureau of Mines, 1925), Part II, p. 545, and later annual numbers (now called *Minerals Yearbook*).

Chart 1
Coke Production, United States
(seasonally adjusted)



* Peaks and troughs of specific cycles.
Contractions (shaded) and expansions (unshaded) are marked off by the monthly reference chronology.

trough to the next. The initial and terminal troughs, however, are weighted one-half each and the intervening values one each.

The specific cycle relatives constitute the basis for what the Bureau calls 'S' tables. Five such tables are prepared; samples of them, together with explanations of their construction are reprinted here as Tables 6-10. In the same way the reference cycle relatives are the basis for three or four 'R' tables, samples of which are reprinted here as Tables 11-14.

TIMING AND LENGTH OF SPECIFIC CYCLES

The reference dates measure the length of business cycles and of their expansions and contractions. The dates of the turns in a given series yield similar measures of its cycles. By comparing the turning dates of specific cycles with the reference dates, we determine the number of months by which the troughs and peaks in the series precede or follow the reference troughs and peaks.[5]

These procedures are illustrated in Table 6. After the specific cycles have been marked off, the dates of the turning points are entered in column 1. The reference dates with which the specific cycle turns are compared are entered in columns 3 and 5. The differences in months between the turning dates of the specific cycles and the reference dates are then entered in columns 2 and 4. The durations of the specific cycles and their phases are shown in columns 6 to 8. The differences between the durations of specific cycles and corresponding reference cycles are shown in columns 9 to 11. Finally, in columns 12 and 13 the lengths of the specific cycle phases are expressed as percentages of the lengths of full cycles.[6]

The timing of the turns of specific cycles when measured from

[5] For series treated invertedly (see above), troughs are matched with reference peaks, and peaks with reference troughs.

[6] These procedures are simple and straightforward in the case of a series such as coke production in which every specific cycle can be matched with a closely concurrent reference cycle on a 'one to one' basis. If a series skips a reference cycle, however, or goes through two cycles of its own while business is going through one, it is often puzzling to decide which of two specific cycle turns should be matched with a given reference turn, or which of two reference turns should be matched with a given specific cycle turn, or whether no comparisons at all should be made. The procedure by which these choices are made has been reduced, as far as possible, to an objective and mechanical basis. The rules and an explanation of them are set forth in *Measuring Business Cycles*, pp. 116 ff.

TABLE 6

Sample of Table S1: Timing and Length of Specific Cycles
Coke Production

DATES OF SPECIFIC CYCLES			TIMING AT REFERENCE				LENGTH OF CYCLICAL MOVEMENTS (MO.)						% OF LENGTH OF SPECIFIC CYCLES	
			Peak		Trough		Specific cycles			Excess over ref. cycles				
Trough	Peak	Trough	Lead (−) or lag (+) months	Ref. peak	Lead (−) or lag (+) months	Ref. trough	Exp.	Contr.	Cycle	Exp.	Contr.	Cycle	Exp.	Contr.
(1)			(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
		11/14			−1	12/14								
11/14	7/18	5/19	−1	8/18	+1	4/19	44	10	54	0	+2	+2	81	19
5/19	8/20	7/21	+7	1/20	−2	9/21	15	11	26	+6	−9	−3	58	42
7/21	5/23	7/24	0	5/23	0	7/24	22	14	36	+2	0	+2	61	39
7/24	2/26	11/27	−8	10/26	−1	12/27	19	21	40	−8	+7	−1	48	52
11/27	7/29	8/32	+1	6/29	−7	3/33	20	37	57	+2	−8	−6	35	65
Average			−0.2		−1.7		24.0	18.6	42.6	+0.4	−1.6	−1.2	57	43
Average deviation			3.4		1.9		8.0	8.3	10.3	3.5	5.5	2.6	12	12

annual data is necessarily crude. The year of the specific cycle turn may be compared with the year of the corresponding reference cycle turn or the midpoint of the year of the specific cycle turn with the midpoint of the corresponding monthly reference cycle turn. For single-date series, the latter method involves a comparison of turns on that date with the corresponding monthly reference turns. Both theoretical expectation and experiment support the view that the second method is better (see Sec. 2 below).

It is a characteristic of timing measures made from annual data, however, that the measures for individual turns have little value in themselves. They are used only to establish an average timing relation for several cycles. The National Bureau does not make such comparisons or compute averages unless the series conforms well to business cycles and at least a dozen specific and reference turns can be compared. In one class of cases, however, we did not adhere to these rules. When preparing tables combining the timing behavior of ten groups of manufacturing industries, we noted every comparison possible in each individual series. But the results are used only to help establish the timing characteristics that are applicable to manufacturing as a whole, not the differences that may characterize the behavior of the individual groups (the validity of our procedure is discussed further in Sec. 2 below).

The length of specific cycles based on annual data is measured in the same way as of those based on monthly data. For the former, however, columns 9-11 of Table 6 are omitted.

MEASURING SPECIFIC CYCLE AMPLITUDE

Amplitude is measured by the rise of the specific cycle relatives from the initial trough of a cycle to the peak and of the fall from the peak to the terminal trough. To diminish the influence of random factors, we use 3-month averages centered on the troughs and peaks. Of course, the amplitudes express the rise and fall as percentages of the average value of the series during each cycle.

Table 7 gives these amplitude measures in three forms. Columns 2-4 show the 3-month averages of the specific cycle relatives centered on the initial trough, peak, and terminal trough. Columns 5-7, obtained from columns 2-4, show the rise from trough to peak, the fall from peak to trough, and the total rise and fall. Columns 8-10, obtained by dividing the figures in columns 5-7 of Table 7 by the corresponding duration figures, columns 6-8 of Table 6, show the amplitudes per month.

TABLE 7
Sample of Table S2: Amplitude of Specific Cycles
Coke Production

DATES OF SPECIFIC CYCLES	3-MO. AV. IN SPECIFIC CYCLE RELATIVES CENTERED ON			AMPLITUDE OF			PER MO. AMPLITUDE OF		
Trough-Peak-Trough	Initial trough	Peak	Terminal trough	Rise	Fall	Rise & fall	Rise	Fall	Rise & fall
11/14–7/18– 5/19	55.5	119.6	74.5	64.1	45.1	109.2	1.5	4.5	2.0
5/19–8/20– 7/21	88.7	125.9	45.0	37.2	80.9	118.1	2.5	7.4	4.5
7/21–5/23– 7/24	44.3	144.0	82.6	99.7	61.4	161.1	4.5	4.4	4.5
7/24–2/26–11/27	69.4	118.2	92.1	48.8	26.1	74.9	2.6	1.2	1.9
11/27–7/29– 8/32	105.5	141.6	41.7	36.1	99.9	136.0	1.8	2.7	2.4
Average	72.7	129.9	67.2	57.2	62.7	119.9	2.6	4.0	3.1
Average deviation	19.5	10.4	19.1	19.8	22.2	23.0	0.8	1.7	1.2

Amplitude measures for annual data are made in the same fashion as for monthly data. The standings in columns 2-4 of Table 7, however, are based on the years (or single dates) marking the cyclical turns.

MEASURING SECULAR MOVEMENTS

Our method of computing cycle relatives as percentages of the average value during a specific or a reference cycle eliminates from the original data what we call the 'inter-cycle' portion of the secular trend. We do not try to eliminate the 'intra-cycle' portion, because we wish to reproduce as faithfully as may be the 'cyclical units' of actual economic experience.

Table 8 throws into relief the secular component of the specific cycles. Columns 2 and 3 show the average values of the seasonally adjusted data during the phases of specific cycles. Column 4 shows the average values during full specific cycles, the values on which the specific cycle relatives are based. Column 5 shows the percentage change from the average standing during a contraction to the average during the following expansion, and column 6 shows the percentage change from the average standing during an expansion to the average during the following contraction. Column 7 shows the percentage change from the average standing during one full specific cycle to that during the next. And column 8 reduces the measures in column 7 to a per month basis, the divisor being the number of months from the midpoint of one cycle to the midpoint of the next.

