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CHAPTER VI

COVARIATION OF SHORT-TERM INTEREST RATE DIFFERENTIALS AND EXCHANGE RATES

Section 1. Formation of Pairs

(1) It has now become possible to consider the cyclical covariation of the short-term interest rate differentials[1] and the exchange rates. The generally assumed mechanism of the transfer of short-term funds between two countries would make the appearance of a high degree of covariation in each pair of series plausible (see Chapter IV, section 1). Indeed this correspondence would be expected, unless this mechanism were systematically offset by counteracting forces. Occasionally that may have happened but hardly very frequently, unless the experience of the prewartime has been grossly misinterpreted. On the other hand disparities between expected and observed values may relate to the absolute levels of differentials or exchanges, or both. When this is the case a new element has been introduced which we shall find very difficult to cope with.

(2) The fact that each set of two time series is interdependent with the other sets is in many ways a seriously complicating factor; but it will play no important role in the following. There we simply compare the differentials of one pair of countries with the exchange rates of the *same* countries. There is nothing objectionable in this, and complications due to a further interdependence do not immediately arise. Likewise it is within the province of statistical propriety to compare, under strictly specified conditions, the results relating to one pair of countries with those obtained for another pair. If in the second pair a country included in the first pair reappears, some account must be taken of the interdependence.

(3) We begin with the study of the *specific cycles*. Charts 18 to 23 show clearly recognizable cycles. Because of their nature as relative series it is necessary to make an arbitrary decision what should constitute a peak and what a trough. We are at liberty to

[1] Except when otherwise necessary, we shall again abbreviate this term and speak simply of the differentials.

decide this arbitrarily for one set, e.g., for the differentials, but then for the other set (exchange rates) the extrema are uniquely determined as either peaks or troughs. Even before such a choice is made for the first set—it is quite immaterial whether we choose the differentials or the exchange rates for this role—the extrema can be marked off, since the process of determining extrema should be sufficiently objective (or "mechanical") at any rate to yield the same dates, even though a peak may have to be transformed into a trough or vice versa through inversion of the series.

(4) We forego the usual comparison of the specific cycles with the reference cycles. This is justified by the nature of the two sets of series, each one being a relative series. It is not to be expected that a pair formed by the differential series and the exchange rate for the same two countries should *together* show any conclusive behavior in regard to the reference cycle of either (or both) countries. Nevertheless a comparison of each pair with the corresponding pair of reference cycles can be carried out under certain restrictions. We shall refer back to Table 4 in Chapter II, where the same pairs are formed, which we shall discuss presently.

The first important point to settle is the determination of the exact pairs which are to be measured. The choice is dictated by our acceptance of the economic mechanism referred to repeatedly. That is to say, if the interest rate in A rises relatively to that of B a shift of funds from B to A will (presumably) occur, and this requires the purchase in B of currency of A with that of B. We may therefore measure either the parallelism of movement between these two series—then we have to compare the differential A over B with the exchange of B on A, i.e., in terms of units of currency B to be paid for a unit of A; or we measure the countermovement, in which case we either invert the differential or the quotation of the currency (but not both). Since it is preferable to measure a parallel movement than a countermovement, this then determines the exact pairs, which are in Table 65, or, if one wishes, their opposites in both groups. The statement that a parallel movement of two time series, forming one of the above pairs, shows a correspondence as expected from the working of the international mechanism, is therefore permissible, as well as the opposite statement when no parallel movement occurs. This neglects two things: a) a parallel, or opposite, movement may have been due to other reasons; it will therefore be necessary to find out whether other factors work at all or as frequently as those

TABLE 65

Pairing of Short-Term Interest Rate Differentials and Exchange Rates

Differential (A over B)	*Exchange rate (B on A)*
New York over London	£ per $100
Paris over New York	$ per 100 fr
New York over Berlin	M per $100
Berlin over London	£ per 100 M
Paris over London	£ per 100 fr
Paris over Berlin	M per 100 fr

here assumed and what their comparative strength is (if this can be determined); b) we are at present satisfied if there is a parallelism in the *direction* of movement, but make no statements about the extent or magnitude involved. In other words "parallel" is not to be taken any more literally than before, when covariation of exactly the same kind was measured. They are given, according to our definitions (cf. page 44), when two or more series have an expansion or contraction between specifically defined turning points. It is exactly the same here, obviously the amplitude aspect looms larger than before.

