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Appendix F

TIMING ANALYSIS

The determination of specific and reference chronologies makes possible a simple yet precise measure of timing for all corresponding series. One need merely count off the years of lead or lag, if any, and compute a mean lead or lag with an average deviation as a measure of dispersion. This is one of the standard cyclical timing measures worked out and used by the National Bureau of Economic Research in previous investigations.[13] The measure is derived from a direct comparison between matching or "corresponding" specific and reference peaks and troughs, i.e., between turning points for selected activities and residential building. The specific chronologies of a local residential building series are related, as we have previously stated, to reference chronologies of the corresponding larger regional or national aggregate. Altogether some 661 specific turning points, about 85 per cent of the total available, were matched for 118 series, involving, all told, some 260 long reference cycles. The results are set forth in Table F-1. The 119 unmatched turning points represent "extra" specific cycles or "skipped" reference cycles. Nearly two-thirds of the unmatched turning points relate to Ohio experience; non-Ohio reference and specific cycle patterns are more synchronized. In the great majority of cases, turning points were more easily matched than was indicated in the case of national business-cycle chronologies. The heterogeneity of the series there dealt with, measuring against a single reference scale all phases of business life analyzed on a sensitive monthly or quarterly basis, made the operation of "matching" specific with business cycles "very hazardous" [41, p. 117]. The greater homogeneity of our series and predominant use of local reference chronologies simplified the task of judgment. Nearly half the unmatched turns were found in "irregular" series—nearly four-fifths of which were in Ohio—with only slight apparent relation to building cycles. In a small minority of cases, the scope for judgment was wide and the resulting measures were unreliable.

Even when turns are successfully matched, the resulting leads

TABLE F-1
General Characteristics of 169 Analyzed Series

	Building Series			*Other Series*			
	Ohio	*Non-Ohio*	*Total*	*Ohio*	*Non-Ohio*	*Total*	*Total*
1. Number of series with:							
a. Matched turning points	34[a]	24	58	33[a]	34[a]	67	125
b. Reference cycle only	0	0	0	32	3	35	35
c. Specific cycle only	0	4	4	0	5	5	9
Total	34	28	62	65	42	107	169
2. Number of turning points:							
a. Matched	180	131	311	148	202	350	661
b. Unmatched	53	27	80	22	17	39	119
3. Number of long reference cycles included in:							
a. (1a) above	84 1/2	32	116 1/2	66 1/2	89 1/2	156	272 1/2
b. (1b) above	2	0	2	67	7	74	76
Total	86 1/2	32	118 1/2	133 1/2	96 1/2	230	348 1/2

NOTE: This table includes all local building series analyzed on a nationwide reference chronology.
[a] Contains one series which was noncorresponding by turning points.

or lags must be used with caution as a measure of structural temporal relationship. In the first place, the practice of setting reference dates at the close of a flat or double peak or trough produces a bias. Secondly, the temporal relationship holds only for turning-point years themselves. But even a long time series running over three long cycles will yield only seven eligible turning points; a two-cycle series will yield only five eligible turning-point years. Not all eligible turning points will be successfully matched. The use of unsmoothed annual returns allows what Mitchell once characterized as the "cloud of random happenings" to affect chronology when operative in the turning-point zone [193, p. 98]. In addition structural changes are at work—and more potently in long than in short cycles. Temporal relationships may well vary with the strength of influences which expand or contract durations. For these reasons, it has always been indicated that they were "highly variable" in the business cycle [42, p. 179]. It was just this high variability in temporal relationships which the Harvard research group found so disconcerting when an attempt was made to estimate them among covarying time series.[14] The tangible measure of this high variability is taken by our mean deviation from the mean lead-lag and the ratio of the mean lead-lag to its average deviation. For fifty-seven building series, the mean lag was .19 ± 1.51 years. The mean deviation for the same measure was 2.06 ± .96 years.