TABLE 8

Sample of Table S3: Secular Movements
Coke Production

DATES OF SPECIFIC CYCLES	AV. MONTHLY STANDING (000 short tons)			% CHANGE FROM PRECEDING PHASE		% CHANGE FROM PRECEDING CYCLE ON BASE OF			
						Preceding cycle		Av. of given & preceding cycle	
Trough Peak Trough	Exp.	Contr.	Cycle	Contr. to exp.	Exp. to contr.	Total	Per mo.	Total	Per mo.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
11/14–7/18– 5/19	4193	4479	4246	...	+7	...	...	...	...
5/19–8/20– 7/21	3906	3099	3565	−13	−21	−16	−0.40	−17	−0.42
7/21–5/23– 7/24	3171	4326	3620	+2	+36	+2	+0.06	+2	+0.06
7/24–2/26–11/27	4107	4488	4307	−5	+9	+19	+0.50	+17	+0.45
11/27–7/29– 8/32	4577	3319	3760	+2	−27	−13	−0.27	−14	−0.29
Average	...	...	...	...	...	...	...	−3.0	−0.05
Average deviation	...	...	...	...	...	...	...	12.5	0.30
Weighted average	...	...	...	...	...	...	...	...	−0.08

Column 9 is the same as column 7 except that the percentages are based on the average of the two cycles being compared instead of on the first cycle. This shift of method frees the percentages from secular 'bias' and permits us to strike averages for all cycles. Column 10 bears the same relation to column 9 as column 8 bears to column 7. The weighted average at the bottom of column 10 is obtained by weighting the entries by the intervals between the midpoints of successive cycles.

In the case of annual data the average standings during expansions and contractions, columns 2 and 3, include all years from one turn to the next. The values at the turns, however, are weighted one-half each. Similarly, the average standing for the full cycle, column 4, includes all the years from trough to trough. The initial and terminal trough values, however, are weighted one-half each, intervening values one each. The other measures in Table 8 are prepared in the same way for monthly and annual data.

CYCLICAL PATTERNS

To depict the behavior of a series during the course of its cycles in more detail than in Table 7, each cycle is divided into nine stages. Stage I covers the three months centered on the initial trough, stage V the three months centered on the peak, and stage IX the three months centered on the terminal trough. Stages II-IV cover successive thirds of the expansion, and stages VI-VIII successive thirds of the contraction. By averaging the specific cycle relatives for the months included in each stage we get 'specific cycle patterns' (Table 9).

TABLE 9

Sample of Table S4: Specific Cycle Patterns

Coke Production

DATES OF SPECIFIC CYCLES Trough Peak Trough	AVERAGE IN SPECIFIC CYCLE RELATIVES AT STAGE								
	I	II	III	IV	V	VI	VII	VIII	IX
	3 mo. centered on initial trough	EXPANSION			3 mo. centered on peak	CONTRACTION			3 mo. centered on terminal trough
		First third	Middle third	Last third		First third	Middle third	Last third	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
11/14–7/18– 5/19	55.5	81.3	108.0	107.1	119.6	118.7	112.6	88.2	74.5
5/19–8/20– 7/21	88.7	101.2	110.9	117.8	125.9	124.4	86.8	50.4	45.0
7/21–5/23– 7/24	44.3	58.8	78.9	124.3	144.0	137.0	118.1	105.5	82.6
7/24–2/26–11/27	69.4	84.8	95.1	106.2	118.2	108.3	105.2	99.0	92.1
11/27–7/29– 8/32	105.5	113.8	118.4	153.3	141.6	122.4	86.2	55.9	41.7
Average	72.7	88.0	102.3	117.7	129.9	122.2	101.8	79.8	67.2
Average deviation	19.5	15.6	12.2	8.9	10.4	6.9	12.2	21.3	19.1

We make 'reference cycle patterns' on a similar plan except that we mark off nine stages on the basis of the turning dates in general business. By dividing each reference cycle into nine segments, we reveal the behavior of economic processes from stage to stage of business cycles. Table 11, presenting the reference cycle patterns, differs from Table 9 in only two respects: the troughs and peaks are taken from the standard list of reference dates instead of from the turning points of specific cycles, and the entries are expressed in units of reference cycle instead of specific cycle relatives.

TABLE 10

Sample of Table S5: Rate of Change from Stage to Stage of Specific Cycles, Coke Production

DATES OF SPECIFIC CYCLES (Trough – Peak – Trough)	AV. CHANGE PER MO. IN SPECIFIC CYCLE RELATIVES BETWEEN STAGES: I-II	II-III	III-IV	IV-V	V-VI	VI-VII	VII-VIII	VIII-IX
	EXPANSION				CONTRACTION			
	Trough to first third	First to middle third	Middle to last third	Last third to peak	Peak to first third	First to middle third	Middle to last third	Last third to trough
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
11/14–7/18– 5/19	+3.4	+1.8	−0.1	+1.7	−0.4	−2.0	−8.1	−6.8
5/19–8/20– 7/21	+4.2	+2.2	+1.5	+2.7	−0.8	−10.7	−10.4	−2.7
7/21–5/23– 7/24	+3.6	+2.9	+6.5	+4.9	−2.8	−4.2	−2.8	−9.2
7/24–2/26–11/27	+4.4	+1.7	+1.8	+3.4	−2.5	−0.5	−1.0	−1.7
11/27–7/29– 8/32	+2.4	+0.7	+2.3	+2.4	−3.0	−3.0	−2.5	−2.2
Average	+3.6	+1.9	+2.4	+3.0	−1.9	−4.1	−5.0	−4.5
Average deviation	0.6	0.6	1.6	0.9	1.0	2.7	3.4	2.8
Av. interval (mo.)	4.3	7.7	7.7	4.3	3.4	5.9	5.9	3.4

Additional information concerning cyclical patterns is supplied by Tables 10 and 12. Table 10, obtained by dividing the differences between successive figures on each line in Table 9 by the number of months from the middle of one specific cycle stage to the middle of the next stage, shows the rate of change from one stage of specific cycles to the next. Table 12, made from Table 11 just as Table 10 is made from Table 9, shows the rate of change from one stage of reference cycles to the next.

When compelled to use annual data our procedure is simpler. The cyclical patterns of Tables 9 and 11 are made on a five- instead of a nine-stage basis, but to avoid confusion we call these stages I, III, V, VII, and IX. The standings at stages I, V, and IX

TABLE 11

Sample of Table R1: Reference Cycle Patterns Coke Production

DATES OF REFERENCE CYCLES (Trough – Peak – Trough)	AVERAGE IN REFERENCE CYCLE RELATIVES AT STAGE: I	II	III	IV	V	VI	VII	VIII	IX
	3 mo. centered on initial trough	EXPANSION: First third	Middle third	Last third	3 mo. centered on peak	CONTRACTION: First third	Middle third	Last third	3 mo. centered on terminal trough
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
12/14– 8/18– 4/19	52.8	83.9	106.7	106.6	118.7	116.7	111.0	91.7	78.1
4/19– 1/20– 9/21	98.4	96.9	116.1	101.3	119.2	123.2	117.1	52.3	53.0
9/21– 5/23– 7/24	48.4	65.3	80.2	124.2	139.5	132.7	114.4	102.2	80.0
7/24–10/26–12/27	69.5	90.0	98.4	111.6	107.4	105.0	102.4	94.5	94.0
12/27– 6/29– 3/33	114.4	123.1	124.8	138.9	150.2	128.2	83.3	52.3	49.1
Average	76.7	91.4	105.2	116.5	127.0	121.2	105.6	78.6	70.8
Average deviation	23.8	14.8	12.8	12.0	14.3	8.2	10.2	21.0	15.8

TABLE 12

Sample of Table R2: Rate of Change from Stage to Stage of Reference Cycles, Coke Production