The expectation of a high degree of covariation is justified only if one can assume that the other disturbing factors are either very small or neutralize each other in the long run, so that correspondence of movement would still be the normal expectation. Aside from the other influences mentioned (foreign trade, etc.) there is the one noted in Chapter IV. It consists in the simultaneous pull exercised upon a given money market by several others. If therefore we observe a rise in one differential, then it is not necessary to assume that the exchange must move in the same direction, because a differential between the given and a third money market may have risen more, and we shall instead see a flow of funds to the third. This introduces the possibility of a minimal incentive determined by the maximum pull at a given moment of time. All this is very difficult to handle statistically, although the conceptual side of the matter is quite simple.

Once the corresponding pairs have been determined it is possible to compare the specific cycles not only for their turning points, i.e., durations, but also for the "expansion" and "contraction" phases. Furthermore we can compare one pair with others if care is taken to exclude pairs which would be the inverse of those already chosen. At any rate there can be no doubt about the measurements of the over-all duration of specific cycles. But we shall postpone the discussion of their duration until somewhat later (cf. page 287), because it will be found preferable to examine them together with a subcycle which, as we shall see, is covered by the specific cycles. In this manner the properties of both kinds of cycles will become clearer. It will be seen that we are forced to subject these pairs of series to many more measurements than others, a necessity which unfortunately makes a certain amount of repetition unavoidable.

Section 2. Discussion of the Covariations

(5) The specific cycle covariation for each pair is shown in Table 66. A picture is easily obtained from Charts 18 to 23, to which reference will be made especially in connection with the previously mentioned subcycles.

TABLE 66

Phase Comparison of Specific Cycles of Short-Term Interest Rate Differentials and Foreign Exchange Rates, Prewar, Seasonally Corrected Data

		SAME PHASE IN:				SAME PHASE IN:			
	Months covered[a]	*Expansions*	*Contractions*	*Total*	*Different phase*	*Expansions*	*Contractions*	*Total*	*Different phase*
		MONTHS				PERCENTAGES			
New York–London[b]	222	62	57	119	103	27.9	25.7	53.6	46.4
Paris–New York	339	86	117	203	136	25.4	34.5	59.9	40.1
New York–Berlin	253	99	53	152	101	39.1	21.0	60.1	39.9
Berlin–London	274	61	70	131	143	22.3	25.5	47.8	52.2
Paris–London	321	102	76	178	143	31.8	23.7	55.5	44.5
Paris–Berlin	286	81	88	169	117	28.3	30.8	59.1	40.9

Note on procedure followed for comparing short-term interest rate differentials and exchange rates: in comparing the movements of the short-term interest rate differentials and the movements of the exchange rates for six pairs of countries the parallel movements of the two series were measured (i.e., the differential of A over B with the exchange of B on A were compared cf. p. 281). Table 65 gives the exact pairs formed when the movement between the exchange rates and differentials is parallel. Where the exchange rate data were not available in the form indicated in Table 65, we inverted the exchange rate series to make the comparison.

[a] The following are the exact periods used:
New York–London: Dec. 1878 to Mar. 1901
Paris–New York: Apr. 1881 to Oct. 1912
New York–Berlin: Sept. 1887 to Mar. 1913
Berlin–London: Jan. 1880 to July 1908
Paris–London: Feb. 1881 to May 1911
Paris–Berlin: Nov. 1877 to Dec. 1908

[b] For detailed description of each pair's differentials and exchange rates, see text.

TABLE 67

Phase Comparison of Specific Cycles of Short-Term Interest Rate Differentials and Foreign Exchange Rates, 1925–1931, Seasonally Corrected Data

	SAME PHASE IN:				SAME PHASE IN:			
	Expansions	*Contractions*	*Total*	*Different phase*	*Expansions*	*Contractions*	*Total*	*Different phase*
	MONTHS				PERCENTAGES			
New York–London	18	0	18	3	85.7	00.0	85.7	14.3
Paris–New York	3	21	24	15	07.7	53.8	61.5	38.5
New York–Berlin	11	0	11	8	57.9	00.0	57.9	42.1
Berlin–London	11	13	24	27	21.6	25.5	47.1	52.9
Paris–London	...	...	...	...	...	...	...	...
Paris–Berlin	...	...	...	...	...	...	...	...