Because of this high variability, our lead-lag measure at turning points was supplemented by two alternative measures. One is another NBER standard timing measure, derived directly from review of reference cycle patterns. The procedure of determining lead-lag from reference cycle patterns is comprehensively described in [41, pp. 185 ff.]. On the basis of successive and average reference cycle patterns, each series was classified as either positive, inverted, neutral, or irregular. Classification was carried through on the basis of six rules crystallized along lines previously developed in the National Bureau:

A. Neutral Series
   1. Expansion segment covers two reference expansion phases and two reference contraction phases.
B. Postive and Inverted Series
   2. Must generally rise for at least two but not more than six

consecutive stages or fall for at least two but not more than six consecutive stages.

3. More than half of the phase movements are conforming (positive) or more than half are nonconforming (inverted).
4. The selected expansion must contain more stages of expansion than contraction.

C. Irregular Series

5. All patterns are irregular if they do not meet A and B above or if successive cycle patterns diverge essentially from the average pattern.

D. Trend

6. Leveling off in a phase is only considered a movement if it is in clear contrast with a trend of the opposite phase.

The most unambiguous is rule 1. It indicates that specific turning points will tend to be placed at nearly the center of reference cycle phases.

The effect of rules 2 and 4 is to screen out irregular series. Under rule 2, a series is considered irregular if its reference cycle pattern over the eight cycle stages moves continually in the same direction or continually changes direction. Under rule 4, a series is considered irregular unless the selected expansion segment contains more stages of expansion than contraction. If, for example, it seems that expansion runs from II-VIII, then at least four of these stages must involve expansion.

Rule 3 provided the basis for characterizing a given series as positive or inverted. Patterns with five or more phases which conform to standard (rise during reference expansion I-V and fall in reference contractions V-IX) are positive; and vice versa for the inverted.

These rules were chiefly used to evaluate a time series as reflected by its average and successive reference cycle pattern. If these successive patterns were themselves irregular, or fluctuated excessively in form, then regardless of the behavior of the average pattern the series was classed as "irregular." Usually irregular series were so exhibited both in their individual and average versions. Discretion in classification was exercised chiefly when use of the rules yielded a different outcome with individual cycle patterns and their average.

The results of this allocation into classes of 160 reference series are summed up in Table F-2. It is interesting to compare this pattern of distribution of building cycles with the analogous pattern of distribution of 794 American series for business cycles. The respective per cent shares for each class are set forth in the following tabulation:

Cycle Class	*794 Series Analyzed for Short Business Cycles*	*160 Series Analyzed for Building Cycles*
Positive	76.5	71.3
Inverted	9.8	10.0
Irregular	10.7	16.3
Neutral	3.1	2.5

SOURCE: [193, pp. 53-56].

We see that the distribution of building reference cycle patterns by type closely resembles the analogous distribution of business-cycle reference cycle patterns. The principal pattern divergence is the larger number of irregulars in building cycles. Most of these are found in Ohio and include few series measuring building activity directly. The more common types are series relating to activities only slightly affected by waves of building, e.g., manufacturing value, mortgage lending series, sluggish series such as marriages, or average value series. The last are affected by a crisscross of influences, including price movements proper, as well as shifts in distribution by type of deed (purchase or mortgage) or size of instrument. Over half of the Ohio irregulars were found in the sample group made up of counties with a low degree of urbanization, heavily dependent upon farming. It is a measure of the diffuse quality and lack of

TABLE F-2
Classification of Local Reference Series by Type

Classification of 160 Reference Series	*Building*			*Other*			
	Ohio	*Non-Ohio*	*Total*	*Ohio*	*Non-Ohio*	*Total*	*Total*
Positive	25	22	47	44	23	67	114
Inverted	2	0	2	8	6	14	16
Irregular	7	2	9	12	5	17	26
Neutral	0	0	0	1	3	4	4
Total	34	24	58	65	37	102	160

coherence in realty and building markets of such areas that seven out of sixteen reference cycle patterns in this area were irregular, while in other sample group areas no more than three patterns were found to be irregular.