DATES OF REFERENCE CYCLES: Trough	Peak	Trough	AV. CHANGE PER MO. IN REFERENCE CYCLE RELATIVES BETWEEN STAGES: I-II	II-III	III-IV	IV-V	V-VI	VI-VII	VII-VIII	VIII-IX
			EXPANSION				CONTRACTION			
			Trough to first third	First to middle third	Middle to last third	Last third to peak	Peak to first third	First to middle third	Middle to last third	Last third to trough
(1)			(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
12/14–	8/18–	4/19	+4.1	+1.6	0.0	+1.6	−1.3	−2.3	−7.7	−9.1
4/19–	1/20–	9/21	−0.8	+7.7	−5.9	+9.0	+1.1	−0.9	−10.0	+0.2
9/21–	5/23–	7/24	+4.3	+2.6	+6.8	+4.4	−2.7	−4.1	−2.7	−8.9
7/24–	10/26–	12/27	+4.1	+1.0	+1.6	−0.8	−1.0	−0.6	−1.8	−0.2
12/27–	6/29–	3/33	+2.5	+0.3	+2.6	+3.2	−2.8	−3.1	−2.1	−0.4
Average			+2.8	+2.6	+1.0	+3.5	−1.3	−2.2	−4.9	−3.7
Average deviation			1.6	2.0	3.2	2.6	1.1	1.2	3.2	4.3
Av. interval (mo.)			4.3	7.5	7.5	4.3	3.6	6.5	6.5	3.6

are, of course, the same as the standings computed for initial trough, peak, and terminal trough in Table 7. The mid-expansion and mid-contraction standings (stages III and VII) are approximated as closely as possible. If an expansion lasts three years, for example, the value in the second year is taken to represent stage III. If it lasts four years, the stage III standing is computed by averaging the two middle years. If the expansion lasts only two years, we have to calculate a stage III standing by interpolation, that is, by striking an average of the trough and peak values.[7]

Tables 10 and 12 are prepared in the same way for annual as for monthly data. Applied to annual data, however, the entries are confined to the rate of change from trough to mid-expansion (I-III), mid-expansion to peak (III-V), peak to mid-contraction (V-VII), and mid-contraction to terminal trough (VII-IX).

MEASURES OF CONFORMITY TO BUSINESS CYCLES: MONTHLY DATA

The comparisons in Table 6 between specific and reference cycles show roughly how the wavelike movements in a given series conform to the movements in general business activity. Further light is shed by the similarity or difference between the average specific cycle and the average reference cycle patterns of Tables 9 and 11. But it is desirable to measure explicitly the varying degrees of conformity.

Table 13 gives the measures we seek. Column 4, derived from

[7] For treatment of phases longer than four years, see *Measuring Business Cycles*, p. 199.

TABLE 13

Sample of Table R3: Conformity to Business Cycles
Coke Production

DATES OF REFERENCE CYCLES Trough Peak Trough	CHANGE IN REFERENCE CYCLE RELATIVES DURING REFERENCE EXPANSION Total change	Inter-val in mo.	Av. change per mo.	CONTRACTION Total change	Inter-val in mo.	Av. change per mo.	AV. CHANGE PER MO. DURING REF. CONTR. MINUS THAT DURING Pre-ceding ref. exp.	Suc-ceeding ref. exp.[a]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
12/14– 8/18– 4/19	+65.9	44.0	+1.50	−40.6	8.0	−5.08	−6.58	—
4/19– 1/20– 9/21	+20.8	9.0	+2.31	−66.2	20.0	−3.31	−5.62	—
9/21– 5/23– 7/24	+91.1	20.0	+4.56	−59.5	14.0	−4.25	−8.81	—
7/24–10/26–12/27	+37.9	27.0	+1.40	−13.4	14.0	−0.96	−2.36	—
12/27– 6/29– 3/33	+35.8	18.0	+1.99	−101.1	45.0	−2.25	−4.24	...
Average	+50.3	...	+2.35	−56.2	...	−3.17	−5.52	...
Average deviation	...	...	0.88	...	...	1.25	1.78	...
Index of conformity to reference								
Expansions			+100					
Contractions						+100		
Cycles, trough to trough							+100	
Cycles, peak to peak								+100
Cycles, both ways							+100	

[a] Only the sign of the difference is entered.

columns 2 and 3, supplies essential information on the conformity of the series to business cycle expansions. That is, the entries in column 4 indicate the average rise or fall per month during successive reference expansions; the average near the bottom is the average rate of change during all the reference expansions covered by the series. Column 7 supplies similar information concerning the behavior of the series during reference contractions. Finally, column 8 expresses the difference between the rates of change during reference expansions and contractions; this measure is needed because some series with rapidly rising trends continue to advance even during reference contractions, and we wish to know how much, if at all, the rate is intensified during expansions in general business and diminished during contractions.

While the averages near the bottom of columns 4, 7, and 8 are useful measures of conformity, they do not indicate the regularity with which a series 'responds' to the stimuli of general business expansion and contraction. To bring out this feature of cyclical behavior we make a second set of conformity measures, 'indexes of conformity', which take account of the direction of the movements but not their magnitude. When a series rises during a reference expansion we mark it +100; when it remains unchanged we mark it 0; when it falls we mark it −100. By casting up the algebraic sum of these entries for all cycles and dividing by their number, we get an index of conformity to reference expansions. This result, entered at the bottom of column 4, may vary between +100 (positive conformity to all the reference expansions covered) and −100 (inverse conformity to all the expansions). An equal number of positive and inverse movements produces an index of 0.[8] To measure conformity to reference contractions we proceed similarly, but a decline in column 7 is now marked +100, and a rise −100, for a decline means positive conformity to reference contractions and a rise means inverse conformity.

Finally, we make indexes of conformity to business cycles as wholes. Here we wish to take account of the fact that some series rise or decline throughout reference cycles, but at different rates during expansions and contractions. A preliminary index is obtained by crediting each difference in column 8 with +100 when the difference is minus, with −100 when it is plus, then striking an arithmetic mean. This index shows merely the conformity to business cycles marked off by troughs; hence it is supplemented in column 9 by a similar index showing conformity to business cycles marked off by peaks. A weighted average of the two preliminary indexes gives our final index of conformity to business cycles taken as wholes. A value of +100 means that the rate of change per month during a reference contraction is without exception algebraically lower than the rate of change during the preceding and following expansions.

Table 13 illustrates these computations. The 'expansion index' is +100 because all entries in column 4 are plus. The 'contraction index' is +100 because all signs in column 7 are negative. The preliminary 'full cycle index', taken on a trough to trough basis, is +100, as is the index of conformity to full cycles on a peak to peak basis, since all signs in columns 8 and 9 are negative. The final full cycle index is obviously +100, since it is an average of two preliminary indexes each of which is +100.

The procedure illustrated in Table 13 is adequate for a series

[8] An index of +50 means positive conformity in 3 and inverse conformity in 1 case out of 4; an index of +33 means positive conformity in 2 and inverse conformity in 1 case out of 3.

like coke production which typically rises from reference stage I to V and declines from reference stage V to IX. For the many series that normally lead or lag behind the turns of business activity the results furnished by Table 13 would misrepresent their relation to business cycles or the regularity with which they respond. For such series, therefore, a second conformity table, 14, is prepared.

The preparation of Table 14 begins with an attempt to determine the reference cycle phases between which a series typically rises. The usual procedure is to plot cycle by cycle the reference patterns in Table 11. Each stage interval is then inspected to see whether the series rose or fell during it. If there is no great regularity between one business cycle and the next, we dispense with Table 14. If there is considerable regularity, we determine the stages between which the series typically rises and those between which it typically falls. The division of stages between expansion and contraction need not be equal. Thus we may determine that a series typically rises between stages I and VI and falls between VI and IX, or rises between VII and II and falls between II and VII. Only in rare cases, however, do we make divisions more unequal than five stage intervals for expansion and three for contraction, or vice versa.

Once the division of reference cycles has been decided upon, the next step is to classify the series as 'positive', 'inverted', or 'neutral'. This classification determines whether the specific cycles are to be marked off from trough to trough or from peak to peak, and also plays a part in the computation of Table 14. We class a division of reference cycles as positive when the selected expansion segment contains more stages in the reference expansion than in the contraction; or, what comes to the same thing, when the selected contraction segment contains more stages in the reference contraction than in the expansion. We class the division of reference cycles as inverted when the selected expansion covers more stages in the reference contraction than in the expansion. When the selected expansion overlaps equally reference expansions and contractions, the division is classed as neutral.

Whatever the division, it is applied uniformly in subsequent operations to all the reference cycles covered by the series. When the division is positive, the expansion segments are matched with reference expansions and the contraction segments with contractions. When the division is inverted, the contraction segments are matched with reference expansions and the expansion segments with contractions. When the division is neutral, the division is treated as if it were positive; that is, the expansion segments are

TABLE 14

Sample of Table R4: Conformity to Business Cycles
Timing Differences Recognized
Railroad Bond Yields

(Expansion covers stages III-VI. Expansions are matched with reference expansions.)