The table covers the post-World-War-I gold standard years. See footnotes to Table 66. The number of months covered, for each pair, is: New York–London, 21; Paris–New York, 39; New York–Berlin, 19; Berlin–London, 51.

Before the war the periods covered range from 267 months for New York–London to 378 months for Paris–New York. The postwar period is 19 to 51 months, 1925–1931, when the gold (and gold exchange) standard was in operation in all four countries simultaneously. The significance of the selection of these periods will become clear when we arrive at Tables 70 and 71. Their choice is governed in part by the above-mentioned shorter cycles, which are not always observed but occur during the periods listed.

In view of these absolute differences the percentages are of immediate importance. In the prewar period the over-all picture is that of a moderate correspondence of movement. But it is by no means impressive and does not compare well with some covariations already noted.[2] In one case there is even more disagreement than covariation: Berlin–London.

(6) The postwar period exhibits marked changes from the prewar.

For example, the pair New York–London, which did not show the highest covariation in the prewar period, now has a value of 85.7 per cent, exceeding all others. Similar pairs were found only rarely

[2] See the significance test of percentages in Chapter II, section 2, which is applicable to the present situation.

TABLE 68

Comparison of Differential of New York Call Money Rate over London Open-Market Discount Rate and Foreign Exchange Rate, December 1878–March 1901, Seasonally Corrected Data
(267 months)

Specific Cycles of Differential and Foreign Exchange Rate
Phase Comparison

Months covered	SAME PHASE IN: *Expansions*	*Contractions*	*Total*	*Different phase*	SAME PHASE IN: *Expansions*	*Contractions*	*Total*	*Different phase*
		(months)				(percentages)		
267	71	66	137	130	26.6	24.7	51.3	48.7

Number and Duration

NUMBER OF CYCLES: *Differentials*	*Exchange rates*	AVERAGE DURATION OF CYCLES: *Differentials*	*Exchange rates*
		(months)	
7	8	38.1	33.4

before. The other pairs show no drastic changes; but recall the difference in the size of the sample. Nevertheless the notorious facts of high speculative activity during the postwar period, the stabilization of sterling at too high a level, the politically dominated movement of short-term and long-term funds, the influence of German reparations, the decline in international financing of the prewar kind, the growing control by the central banks—none of these factors produced the great irregularity and small covariation otherwise found.

Where a high degree of correspondence appears, it is possibly of an accidental character, devoid of deeper significance for the proving or disproving of our "mechanism."[3] It is noteworthy that the highest postwar correspondence should be shown in pairs of countries involving New York. There were very large movements of funds, especially into Germany, but their motivation was not of the required kind.

(7) Table 4, describing the behavior of the reference cycles for the same pairs of countries, shows in most instances a far better over-all correspondence between their entire business cycles than was shown by the differentials and exchange rates. This is a singular result, especially for the prewar period. The lowest value

[3] Still assuming that a covariation would suffice as a proof.

for the reference cycle covariation is only a fraction of one per cent lower than the best correspondence for the mechanism.

Why should there be so much better correspondence among the entire business cycles—to the extent that they are characterized by the dates of the turning points—than for the differentials and exchange rates, when in the first instance there is no particular a priori expectation, while in the second there is a high one? The parallelism of reference cycles is one of an average behavior; for the other data parallelism would be quite accidental, unless there is a functional dependency such as that postulated by the mechanism of short-term capital transfers. It is difficult to say whether two large averages, i.e., reference cycles, should be expected to move in closer agreement than two individual series when really all four are involved, each one of which is subject to a great number of influences other than those which they exert upon each other directly.

Section 3. The Introduction of Short Cycles

(8) In the graphs of the differentials and exchange series the specific cycles cover up smaller movements which shall simply be called "short cycles." In the present study they are only observed here. They may be a unique phenomenon, perhaps brought forth by peculiarities of the mechanism with which we are at present concerned. It was always clear and has been repeatedly emphasized that the specific cycles cover minor variations in the direction opposite to the particular specific cycle phase under consideration.[4] In our present pairs of series the specific cycles are very long, especially in view of the repeatedly mentioned high speed of adjustment in both, which might even raise the expectation that

[4] These are our rules for the distinction of short cycles:

1. *Duration:* an upswing or downswing of the short cycle must last not less than three months. Shorter movements are recognized if the rise or fall in a single month exceeds the standard set for the amplitude (see rule 3 below) and the whole short cycle lasts at least six months and is not of a length that is a high percentage of a specific cycle.