It is curious that inverted series among business and building cycles should crop up with a frequency so nearly identical, at 10 per cent. Among business cycles, inverted series chiefly record unfavorable business developments like unemployment, commercial failure, or activities with negative income elasticities, or buffer stock inventories maintained to absorb sales instability [193, pp. 62 ff.]. Among building cycles, the same classes tend to invert, such as vacancies (a kind of unemployment of shelter facilities), and foreclosure (which falls into the class of unfavorable business developments). Only rarely will a nonresidential building series become an inverter, though long leads or lags or irregular behavior is common.

Positive and inverted patterns can have a variety of characteristic expansion phases depending upon relative duration and lead or lag. The number of reference patterns in each type is listed by our four-way breakdown in Table F-3. Because of the longer duration of building cycles it seemed advisable in twenty-four cases to recognize two-stage contractions, though this class was not recognized for business cycles. Hence, our list of possible expansion stages is more extended than was the business cycle list.

Despite this variance in classification, the distributive patterns of leads and lags at the peaks or troughs, as detailed in Table F-4, closely resemble the analogous pattern for business cycle series. There are more coincidences of timing in short cycles and there are fewer longer leads and lags. As with business cycles, leads preponderate at troughs; but at peaks, building cycle lags outnumber leads though business cycle leads and lags balance [193, pp. 73 ff.]. This greater preponderance of lags at peaks is owing to the tendency of many real estate and other building-related series to have relatively short contraction periods. These contractions come late and do not last long. Since reference chronologies are not adjusted to the predominant cluster of specific turning points but to one basic activity, other activities less strongly attuned to the predominant rhythm would tend to lead at troughs and lag at peaks.

To a degree, the phase lead-lags of reference cycle patterns

TABLE F-3
Classification of Reference Cycle Averages by Series, Ohio and Non-Ohio, Building and Other

Reference Cycle Stages with Expansion	*Building*		*Other*		
	Ohio	*Non-Ohio*	*Ohio*	*Non-Ohio*	*Total*
V-VIII (inverted)			2		2
V-IX			1		1
V-II					
V-III					
VI-IX					
VI-II					
VI-III	1		1		2
VI-IV	1			1	2
VII-II					
VII-III (neutral)			1	1	2
VII-IV (positive)			1		1
VII-V	1				1
VIII-III			2		2
VIII-IV	2	2			4
VIII-V	2	4	5	3	14
VIII-VI	1		5		6
VIII-VII	2				2
I-III			1	1	2
I-IV				3	3
I-V	9	6	10	6	31
I-VI	4	2	6	3	15
I-VII	2	3	5	1	11
II-V	1	4	2		7
II-VI			2	1	3
II-VII			4	4	8
III-V		1		1	2
III-VI	1		1		2
III-VII (neutral)				2	2
III-VIII (inverted)				1	1
III-IX			1		1
IV-VII			2	1	3
IV-VIII			1	2	3
IV-IX				1	1
Irregular	7	2	12	5	26
Totals	34	24	65	37	160

TABLE F-4
Leads and Lags, 134 Long Building and 709 Business Cycle Average Reference Cycle Patterns

	Building Series Analyzed		*Business Series Analyzed (Per Cent)*
	Number	*Per Cent*	
Behavior at trough			
2-stage leads	7	5.2	5.3
1-stage leads	34	25.4	18.7
Coincidences	65	48.5	66.1
1-stage lags	18	13.4	5.8
2-stage lags	8	6.0	4.1
3-stage lags	2	1.5	–
All leads	41	30.6	23.9
Coincidences	65	48.5	66.1
All lags	28	20.9	10.0
Behavior at peaks			
2-stage leads	8	6.0	1.5
1-stage leads	15	11.2	14.6
Coincidences	59	44.0	66.7
1-stage lags	29	21.6	13.0
2-stage lags	23	17.2	4.0
All leads	23	17.2	16.1
Coincidences	59	44.0	66.7
All lags	52	38.8	17.1

NOTE: In addition to the series analyzed, there were twenty-six irregular building series and eighty-five irregular business series.