Dates of reference cycles (1) Trough	Peak	Trough	Change in reference cycle relatives during stages matched with reference: Expansion: Total change (2)	Interval in mo. (3)	Av. change per mo. (4)	Contraction: Total change (5)	Interval in mo. (6)	Av. change per mo. (7)	Av. change per mo. during stages matched with ref. contr. minus that during stages matched with: Preceding ref. exp. (8)	Succeeding ref. exp.[e] (9)
12/54	6/57	12/58	...	...	...	−18.8[a]	25.5	−0.74[a]	...	−
12/58	10/60	6/61	+0.9	12.5	+0.07	−24.4	29.5	−0.83	−0.90	−
6/61	4/65	12/67	+25.4	28.5	+0.89	0.0	35.5	0.00	−0.89	−
12/67	6/69	12/70	+5.2	12.5	+0.42	−6.3	31.5	−0.20	−0.62	+
12/70	10/73	3/79	−6.4	28.0	−0.23	−25.5	72.0	−0.35	−0.12	−
3/79	3/82	5/85	−4.2	24.5	−0.17	−11.7	42.5	−0.28	−0.11	−
5/85	3/87	4/88	+0.8	13.5	+0.06	−5.4	24.0	−0.22	−0.28	−
4/88	7/90	5/91	+5.1	15.5	+0.33	+0.6	18.0	+0.03	−0.30	−
5/91	1/93	6/94	+0.6	13.0	+0.03	−5.5	23.0	−0.24	−0.29	−
6/94	12/95	6/97	−2.0	12.5	−0.16	−5.0	26.5	−0.19	−0.03	+
6/97	6/99	12/00	−4.6	15.5	−0.30	+1.7	25.0	+0.07	+0.37	−
12/00	9/02	8/04	+5.1	14.5	+0.35	+3.5	35.5	+0.10	−0.25	−
8/04	5/07	6/08	+7.9	19.0	+0.42	−4.3	20.0	−0.22	−0.64	−
6/08	1/10	1/12	+5.0	14.0	+0.36	+2.0	25.5	+0.08	−0.28	−
1/12	1/13	12/14	+4.2[b]	10.0	+0.42[b]	−0.2[b]	41.0	0.00[b]	−0.42[b]	−
12/14	8/18	4/19	+16.6	28.5	+0.71	+2.1	11.0	+0.19	−0.52	−
4/19	1/20	9/21	+8.7	8.0	+1.09	−19.2	26.5	−0.72	−1.81	−
9/21	5/23	7/24	+5.7	12.5	+0.46	−3.0	25.0	−0.12	−0.58	+
7/24	10/26	12/27	−4.1	16.0	−0.26	+1.4	20.5	+0.07	+0.33	+
12/27	6/29	3/33	+1.0	17.0	+0.06	−19.4	62.0	−0.31	−0.37	...
Average[c]			+3.7	...	+0.24	−6.2	...	−0.17	−0.41	...
Average deviation[d]			...	...	0.32	...	...	0.20	0.33	...
Index of conformity to reference										
Expansions					+47					
Contractions								+80		
Cycles, trough to trough									+79	
Cycles, peak to peak										+58
Cycles, both ways										+68

[a] Computed on base of inverted cycle, June 1857–Oct. 1860. Excluded from av. and av. dev.
[b] Computed on base omitting Aug.–Nov. 1914.
[c] Arithmetic mean determined separately for each column. Hence (7) − (4) *may* differ from (8) in the last place.
[d] Measured from the mean.
[e] Only the sign of the difference is entered.

matched arbitrarily with reference expansions and the contraction segments with contractions. For each series we indicate the procedure by writing at the top of Table 14 what stages are considered characteristic of expansions, and whether expansions are matched with reference expansions or contractions, implying that contractions are matched with the other reference phase.[9]

The other steps in preparing Table 14 are like those for Table 13 except in one respect. For any given cycle the average rate of change per month is computed uniformly for whatever stages have been matched with expansion, not uniformly for stages I-V as in Table 13. Similarly, the average rate of change per month is computed for whatever stages have been matched with contraction, not uniformly for stages V-I.

MEASURES OF CONFORMITY TO BUSINESS CYCLES: ANNUAL DATA

The procedure for preparing Table 13 from annual data is exactly the same as from monthly data. Expansions and contractions, of course, are marked off according to the calendar year, fiscal year, or, in the case of single-date year end series, according to a special end of year chronology. For Table 14, however, a choice of methods is open. If we proceed by the methods applied to monthly data, the stages matched with reference expansions are restricted by the five-stage pattern used for annual series. The stages matched with expansions may, in principle, be I-III, I-V, I-VII, III-V, III-VII, III-IX, V-VII, V-IX, V-III, VII-IX, VII-III, and VII-V. In practice, however, the alternatives are fewer. Since reference phases and, in particular, American contractions, frequently last only a year the standings at stages III and VII are often purely artificial. There is, therefore, seldom enough solid evidence to justify a division between typical expansions and contractions at stage VII. And in short series it is often impossible to use stage III. When stage VII is excluded, the choices are I-III, I-V, III-V, III-IX, V-IX, and V-III. When both III and VII are excluded, the sole choices are I-V and V-IX, that is, Table 14 becomes impossible, and we are restricted to Table 13.

To avoid these difficulties another procedure was devised and

[9] This paragraph and the one preceding are from *Measuring Business Cycles*, pp. 188-9.

is generally used in this study. Instead of attempting to determine the timing of a series in terms of cycle stages, we use the regular timing measures described above to determine its tendency to lead or lag in terms of months. Thus if a series tends to lead the reference dates by 12 months, we simply postdate it one year, then compute its conformity on the basis of a typical expansion running from stage I to V, as in Table 13. If a series tends to lag 12 months, we predate it one year and again proceed as in Table 13. If a calendar year series tends to lag 6 months, we predate it 6 months, that is, the figures for calendar years 1929, 1930, etc. are treated like figures for the fiscal years ended June 30, 1929, 1930, etc. Conformity is then computed on a typical expansion running from stage I to V of the fiscal year reference cycles. If a calendar year series tends to lead 6 months, we postdate it 6 months; that is, calendar year figures for 1928, 1929, etc. are treated like figures for the fiscal years 1929, 1930, etc. In this case again conformity indexes can be derived by matching the series synchronously with fiscal year reference dates. To give additional flexibility, special reference dates were determined for years ending March 31 and September 30. In this way we can deal with the following timing categories in months (leads are marked —, lags +): —12, —9, —6, —3, synchronous, +3, +6, +9, and +12. The full reference chronology for these timing categories is set forth in Table 15. The timing measures are rounded to determine under which category a series falls for the purpose of measuring conformity. Series that appear to lead or lag by more than one year are treated as if their lead or lag were only 12 months.

The accuracy of this procedure obviously depends in part upon whether we can determine the timing of the series whose conformity is to be measured. As will be shown below, however, timing measures from annual data cannot be assumed to be wholly reliable. To reduce the danger of being misled we adhere to two rules. As in measuring the timing of annual data, only groups of series are measured for conformity, and conclusions are drawn only about the groups as wholes, not about individual members. And we never measure conformity on other than a synchronous basis unless the indicated lead or lag is based on at least seven comparisons between specific and reference cycle turns.

The procedure for end of year series is analogous to that for calendar year series. The conformity of synchronous series is measured by the chronology of the year ends when business reached its peaks and troughs. A year end series that tends to lag a quarter-year is predated 3 months, that is, its values are treated as if they were for September 30. Conformity is then measured on a synchronous basis in conjunction with a September 30 chronology of business cycle turns. In effect we observe our predated series to see whether it regularly rises during expansions bounded by years when the September 30 levels of business were low or high, and

TABLE 15

Reference Dates for Annual Series with Various Leads or Lags Relative to General Business

The years in each column are the calendar years when a process may be expected to reach its peaks and troughs under the specified assumptions regarding its timing.