2. *Continuity:* rise or fall during three consecutive months, or during at least six months, interrupted by not more than two slight inverse movements, or five months interrupted by one slight inverse movement.

3. *Amplitude:* total rise or fall of at least one per cent for the interest rate differential series, and of 0.25 per cent of the parity for the exchange series.

These criteria are admittedly arbitrary, but we hope that they will be found plausible, since they still leave some room for random disturbances, to which these two groups of series may be particularly sensitive.

there would be no cycles at all, or a tendency for them gradually to disappear or to become shorter and shorter.

The criteria for short cycles are similar to those for specific cycles. In both cases it is possible—and does indeed happen—that minor fluctuations occur between peaks and troughs. These are neglected, according to the definitions used. Like all definitions, those for short cycles are arbitrary. The reader will observe from Charts 18 to 23 that if a relaxation of our standards is permitted more "short" cycles appear, and there may be covariation among these too. But we limit ourselves to the definition given in footnote 4. This accounts also for the periods listed in footnote a of Table 66. These are the times when short cycles fulfilling the criteria of our definition can be observed with considerable frequency. However, the charts show the entire period from approximately 1870 to 1914, and all short cycles are marked off no matter when they occur.

During the periods covered by the subsequent computations it happens from time to time that in either one of the two series, or in both at the same time, no short cycles as defined appear. These months have been omitted from the computation, but they are, of course, shown in the charts. These are periods of movement where, under a less stringent set of criteria, a "secondary short cycle" might be recognized. Their peaks are marked off in the charts by crosses. Thus our short cycles as defined, even in the periods selected (cf. footnote a, Table 66), do not necessarily form a continuous chain. All these difficulties—if there be any at all—disappear, of course, completely when the sign correlations of section 5 below are used. For New York–London, Paris–Berlin, and Berlin–London where several years past the comparison periods are included the charts indicate isolated and scattered short cycles as defined. Here we have clear instances of a phenomenon, alluded to at several points in this work, in which even business cycles do not always show continuous chains, but often more complicated patterns of cyclical and noncyclical time intervals.

Section 4. Specific Cycles and Short Cycles Compared

(9) Table 69 indicates the number and duration of specific and short cycles both for differentials and exchange rates. The periods covered are those just discussed for the prewar period, using the procedure that only complete cycles, from trough to trough, are counted. Parts of incomplete cycles are eliminated. For the short

TABLE 69

Number and Duration of Specific Cycles and Short Cycles of Short-Term Interest Rate Differentials and Foreign Exchange Rates, Prewar[a]

	NUMBER OF CYCLES[b]				AVERAGE DURATION OF CYCLES (months)			
	DIFFERENTIALS		EXCHANGE RATES		DIFFERENTIALS		EXCHANGE RATES	
	Specific cycles	*Short cycles*	*Specific cycles*	*Short cycles*	*Specific cycles*	*Short cycles*	*Specific cycles*	*Short cycles*
New York–London[c]	4	20	8	16	55.5	11.2	33.4	14.4
Paris–New York	8	12	9	22	44.4	21.3	40.2	15.3
New York–Berlin	5	14	8	17	50.6	16.2	36.4	14.6
Berlin–London	4	23	7	16	68.5	13.5	45.9	15.1
Paris–London	6	21	10	13	53.5	15.1	36.3	14.5
Paris–Berlin	5	12	5	20	72.2	24.3	57.2	16.6
				Average	55.8	16.0	40.2	15.2
			Postwar					
All series	9	13	5	23	40.8	22.8	29.4	12.5

[a] See Table 66, footnote a, for prewar periods covered by each pair of countries. The postwar period is uniformly 84 months.

[b] Only complete cycles, taken from trough to trough, are counted. Parts of cycles at both ends of a series, with their respective durations, are dropped.

[c] For detailed description of each pair's differentials and exchange rates, see footnote b, Table 66.

postwar period we make only one measurement for all six pairs together.

There are many more short cycles than specific cycles. The increase in numbers is greater for the differentials than for the exchange rates. In general we have now in most instances more than twice as many short cycles as specific cycles.