SOURCE: Data for business cycles taken from [193, p. 53]. Mitchell's schedule of percentages were adjusted to exclude per cent of irregular series, making analyzed series equal to 100 per cent.

are free from some of the biases which affect turning-point lead-lags. Thus, irregular or short-cyclical influences which accentuate peak or trough values are smoothed in reference cycle patterns. The reference cycle phase leads or lags may be converted into years by average cycle duration and then may be used to check turning-point lead-lags.

The mean and median lead-lags by reference cycle and turning-point analysis are set forth for all of our building and nonbuilding series in Table F-5. From this table, it appears that computation of lead-lags by reference cycle patterns in building activity comes out with appreciably longer lags (.41 over .19 years) but that the reverse occurs with nonbuilding series. Reference cycle results for building series are more concentrated than the distribution of lead-lags on a turning-point basis. Scatter diagrams of paired observations exhibit a relatively wide variance with one quarter of all observations falling outside a three-year range around the central tendencies. Uncertainty thus remains regarding our lead-lag measures, and to allay this uncertainty a third test was developed by pairing smoothed specific and reference series over the lead-lag spectrum and determining optimum lead-lag by the highest correlation coefficient.[15]

Before correlation, it was necessary to remove the role of short cyclical or irregular movements from the data. We experimented at first with interpolated overlapping average specific short cycle standings. But since short cycles overlapped very often during contractions with long-swing movements, use of a moving average of three to five years was found preferable. The correlations were carried out for eleven different time-period pairs (five-year lag to five-year lead). Trend was not removed from the series before the correlation but was removed from the correlation coefficients by a conversion formula.[16]

This permitted account to be taken of the effects in each case of removal of trend from the pattern of the correlation coefficients. The resulting set of correlation coefficients was graphed on standard scales, with serial lags for the *X* axis and the correlation coefficient on the *Y* axis, making up a "correlogram." As computed, the reference series (residential or total building) is treated as the dependent variable with fixed timing, while the other correlated variable is given variable timing from plus five years to a serial lead of minus five years. Only for a few series with extreme leads (such as vacancies) was the serial order high enough to disclose two turns for the mean period of fluctuation. For a few series with a long duration and long lead-lag, the serial order was too low to permit the optimum correlation clearly to emerge (as was true of Stockholm vacancy, series 0040). But in all cases the level of the correlogram at or near the optimum lead-lag provided an independent measure of the amount of variation in the reference variable "explained" by

TABLE F-5
Means and Standard Deviations of Timing Meaures, Ohio and Non-Ohio, Building and Other

	Average Lead-Lag, Turning-Point Method (1)	*Average Deviation, Lead-Lag, Turning Point (2)*	*Average Lead-Lag, Reference-Phase Method (3)*	*Average Lead-Lag, Correlation Method (4)*
		Building		
Ohio				
Mean	.16 (1.62)	1.97 (.71)	.53 (1.53)	−.138 (1.8)
Number of series	33	33	27	18
Non-Ohio				
Mean	.24 (1.34)	2.20 (1.18)	.25 (1.76)	.500 (.50)
Number of series	24	24	22	4
		Other		

Ohio				
Mean	.78 (1.66)[a]	2.12 (1.18)[a]	.27 (1.78)	.786 (1.82)
Number of series	32	32	53	28
Non-Ohio				
Mean	−.34 (2.08)	1.96 (.83)	−.12 (2.31)	−.733 (2.21)
Number of series	33	33	32	30
		Total		
Building				
Mean	.19 (1.51)	2.06 (.96)	.41 (1.63)	−.022 (2.17)
Number of series	57	57	49	22
Other				
Mean	.21 (1.97)[a]	2.04 (1.02)[a]	.15 (2.00)	0 (1.66)
Number of series	65	65	85	58