	LEAD (−), LAG (+), MONTHS								
	−12	−9	−6	−3	0	+3	+6	+9	+12
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	CALENDAR YEAR SERIES								
Trough	1913	1914	1914	1914	1914	1915	1915	1915	1915
Peak	1917	1917	1917	1917	1918	1918	1918	1918	1919
Trough	1918	1918	1918	1918/19	1919	1919	1919	1919/20	1920
Peak	1919	1919	1919	1919/20	1920	1920	1920	1920/21	1921
Trough	1920	1920	1921	1921	1921	1921	1922	1922	1922
Peak	1922	1922	1922	1923	1923	1923	1923	1924	1924
Trough	1923	1923	1923	1924	1924	1924	1924	1925	1925
Peak	1925	1926	1926	1926	1926	1927	1927	1927	1927
Trough	1926	1927	1927	1927	1927	1928	1928	1928	1928
Peak	1928	1928	1928	1929	1929	1929	1929	1930	1930
Trough	1931	1931	1932	1932	1932	1932	1933	1933	1933
Peak	1936	1936	1936	1936	1937	1937	1937	1937	1938
Trough	1937	1937	1938	1938	1938	1938	1939	1939	1939
	YEAR END SERIES								
Peak	1911	1911	1912	1912	1912	1912	1913	1913	1913
Trough	1913	1913	1913	1914	1914	1914	1914	1915	1915
Peak	1916	1916	1917	1917	1917	1917	1918	1918	1918
Trough	1917	1917	1918	1918	1918	1918	1919	1919	1919
Peak	1918	1918	1919	1919	1919	1919	1920	1920	1920
Trough	1919	1920	1920	1920	1920	1921	1921	1921	1921
Peak	1921	1922	1922	1922	1922	1923	1923	1923	1923
Trough	1922	1923	1923	1923	1923	1924	1924	1924	1924
Peak	1925	1925	1925	1926	1926	1926	1926	1927	1927
Trough	1926	1926	1926	1927	1927	1927	1927	1928	1928
Peak	1927	1928	1928	1928	1928	1929	1929	1929	1929
Trough	1931	1931	1931	1932	1932	1932	1932	1933	1933
Peak	1935	1936	1936	1936	1936	1937	1937	1937	1937
Trough	1936	1937	1937	1937	1937	1938	1938	1938	1938

See Appendix B for notes on the derivation of this table.

whether it regularly falls during contractions bounded by these years but looking from peaks to troughs. An end of year series that lags one-half year is predated 6 months and matched with a June 30 chronology. An end of year series that leads one-half year is postdated 6 months, that is, figures for December 31, 1928 and 1929 are treated like figures for June 30, 1929 and 1930, respectively. Its conformity is then measured on a June 30 chronology. Similar procedures are applied to other timing categories ranging from 12-month leads to 12-month lags. The reference chronology used in conjunction with year end series is set forth in the lower half of Table 15.

AVERAGES AND AVERAGE DEVIATIONS

Most of the measures described above are made for every reference and for every specific cycle covered by a series, then averaged for each set of cycles. When averages are struck for all the cycles covered by a series, features peculiar to single cycles tend to fade, while features common to all or most cycles tend to stand out prominently.

In general, the more cycles a series covers, the greater is our confidence that the average discloses faithfully what cyclical behavior is typical of the economic process represented. But in analyzing price and value series, we usually exclude cycles affected by grave monetary disturbances from the averages. We make exclusions also when some exceptionally powerful random factor, such as a major strike, has warped an individual cycle out of resemblance to other cycles in the array. When a long series gives definite indications of having undergone a secular or structural change, we divide it into relatively homogeneous segments and compute an average for each segment.

Our attempt to find what cyclical behavior is characteristic of different economic processes does not end in the contemplation of averages, for a leading feature of specific and of business cycles is that they vary in length, intensity, and other respects. To keep this feature prominently before our minds, we compute average deviations from the averages. These deviations are simple measures of the degree to which the figures for individual cycles in a series are clustered about the arithmetic means which we use to represent 'central tendencies'.

CHARTS OF CYCLICAL PATTERNS

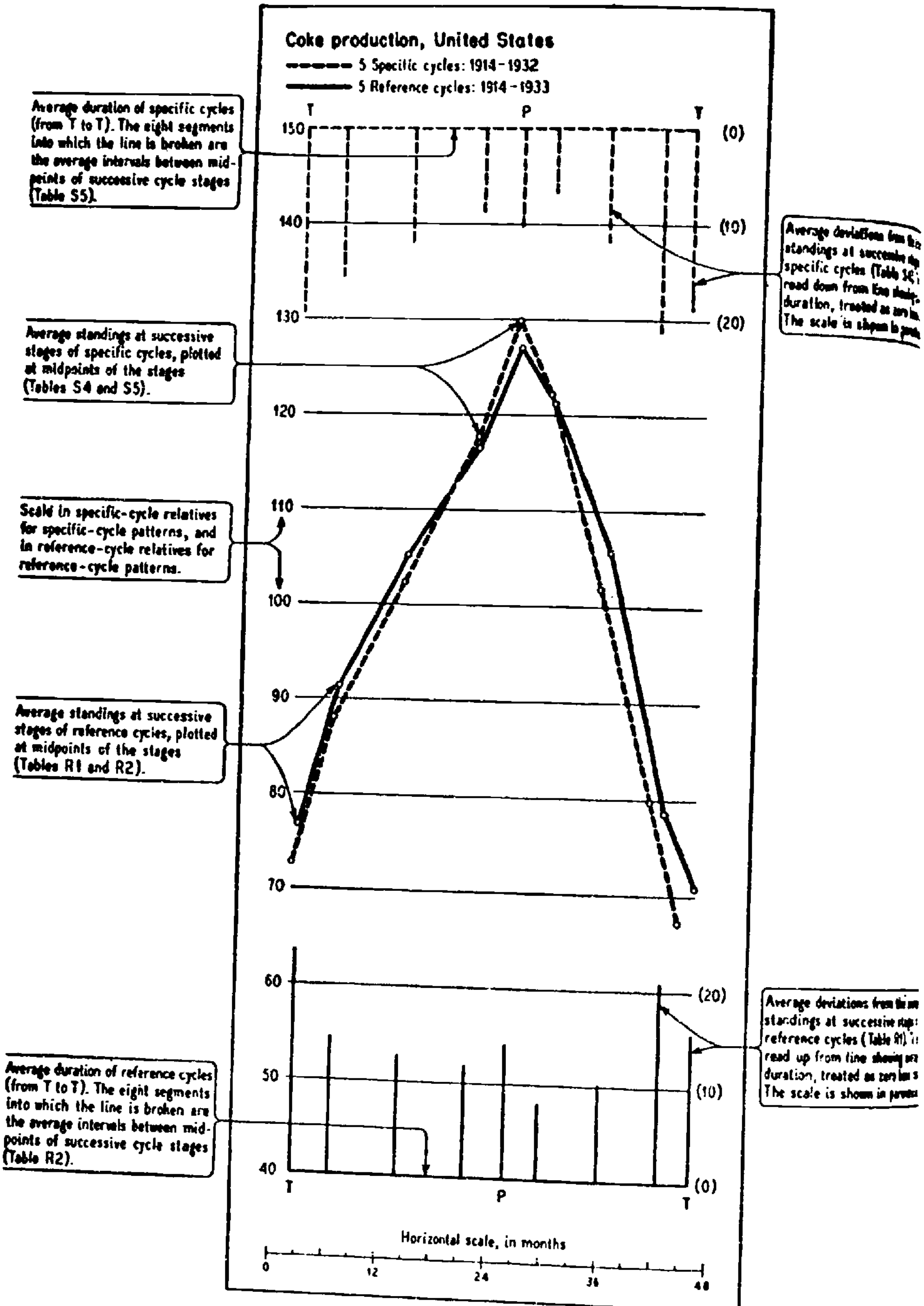
Several results of our analysis that lend themselves readily to graphic presentation are embodied in charts of cyclical patterns. The sample for coke production, Chart 2, pictures the averages and average deviations in Tables 9 and 11, and certain additional measures from Tables 6, 10, and 12. The curves trace the specific and reference cycle patterns made by averaging the standings of the individual cycles at each of the nine stages in Tables 9 and 11. Since coke production corresponds closely in timing to business cycles, the two patterns are almost identical. The more irregular the timing of a series in relation to business cycles, the smaller will be the amplitude of the reference cycle pattern relative to that of the specific cycle pattern. The representative value of the two patterns is indicated by the lengths of the vertical lines, which show the average deviations of the individual cycles from their average standings at the nine stages.