There are corresponding changes in the *average duration of the two kinds of cycles*. For the specific cycles the average of the averages is 55.8 months for the differentials and 40.2 months for the exchange rates. For the short cycles we obtain an average monthly duration (for all six pairs of countries) of 16.0 for differentials and 15.2 for exchange rates. Besides the great shortening of the cycles these latter two values deviate much less from each other than the averages for the specific cycles. This is clearly a first indication that we may find a much better pair by pair correspondence than thus far observed in our statistics. Our averages in Table 69 should be compared with those previously discussed in order to see them in their proper perspective[5] (cf. e.g., Tables 6, 13, and 29).

We have not arranged a complete table corresponding to Table 69 covering the postwar period because for the Paris–Berlin and Paris–London exchange rate series no complete specific cycles have been found for 1925–1931. Of the remaining four pairs there are only one or two specific cycles, hardly enough to give the notion of an average any meaning. However we have added to Table 69 such values as can be determined within these limits, i.e., we have counted all the specific and short cycles for all six pairs of countries wherever they exist, and have determined their average duration. These latter figures should be compared, though with great caution, with the averages of averages indicated in the preceding paragraph. The averages for the specific cycles are very much shorter, but those for the short cycles are shorter only for the exchange rates.

To sum up: the question remains why there should be (throughout the prewar period) more specific cycles for the exchange rate than for the differentials (excepting only Paris–Berlin, where there is equality). There is no difference in the method of their determination to account for this. So it must be a real phenomenon. As far as we can see there is nothing in the extensive literature on exchange rates to suggest that this observation has been made, much less that it has been explained. A plausible suggestion seems to be that the number of variables determining the general (and also the cyclical) behavior of exchange rates is considerably greater than that of the short-term interest rate differentials.

(10) Table 70, describing the prewar short cycles for both groups of series, should be read in conjunction with Table 66. The increase of covariation which accompanies the identification of the short cycle is quite marked. It constitutes a real, empirical phenomenon, not merely the product of an arbitrary statistical manipulation. The fact that covariations do not occur before the war outside the periods covered by our Table 70 is in itself of interest. We may perhaps say that if a mechanism is described by these statistics, it did not work throughout the whole prewar period with the same degree of perfection.

[5] The short cycles are only a little longer, as a rule, than seasonal cycles. The data are seasonally corrected. Thus much depends on their accuracy and the effectiveness of the correction.

TABLE 70

Phase Comparison of Short Cycles of Short-Term Interest Rate Differentials and Foreign Exchange Rates, Prewar, Seasonally Corrected Data

	Months covered[a]	SAME PHASE IN: Ex-pansions	SAME PHASE IN: Con-tractions	SAME PHASE IN: Total	Dif-ferent phase	SAME PHASE IN: Ex-pansions	SAME PHASE IN: Con-tractions	SAME PHASE IN: Total	Dif-ferent phase
		MONTHS				PERCENTAGES			
New York–London[b]	205	67	56	123	82	32.7	27.3	60.0	40.0
Paris–New York	225	69	73	142	83	30.7	32.4	63.1	36.9
New York–Berlin	197	75	55	130	67	38.1	27.9	66.0	34.0
Berlin–London	233	86	77	163	70	36.9	33.1	70.0	30.0
Paris–London	166	53	43	96	70	31.9	25.9	57.8	42.2
Paris–Berlin	264	99	88	187	77	37.5	33.3	70.8	29.2

[a] For exact periods covered, see footnote a, Table 66.
[b] For detailed description of each pair's differentials and exchange rates, see footnote b, Table 66.

On Charts 18 to 23 the interest rate differentials Paris–London and New York–London are shown for the entire prewar period. The asterisks mark the troughs and peaks for the specific cycles, the circles mark the troughs and peaks of the short cycles. Every specific cycle turning point is occasionally also a turning point of a shorter cycle.

The greater phase correspondence shown for short cycles is seen from the fact that for every single pair the percentage of months in the same phase is higher when short cycles rather than specific cycles are used (Table 66). For Berlin–London and Paris–Berlin the improvement is particularly noticeable.

The correspondence Paris–London with 57.8 per cent while still high is not as good as the one observed earlier (Table 15) for specific cycles of the short-term interest rates themselves. These two money markets were undoubtedly the most highly developed before World War I. A low differential between two communicating markets probably indicates that there are large flows of funds between these centers; a good cycle correspondence shows merely that there is good reason to believe that the funds which flowed between the respective countries were sufficient and effective to close the gap which had opened. It does not unfortunately say anything about the absolute magnitudes involved.