NOTE: Figures in parentheses are standard deviations.
[a] Uses inverted measure for 0232.

a linear regression on the correlated variable. The optimum correlation coefficient thus may serve as a crude measure of covariation between cycles of the reference series and of the "specific" series. Unlike other measures of synchronization or conformity, the correlation coefficient allows for covariation in form or magnitude of movement as well as in direction of movement.

Of course the correlation coefficient for a sample of observations is subject to sampling variation. However, the reliability of the observed correlation coefficients must be estimated by complex methods. See [84, pp. 293 ff.].

The form of the correlogram may point to disturbance in the serial correlation. It does not however directly indicate the source of this disturbance, which could be due to timing or amplitude irregularities or variation in allocation by phases of cycle duration in successive cycles either of the reference series or of the "specific" series. The fact that only comparatively few long cycles were available for tabulation meant that the five-year segments dropped from the correlation at either end of the serial order could exert an influence on the correlogram. In general, the sinelike form of the correlogram can be affected by random factors when only a short term of experience of two serially correlated autoregressive series oscillating irregularly around the same mean period are available for scrutiny [151, p. 406]. If a sufficiently long segment of experience were available for analysis, the form of the correlogram (if extended over advanced serial orders) would have provided a method of determining the underlying character of the temporal relationship [151, p. 404].

Comparison of different correlograms for the same reference series or local area or aggregate, however, points to characteristics of the relationship which are obscure in the original time-series or which are only weakly exhibited in the contrast of specific and reference cycle patterns. The correlograms therefore are serviceable for more than measuring optimum lead-lag. They supplement our exhibit of reference and specific cycle patterns. We have accordingly presented correlograms along with cycle patterns whenever the need arose.

The general level of lead-lags for building and other series in Ohio and elsewhere was presented earlier in Table F-5, col. 4. The mean level of lead-lags can be compared by the three different measures. For building series, reference cycle methods tend to lag and correlogram analysis to lead, with turning-point methods in between. For nonbuilding series no uniform tendency stands out. All three methods yield essentially the same result, since all three point to very short leads or lags, less than one year, on the average.

To permit divergencies in methods of estimation to stand out more clearly, the spread between high and low measures of lead-lag by the three methods was tabulated. One hundred and eight local series were analyzed where at least two alternative timing methods were practiced; in four cases out of five the three methods were utilized. We excluded the eight residential building series of England, for which no correlogram analysis was prepared. The results are as follows:

Spread Between High-Low Lead or Lag by the Three Estimation Methods (Years)	*Number of Series*		
	Ohio	Non-Ohio	Total
0– .99	18	16	34
1.0–1.99	21	19	41
2.0–2.99	14	5	19
3.0–3.99	7	5	12
4 and over	1	2	3
Total	61	47	108

The three instances of four and over years involve a volatile Berlin migration series (0024) and two unsystematic Ohio series—mean value of town (nonfarm) lot mortgages for group V (0241) and number of town acres sold for group IV (0305). Two series with very large gaps, the value of commercial building, Ohio, group I (0187) and the number of town lot mortgages, Ohio, group IV (0232), were excluded because the basis for classification (positive and inverted) diverged, depending on analysis of turning points, reference cycle patterns, or correlograms. The table indicates that in seven cases out of ten the highest spread between alternative timing measures was less than two years; and that only in 13.8 per cent of the cases was the spread over three years. Considering the diversity in methods of smoothing employed (between reference cycle stages and moving average), divergencies of coverage (complete series with correlograms, corresponding turning points or characteristic stage phases) and divergent methods of handling extreme values (by least squares or simple averaging), the diversity in results achieved is understandable.