The long horizontal lines above and below the cyclical patterns represent the average lengths of the specific and reference cycles. We call them 'duration lines'. The vertical lines representing the average deviations from the average standings are dropped from or erected at the midpoints of the cycle stages. The ruler at the bottom of the chart defines the time scale; with its aid all durations can be approximated.

When, as in coke production, the specific and reference cycles correspond to each other, the two duration lines are placed so that they show average leads or lags. When specific and reference cycles do not correspond throughout, the duration lines are so placed that the peak standings of the two patterns are aligned vertically.

With a few exceptions when amplitudes are very wide, the charts of cyclical patterns presented below were drawn to a strictly uniform set of scales. However, to help the reader understand our method, the scales in Chart 2 are larger. The explanatory comments are not repeated for subsequent charts, nor are the scale numbers for average deviations of the standings in successive cycle stages.

Chart 2
Sample Chart of Cyclical Patterns



T represents the trough stage (I or IX), P the peak stage (V). For explanation of how the line representing the average duration of specific cycles is placed in relation to the line representing the average duration of reference cycles, see text.

2 *Reliability of Annual Data*

Most business cycles in the United States and, indeed, in other major commercial countries, are relatively brief. The National Bureau has identified 21 business cycles between 1854 and 1938 in the United States.[10] Their average length was almost exactly four years. Only 6 were longer; the others lasted 48 months or less. The brevity of most business cycles greatly restricts the number of observations that can be made on annual data. In a 4-year cycle in which expansion and contraction are equal, we might have 5 annual observations: one at the initial trough, one at the peak, one at the terminal trough, and one each at mid-expansion and mid-contraction. If expansion and contraction are not equal, the observations on the shorter phase are reduced to 2, and if the full cycle itself is shorter than 4 years, the number of observations may be no more than 2 on expansion or contraction.

In these circumstances, annual data necessarily distort, in greater or less degree, our view of the actual cyclical behavior of economic series. This happens partly because some cycles that appear in a monthly series are skipped in its annual form; more rarely because annual data inject cycles not found in the monthly series. Corresponding cycles in monthly and annual series, moreover, are likely to be of different length and shape. A monthly series may reach a cyclical peak in June of a given year, but in annual form it may reach a peak in the same year or in the year preceding or following. Thus the form of the data may affect the timing as well as the length of the cycles in a series. For closely corresponding cycles, when both monthly and annual data turn in the same year, the amplitude of the swing in the latter is necessarily less, since in monthly series the standing at the peak covers the three months centered on the highest value attained during the cycle, and the standing at the trough the three months centered on the lowest value. The same results are probable even when the cycles in the annual and monthly data do not correspond closely. Annual data not only distort results; they seriously reduce the information yielded. The year is a coarser unit of measurement than the month or the quarter, a matter of obvious importance when timing and duration are to be measured. Used with caution, how-

[10] Ibid., p. 78.

ever, and a knowledge of their limitations, annual data can be of great value.

In what ways and to what degree will our measures be affected by the use of annual data? For a detailed discussion and the results of many illuminating tests, readers are referred to *Measuring Business Cycles,* Chapter 6. The argument below is confined to the three measures we use most frequently: timing, amplitude, and conformity.

TIMING

We measure the timing of annual data by comparing the monthly reference cycle turn with the midpoint of the corresponding annual specific cycle turn. We prefer this procedure to the alternative—comparing an annual specific cycle turn with the midpoint of the corresponding annual reference turn. Test comparisons support this preference,[11] as does the logic of the case. We take as our standard the results that would be attained by comparing monthly specific cycle turns with monthly reference cycle turns. The method we prefer will produce an error whenever the monthly specific cycle turn does not occur at the midpoint of the year in which the annual series reaches a peak or trough; in the case of year end series, whenever it does not occur at the end of the year in which the annual series turns. But a procedure that depends upon comparisons of midpoints of annual specific cycle turns with midpoints of annual reference turns can be in error because it misplaces the one or the other, and these sources of error will tend to augment more often than they will tend to offset each other.[12]

[11] Ibid., Table 61.

[12] Call the procedure by which monthly specific cycle turns are compared with monthly reference turns Method A; that by which annual specific cycle turns are compared with monthly reference turns Method B; and that by which annual specific cycle turns are compared with annual reference turns Method C. If M stands for the monthly specific cycle turn and N for the monthly reference turn, timing by Method A = M − N. Timing by Method B = M + S − N, where S is the distortion in the timing of the specific cycle turn caused by annual data. Timing by Method C = (M + S) − (N + R), where R is the distortion in the timing of the reference turn caused by annual data. The difference between Methods A and B is S; that between Methods A and C is S − R.

Whether Method B will yield a better approximation to Method A than Method C depends on whether S − R tends to exceed S. For any group of

The elimination of distortion due to the misplacement of the date of reference cycle turns, however, still leaves important sources of error due to the misplacement of specific cycle turns. Since most of the annual data used below are end of year series, our argument is developed with reference to such series. With minor modifications, however, it is applicable to annual data generally.

Individual timing comparisons made with end of year data are usually in error since the true specific cycle turn is unlikely to occur precisely at the year end. The reliability of annual timing measures, therefore, depends upon averaging many observations. Yet the average of even many observations will yield a poor approximation to the true timing if the direction of the displacement of the specific cycle turns in the annual data is biased relative to the true dates or, in the absence of bias, if the errors do not offset one another sufficiently in a small sample.

The displacement may be biased if, in the period under review, the monthly reference cycle turns usually occur nearer the beginning than the ends of years, or the reverse. Consider a series, A, with monthly turns that are synchronous with reference turns. If the reference turns usually occur in the second half of calendar years, the specific cycle turns in the year end version of series A will tend to come at the ends of the years in which the reference turns occur rather than at their beginning, other things being equal. An average of individual timing measures would be biased in the direction of a lag. Similarly, if the reference turns usually occur in the first half of calendar years, the measure of timing from annual data would be biased in favor of a lead.

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reference cycles R may be plus, minus, or zero on the average. If many series are analyzed for the period covered by reference cycles, the expectation is that S will be plus in as many cases as it will be minus. Now if R is zero, the results of Method B will agree with those of Method C. If S is zero on the average, S − R must exceed S, unless R too is zero, in which case Methods B and C again give the same results. If S and R are of opposite sign, then S − R once more must exceed S. And the same will be true when S and R are of the same sign whenever R > 2S. Hence there is a greater probability that (S − R) > S than that (S − R) < S. The expectation, therefore, is that Method B will give a better approximation to Method A than will Method C.

This argument is adapted from *Measuring Business Cycles*, p. 229, note 25.

This particular source of error, fortunately, is unlikely to trouble us much. In the period since 1913, with which this study is generally concerned, National Bureau reference dates are fairly evenly distributed over the calendar year.[13]

NUMBER OF PEAKS AND TROUGHS

	1913-38	1919-38		1913-38	1919-38
January	2	1	July	1	1
February	0	0	August	1	0
March	1	1	September	1	1
April	1	1	October	1	1
May	3	3	November	0	0
June	1	1	December	2	1

Another, more important, source of bias will exist if the shapes of specific cycles are such as to throw the peaks and troughs of a year end series back to the ends or forward to the beginnings of the years in which the turns of a corresponding monthly series occur. For example, the peaks in the year end version of a monthly series that declines more slowly immediately after passing its peaks than it rises toward its peaks will tend to come at the ends of the years in which the peaks of the monthly series occur. Indeed, they may not come until the end of the next year. A year end series of this type would tend to show lags on the average, whatever the timing of its cycles in the monthly data. The reverse, of course, would be true if the monthly data generally fell away more rapidly after their peaks than they rose toward them.