TABLE 71

Phase Comparison of Short Cycles of Short-Term Interest Rate Differentials and Foreign Exchange Rates, 1925–1931

	Months covered	SAME PHASE IN: *Expansions*	SAME PHASE IN: *Contractions*	SAME PHASE IN: *Total*	*Different phase*	SAME PHASE IN: *Expansions*	SAME PHASE IN: *Contractions*	SAME PHASE IN: *Total*	*Different phase*
		MONTHS				PERCENTAGES			
New York-London[a]	34	9	7	16	18	26.5	20.6	47.1	52.9
Paris–New York	39	3	21	24	15	07.7	53.8	61.5	38.5
New York-Berlin	24	9	8	17	7	37.5	33.3	70.8	29.2
Berlin–London	57	15	11	26	31	26.3	19.3	45.6	54.4
Paris–London	39	3	17	20	19	07.7	43.6	51.3	48.7
Paris–Berlin	46	17	4	21	25	37.0	08.7	45.7	54.3

[a] For explanations, see footnote b, Table 66.

(11) *The post-World-War-I period* (cf. Table 71) shows a very marked change when compared, first, with the short cycle correspondence just discussed and second, with the specific cycle comparison of Table 67.

We shall, however, refrain from going into a detailed numerical comparison. The fact of the short cycle appears well established, but since we have so far observed it in only a single instance, it would be dangerous to draw far-reaching conclusions from the phenomenon. In addition, a number of definitions of a short cycle other than that in footnote 4 on page 286 were tried out by making all computations accordingly. The resulting tables (not shown in this book) were not very different from the results finally accepted But there were changes, mostly placing one pair of money markets over another pair.

There were no large shifts in the over-all picture. There were always many more short cycles than specific cycles. Apparently certain regularities were highly sensitive, depending on whether or not only complete cycles were counted, whether short cycles were used even when they did not form a continuous sequence of short cycles, and so forth. The reader can judge from Charts 18–22 whether the final choice made for the above computations is justified and reasonable.

The alternative computations require also a considerable effort. This would not matter much if one were guided firmly by a good and strong theory to justify them. It would even be helpful to know of the existence of short cycles (other than seasonal variations, of course) from other areas of business cycle research. So far there seem to have been few such indications.

The whole matter is closely tied up with the fact that we are comparing not only specific cycles and short cycles, but also two institutionally different periods in which they fell. If the samples were more nearly comparable the figures might give a more reliable estimate of the significance of the institutional differences. But the samples are quite unlike. On the other hand one can hardly doubt that the huge lending operations, some connected with German reparations, upset the classical mechanism.

It is clear that the procedure of finding and determining short cycles is essentially subjective and intuitive. This was noted in earlier discussions of specific and reference cycles. There the background is, however, much firmer. Now, instead of extending the search to other and quite different series, one can turn from intuitive methods and search for short cycles objectively, through the strictly mathematical analysis referred to in the first chapter. Another possibility is to put aside the notion of cycles altogether, as in the next section.

To sum up: Short cycles exist; they are meaningful intuitively; and their covariation in the series here under consideration is significant. But much more work is required before numerical results can be obtained in the different areas of international interaction.

Section 5. Sign Correlations of Interest Rate Differentials and Exchange Rates

(12) In order to achieve further progress we shall now drop the restrictions to any and all types of cycles and study the series in two ways; first, by investigating month to month changes and, second, by admitting the possibility of a true lag (at least in an experimental way) between the two factors, taking each one separately as leading and as lagging.

(13) The techniques from among which a choice has to be made in order to investigate the correspondence and covariation of the two series forming each pair[6] belong to the broad field of correlation. We shall make some further use of the correlation coefficient as we have already done (cf. Table 45), but shall chiefly rely on

[6] As defined above, pages 280–281.

the modified chi-square contingency test developed by A. Wald, which is simpler and achieves our aims at least as well (cf. pages 107 ff.). In applying the latter we consider covariations for each pair where only the direction of movement is taken into account. That is to say we consider it as a positive event when in (the transition to) the same month the exchange rate and the differential both rise or both fall as compared with their stand in the previous month; otherwise it is a negative event.

(14) Table 72 summarizes the results of our statistical operations. There are altogether three different kinds of computations. The data are the same for all. No cycles of any sort enter into the calculations. The periods covered are, first, the entire prewar period, where the longest available sets of data are taken; they range from 328 to 462 observations, five pairs having 427 members and over. These are exceptionally long series for the kinds of tests to which they are subjected, so that problems of comparability, etc., do not arise at all. The periods cover many specific and short cycles. The latter did not always exist, so we have investigated those months separately from the entire series (67–156 observations, third section of Table 72).

Finally the postwar gold standard period 1925–1931 (83 observations) has been considered. We have not hesitated to compare the results for the latter with any of the former, because the numbers are large enough at any rate. The prewar period is studied twice, first for seasonally corrected, then for uncorrected data. It is desirable to know whether the seasonal correction changes the result very much. Generally the expectation of a higher coefficient of correlation for uncorrected data than for corrected would seem justified on the ground that seasonal variations that are similar in pattern represent a common factor between correlated series where they occur in appreciable strength. Their removal would therefore lower the coefficient. When this is the case, it would have to show up also for our coefficient of covariation C, which is better suited for our purposes than the ordinary correlation coefficient.

It is clear that Z, the number of times the exchange rate series and the differential series show the same sign, must be considered in relation to the probability that the outcome is due to chance. For this any level of significance can be chosen, depending on the severity of the standard of investigation. By taking $p < 0.01$ for measuring the deviation from the expected value $E_z = (N - 1)/2$,

TABLE 72

Change in Short-Time Interest Rate Differential Correlated with Change in Exchange Rate Covariation in the Direction of Movements

Period	Pair of countries	N	Z	p	C	Rank according to C
				Prewar period, seasonally corrected data		
Jan. 1878–July 1914	Gt. Britain–France	439	308.5	$p < 0.001$	0.405	1-2
Jan. 1878–July 1914	Gt. Britain–Germany	439	308.5	$p < 0.001$	0.405	1-2
Jan. 1879–July 1914	Gt. Britain–U.S.	427	282.5	$p < 0.001$	0.323	3
Apr. 1887–July 1914	U.S.–Germany	328	212.5	$p < 0.001$	0.296	4
Jan. 1879–July 1914	U.S.–France	427	275	$p < 0.001$	0.288	5
Feb. 1876–July 1914	France–Germany	462	294	$p < 0.001$	0.273	6
				Prewar period, seasonally uncorrected data		
Jan. 1878–July 1914	Gt. Britain–France	439	339	$p < 0.001$	0.544	1
Jan. 1878–July 1914	Gt. Britain–Germany	439	317	$p < 0.001$	0.444	3
Jan. 1879–July 1914	Gt. Britain–U.S.	427	277	$p < 0.001$	0.297	6
Apr. 1887–July 1914	U.S.–Germany	328	216	$p < 0.001$	0.317	5
Jan. 1879–July 1914	U.S.–France	427	297	$p < 0.001$	0.391	4
Feb. 1876–July 1914	France–Germany	462	342.5	$p < 0.001$	0.483	2
				Prewar period, seasonally corrected data[a]		
Aug. 1901–July 1914[b]	Gt. Britain–U.S.	156	105	$p < 0.001$	0.346	
Jan. 1888–Dec. 1901[c]	Gt. Britain–U.S.	156	104	$p < 0.001$	0.333	
Aug. 1908–July 1914[b]	Gt. Britain–Germany	72	53.5	$p < 0.001$	0.486	
Aug. 1902–July 1908[c]	Gt. Britain–Germany	72	52	$p < 0.001$	0.444	
Jan. 1909–July 1914[b]	France–Germany	67	44	$0.01 < p < 0.05$	0.313	
June 1903–Dec. 1908[c]	France–Germany	67	45	$0.01 < p < 0.05$	0.343	
				Postwar gold standard period, 1925–1931, seasonally uncorrected data[d]		
Feb. 1925–Dec. 1931	Gt. Britain–France	83	43	$p > 0.5$	[e]	
Feb. 1925–Dec. 1931	Gt. Britain–Germany	83	37.5	$0.5 > p > 0.2$	[e]	
Jan. 1925–Dec. 1931	Gt. Britain–U.S.	84	44.5	$p > 0.5$	[e]	
Feb. 1925–Dec. 1931	U.S.–Germany	83	49.5	$0.2 > p > 0.1$	[e]	
Feb. 1925–Dec. 1931	U.S.–France	83	47.5	$0.5 > p > 0.2$	[e]	
Feb. 1925–Dec. 1931	France–Germany	83	39	$p > 0.5$	[e]	

N = Number of pairs of differences observed.