Even if these sources of bias were completely absent, in the sense that the average timing measured from annual data would be accurate when based upon a large number of observations, the errors of individual observations may not cancel in a limited number of cycles. This possibility is heightened somewhat by the fact that annual data sometimes skip cycles that occur in monthly data, thereby reducing the number of comparisons yielded by a given number of cycles. The seriousness of these sources of error can be appraised only by comparing results from monthly and annual data. To this end we prepared average timing measures for

[13] If we call January 0.5, February 1.5, March 2.5, December 11.5, and so on, a perfectly even distribution of reference cycle turns would yield an 'average' turn with a value of 6. But the 'average' reference turn since 1913 has a value of 5.8 and the 'average' turn since 1919 a value of 5.6. Moreover, the distribution of reference cycle turns by months is markedly even.

monthly and annual data for 6 series. In order to approximate the kind of annual data used in this study, we constructed annual series from December values, and computed average leads and lags for periods covering 5 or 6 reference cycles.

The discrepancies between the measures derived from monthly and annual data are serious but not so large as to render annual data unusable. The average difference is roughly 2.6 months, and more than 75 percent of the measures from annual data are within 4 months of the measures yielded by monthly data.

Table 16

Average Timing of Specific Cycles during Brief Periods, Six American Series, Monthly and Annual (December) Data

Period covered	Timing at reference peaks: Number of observations		Av. lead (−) or lag (+), months		Timing at reference troughs: Number of observations		Av. lead (−) or lag (+), months	
	M	A	M	A	M	A	M	A
DEFLATED CLEARINGS								
1879-1897	5	3	+3.8	−1.3	5	3	−6.2	−4.7
1897-1914	5	3	+4.2	+1.7	5	3	−7.4	−8.3
1914-1933	4	2	+1.2	−3.5	5	3	−3.8	0
PIG IRON PRODUCTION								
1879-1897	5	3	+0.8	−1.3	5	2	−3.2	−5.5
1897-1914	5	5	+3.4	+0.4	5	5	−7.2	−6.6
1914-1933	5	5	+1.4	−1.2	6	6	−0.3	+0.2
RAILROAD STOCK PRICES								
1858-1888	5	5	−7.6	−8.4	5	5	−13.4	−14.8
1888-1908	6	5	−2.2	−4.4	6	5	−1.2	−1.0
1908-1933	6	5*	−7.3	−2.8*	7	7	−8.6	−7.7
SHARES TRADED								
1879-1897	5	5	−11.4	−7.6	5	4*	−2.2	−2.0*
1897-1914	5	4	−12.0	−13.5	5	4	−4.8	−5.2
1914-1933	5	4	−7.8	−12.2	6	5	−6.5	−3.2
CALL MONEY RATES								
1858-1888	6	6	−3.3	−8.0	6	6	−1.2	−2.3
1888-1908	6	6	+4.2	−2.7	6	6	+3.0	+1.2
1908-1933	7	6	−1.0	−2.0	7	6	+2.6	+4.2
RAILROAD BOND YIELDS								
1858-1888	6	6	+9.2	+8.0	6	6	+17.8	+11.7
1888-1908	5	4	+9.2	+8.2	5	4	+14.4	+10.5
1908-1933	5	5	+4.8	+7.8	5	5	+1.8	+8.2

The sources of this and other tables of Chapter 3 are described in *Measuring Business Cycles*, p. 210, notes 6 and 7.

* In comparing monthly reference dates and the turns of year end or other single-date series, we omit leads or lags longer than 24 months in order to avoid prejudicing averages based on few comparisons. Accordingly, one lead was omitted in each case designated by an asterisk.

M: monthly date; A: annual.

In one respect the comparisons of Table 16 put the results to be expected from our inventory materials in a less favorable light than is just. The averages are usually based on 6 comparisons or fewer; in some cases on only 2 or 3. Our timing measures on annual inventory data are usually based on 7 to 10 comparisons. To do this, however, we have to lump together observations on peaks and troughs, a procedure that would increase the likelihood of error if the timing of stocks at peaks and troughs were significantly different. Since we have not found any evidence of such a difference in annual inventory data, it seems valid to combine our comparisons at peaks and troughs into single averages. We expect the results to be somewhat better than those suggested by Table 16.

For all that, annual data can obviously provide only crude indications of timing. We attempt therefore to safeguard our results by taking two precautions. First, we disregard small differences in timing relations—differences of, say, less than 3 or 4 months. Secondly, we confine attention to results that appear to be characteristic of manufacturing as a whole as judged by a consensus of nine or ten groups of industries.

AMPLITUDE

When cycles in the monthly and annual forms of a series correspond closely in time, the amplitudes of the latter will almost always be smaller. The reason, as already stated, is that in monthly series the standing at the peak covers the 3 months centered on the highest value attained during the cycle, and the standing at the trough covers the 3 months centered on the lowest value. The peaks and troughs of calendar or fiscal year data, of course, cover many more months and cannot stand as high as the peak value or as low as the trough value in monthly series. When the cyclical peaks and troughs of the monthly series occur in the same years as those in the annual series, the rule hardly admits of exception,[14] and the same relations may be expected to hold in a large majority of cases when the cyclical turns of monthly and annual data occur in different years, if the cycles correspond approximately.

14 The rule might be upset in rare instances if a random peak or trough is disregarded in marking off specific cycles in monthly data, or if the month preceding and the month succeeding the peak (trough) month are sufficiently below (above) the calendar year average.

The same relations may be expected to hold also when single-date annual series are in question, but now two further exceptions must be noted. If the highest value in a monthly series occurs in close proximity to the day or month when the annual series reaches its peak, the monthly peak may be lower than the annual since peaks in monthly series are 3-month averages centered on the highest value. The relation may be upset also if random high or low values occur on the day or month for which the annual data are reported and if they are taken to be the annual, but not the monthly, cyclical peaks or troughs, as is likely to be the case. That annual data tend to yield smaller amplitudes than monthly data, however, is the basic rule whatever the form of the annual data, and it leaves its imprint clearly on test comparisons.

It has been established also that the reduction in amplitude produced by annual summarizing varies inversely to the length of cyclical phases, though several other factors combine to cause the degree of reduction to vary widely: the months in which the cyclical turns occur, the amplitude of the movement relative to the underlying trend, and the patterns of both the cyclical swing and of the random fluctuations that accompany it.[15]

These factors serve to make uneven the damping effect of annual data even for cycles that correspond to those in monthly data. The degree of reduction in measures of average amplitude from annual data is rendered still more uneven by the fact that annual data sometimes skip cycles that occur in monthly data and inject cycles not found in monthly data. If annual data skip a contraction in a series with a rising trend, their expansion will tend to almost equal the sum of the two monthly expansions they span. If they skip two successive contractions in these circumstances, their total rise will comprise three expansions in the monthly series. When they skip cycles, the average amplitude of the remaining cycles tends to be larger than it otherwise would be and, in some conditions, larger than the average amplitude measured from monthly data. When they inject cycles, the reverse will, of course, be true, but this happens much less frequently.

The effect of all these factors, which in the aggregate tend to reduce the amplitude of cycles in annual data but which do so un-

[15] See *Measuring Business Cycles*, pp. 230-2.

evenly, is illustrated in Table 17. To preserve the erratic effects that may be expected to characterize single-date series such as the end of year inventory data, our annual series are based on the December values of the sample series.

TABLE 17

Average Amplitude of Specific Cycles, Six American Series during Brief Periods, Monthly and Annual (December) Data

PERIOD COVERED	NO. OF CYCLES		AV. AMPLITUDE IN SPECIFIC CYCLE RELATIVES						AN. AV. AS % OF MONTHLY		
			Rise		Fall		Rise & fall				
	M	A	M	A	M	A	M	A	Rise	Fall	Rise & fall
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
DEFLATED CLEARINGS											
1878-1893	5	3	29.6	38.8	12.5	11.7	42.1	50.5	131	94	120
1893-1910	5	3	27.3	35.9	10.0	10.1	37.3	46.0	132	101	123
1910-1933	5	3	23.7	32.1	17.6	21.9	41.3	54.0	135	124	131
PIG IRON PRODUCTION											
1879-1896	5	2	62.3	78.2	44.4	52.2	106.7	130.5	126	118	122
1896-1914	5	5	64.4	60.2	48.3	48.1	112.8	108.4	93	100	96
1914-1933	5	6	59.5	29.4	71.5	40.0	131.0	69.3	49	56	53
RAILROAD STOCK PRICES											
1857-1889	6	6	45.8	33.6	30.6	18.1	76.4	51.6	73	59	68
1889-1907	6	5	29.2	27.6	22.7	20.1	51.9	47.7	95	89	92
1907-1932	6	6	31.7	25.1	42.0	34.4	73.7	59.5	79	82	81
SHARES TRADED											
1878-1897	5	5	74.5	60.1	73.1	55.9	147.6	116.0	81	76	79
1897-1914	5	4	108.0	76.4	111.5	87.6	219.5	164.1	71	79	75
1914-1933	5	4	111.7	101.3	92.6	67.7	204.3	169.0	91	73	83
CALL MONEY RATES											
1858-1880	7	8	109.9	37.1	108.2	32.4	218.1	69.4	34	30	32
1880-1904	8	8	141.6	94.0	147.9	95.2	289.5	189.1	66	64	65
1904-1931	8	8	95.6	59.9	91.2	63.6	186.8	123.6	63	70	66
RAILROAD BOND YIELDS											
1860-1876	6	4	12.3	9.8	14.4	18.4	26.6	28.1	80	128	106
1876-1905	7	5	7.4	4.6	12.8	8.0	20.2	12.6	62	62	62
1905-1931	7	6	13.0	12.0	10.8	8.9	23.7	20.8	92	82	88
Average of all comparisons									86.3	82.6	85.0
Average deviation									22.8	19.5	21.4

M: monthly data; A: annual. The periods cover, approximately, successive thirds of the specific cycles in monthly data.

Table 17 illustrates the strong tendency for annual data to understate amplitude. Of the 18 comparisons of total rise and fall (col. 12) 13 show smaller amplitures in the annual series than in the monthly. The average degree of understatement is nearly 15 percent. This, however, is relatively unimportant. If the degree of understatement were fairly constant we could readily allow for it.

In any case, our usual concern is not with the absolute amplitude of a series but with judgments about the relative amplitudes of two or more annual series. But the variation in the measures yielded by annual data is great. During 1910-33 cycles in annual reports of deflated clearings had an amplitude 31 percent larger than those in monthly reports. During 1858-80 the amplitude of cycles in call money rates was 68 percent lower in the annual than in the monthly data. For the 18 comparisons of total rise and fall the average deviation from the mean relative amplitude of annual data compared with monthly was 21 percentage points.

Divergences from the mean degree of understatement are widest when the annual data either skip several cycles or inject an extra cycle. Thus every comparison in which the average amplitude measured from annual data was wider than that measured from monthly data involved annual data that skip two or more cycles recognized in the monthly data. The two cases in which the annual data inject a cycle yielded the only comparisons in which the average amplitude was less than half as large as that measured from monthly data.

To render measures of amplitude from annual data useful at all, we use a combination of procedures. First, amplitudes computed from annual data are never compared with those based on monthly data. Secondly, we confine our conclusions to those supported by several series. For example, we base judgments about the relative amplitude of output and inventories for manufacturers in general on measures for nine or ten industry groups. Thirdly, we supplement averages of cyclical amplitude based on all specific cycles observed in two series with averages based only on corresponding cycles. In this way the extreme variations illustrated by Table 17 are avoided.

CONFORMITY

The erratic influences exercised by annual reporting upon the number of cycles, their timing, and their pattern combine to render conformity measures from annual data less reliable than their monthly counterparts. Since annual data sometimes skip contractions when the secular trend of a series is rising, they tend to understate conformity to reference contractions in growing activities. And since they sometimes skip expansions when the secular trend is falling, they tend to underestimate conformity to reference expansion in declining activities. The displacement of peaks and troughs, sometimes forward, sometimes backward in time, helps to conceal regular response to business cycles. Moreover, when there is evidence of a regular lead or lag it can be allowed for more flexibly in monthly or quarterly data. An additional trouble is the irregular way in which annual data alter the patterns of cycles. Finally, if a reference peak or trough is misdated by a year, this is likely to affect the conformity indexes of annual data, while the smaller errors that might be made in monthly reference dates would generally have slight influence on the indexes of monthly series. It may be expected that if an activity conforms well to business cycles annual data will yield conformity indexes that tend to understate its true conformity. If an activity conforms poorly, an-

TABLE 18

Conformity of Monthly and Annual (Calendar Year) Data to Business Cycles, Six American Series

	NO. OF REF. CYCLES*	STAGES MATCHED WITH REF. EXP.	INDEX OF CONFORMITY TO REF.		
			Exp.	Contr.	Cycle
DEFLATED CLEARINGS					
Monthly, 1879-1933	15	VIII-V	+100	+73	+86
Annual, 1878-1932	15	I-V	+100	+7	+86
PIG IRON PRODUCTION					
Monthly, 1879-1933	15	I-V	+100	+100	+100
Annual, 1878-1932	15	I-V	+100	+73	+100
RAILROAD STOCK PRICES					
Monthly, 1858-1933	19*	VIII-IV	+79	+60	+74
Annual, 1858-1932	19*	I-V	+68	+40	+63
SHARES TRADED					
Monthly, 1879-1933	15	VIII-IV	+87	+73	+93
Annual, 1878-1932	15	I-III	+87	+47	+86
CALL MONEY RATES					
Monthly, 1858-1933	19*	I-V	+68	+100	+100
Annual, 1858-1932	19*	I-V	+79	+68	+84
RAILROAD BOND YIELDS					
Monthly, 1858-1933	19*	III-VI	+47	+30	+68
Annual, 1858-1932	19*	III-VII	+26	+35	+63

Source: *Measuring Business Cycles,* Table 82, p. 266.

* The contraction and full cycle indexes cover an additional reference contraction at the beginning of the series.

nual data will yield conformity indexes that may be either higher or lower than monthly data would yield.

The quantitative importance of these various difficulties can, of course, be judged only by comparing results from monthly and annual series (Table 18). The indexes from annual data are usually lower than those from monthly data. In only a few cases, however, are they much lower.[16] In only two comparisons, moreover, are they higher, and then by only minor amounts.

These fairly favorable indications may, however, reflect the relative stability introduced into our measures by the large number of cycles covered by the six test series. Table 19, covering five

TABLE 19

Conformity of Monthly and Annual (December) Data to 5 Business Cycles, Six American Series

	Stages matched with ref. exp.	Lead (−) or lag (+), months	Index of conformity to ref.: Exp.	Contr.	Cycle
	DEFLATED CLEARINGS				
Monthly, 1914-1933	VIII-V		+100	+60	+56
Annual, 1914-1932		0	+100	−20	+78
	PIG IRON PRODUCTION				
Monthly, 1914-1933	I-V		+100	+100	+100
Annual, 1914-1932		0	+60	+20	+33
	RAILROAD STOCK PRICES				
Monthly, 1914-1933	VII-III		+20	+60	+33
Annual, 1913-1931		−6	+20	+20	+33
	SHARES TRADED				
Monthly, 1914-1933	VIII-III		+100	+60	+100
Annual, 1913-1931		−6	+60	+60	+56
	CALL MONEY RATES				
Monthly, 1914-1933	I-V		+60	+100	+100
Annual, 1914-1932		+3	+60	+60	+100
	RAILROAD BOND YIELDS				
Monthly, 1914-1933	I-V		+20	+80	+56
Annual, 1914-1932		+6	+60	+60	+56

16 But bear in mind the instability of our conformity indexes! One defection in 19 cases reduces the index from 100 to 84 as in Call Money Rates; one defection in five cases reduces the index from 100 to 60, etc. See ibid., pp. 183-5, 195.

reference cycles, provides a sterner test. The annual data here employed are of the one month per year variety which resemble our end of year inventory data more closely than annual aggregates. Conformity measures of the annual data are made by the special method described in Section 1 and applied to annual data in the rest of this study.

Reducing the number of cycles does indeed widen the divergence between the indexes yielded by monthly and annual data. The results, however, are still quite good. In one series, pig iron production, the annual indexes would cause us to be doubtful about the response to business cycles when, in fact, conformity was highly regular. In the other five series the indications of conformity yielded by the annual measures are generally accurate in view of the instability of our indexes when few cycles are compared.

While these comparisons of conformity measures are fairly reassuring, the erratic action of annual data must be borne in mind. Low indexes are not necessarily inconsistent with regular association, and sometimes the index may be high when conformity is low. Our practice, therefore, is to base our findings on the showing of several indicators and to reach positive conclusions only when there is a fair consensus.