Z = Number of times the change of the exchange rate and the change of the interest rate showed the same sign (a zero change is counted as one half).

p = Probability that an observed deviation from the expected value as great or greater is due to chance.

C = Coefficient of covariation.

[a] Included in the total prewar period.

[b] Period for which no continuous short cycles could be determined.

[c] Preceding period of the same duration.

[d] No seasonal variations observed, cf. Chapter III.

[e] Not significant.

we are applying a very conservative yardstick, similar to the practices evolved in the use of the straight chi-square test in such cases.[7] The fourth column of Table 72 contains

$$C = 2\left(\frac{Z - E_s}{N - 1}\right),$$

the coefficient of covariation. If the coefficients thus obtained are found significant, i.e., not due to chance (with the stated probability), then they are considered comparable among each other at least to the extent of ranking. The ranking is given in the last column of Table 72.

We begin with the *pre-World-War-I period* for seasonally corrected data, which were used earlier in this chapter. The ranking according to *C* places two pairs, Great Britain–France and Great Britain–Germany, in first place. The third European pair, France–Germany, scores lowest of all six. The occupants of the first (two) places might be expected in the light of all preceding studies, but it is less clear why the third European pair should be at the bottom of the scale. If we compare this with Table 70 where the cyclical correspondence is brought out for both types of cycles, we find that a shift has occurred in that Great Britain–France had then not the highest value, nor one very near it. London–Berlin scored even worse in the specific cycle comparison, but best for the short cycles. This can be interpreted to mean that the specific cycles are quite unsuited as a basis of comparison, but that the short cycles brought out a tendency which the coefficient of covariation finally confirms. It may indicate a need to look for *finer* correspondence than the specific cycles can describe in this case. This is also a challenge for any theoretical interpretation.

For the next computation, using uncorrected data, we find as expected (cf. p. 296 f.) higher coefficients with only one exception. In some instances the increase is substantial. The greatest increase of the coefficient is for France–Germany, from 0.273 to 0.483; much higher than the highest for the corrected data, 0.405. As a consequence the ranking is quite different, except that Great Britain–France remains in the first place. The last is now taken by Great Britain–United States, where also the only drop in the coefficient occurred. This change puts the three pairs containing the United

[7] In fact we usually have $p < 0.001$.

States in the last three places and provides again their clear separation from the three European pairs, which was observed on several other occasions in this study.

It is difficult to avoid the conclusion that the movements of short-term interest rates and exchange rates are so delicate that seasonal correction upsets the information too much. It must also be remembered that the short cycles had periods very near those of the seasonals (Table 69) and there was a genuine need to introduce them into the picture. More of this will be seen in the following.

But even if there were no question of the perfection of the statistical techniques of calculating seasonal variations, and we accepted the results at their face value, we should be more or less forced to accept the measures obtained from the uncorrected data as giving the more accurate picture. The ranking of C according to the seasonally corrected data is suspicious, because there is a good chance that the correction has influenced this ranking for reasons of purely statistical-computational nature. If it has not, we would still have greater confidence in measurement from the uncorrected data, because the ranking on this basis agrees better with our common sense expectation as well as with our earlier measurements. Nothing has emerged, so far, that would induce us to over-ride the commonsense attitude.

The third group of measures, in Table 72, covers months where no continuous short cycles exist. As mentioned an even closer correspondence than the short-cycle covariation might exist during those months; this would at least be true for the periods immediately preceding 1914, when short cycles disappeared possibly because of the influence of stronger forces of interdependence. In order to illuminate the figures, the same number of months immediately preceding the critical period have been measured also.[8] It is interesting to note that the coefficient for London–New York and London–Berlin is considerably higher than that for the same pairs during the preceding period of the same length. This would seem to bear out that the covariation was better, though no short cycles could then be found. For Paris–Berlin the situation is different: the preceding short-cycle period gives a better result, but the entire level of significance $0.01 < p < 0.05$ is unsatisfactory. For the entire 373 months, when short cycles were found,

[8] The present group of computations is calculated on the basis of seasonally corrected data, because these were used for obtaining short cycles.

this pair came out with 70.8 per cent of all short-cycle phases in covariation (cf. Table 70), somewhat better than the worst result, 57.8 for Paris–London, which now has persistently given the highest correspondence! The proper interpretation will only be possible in the light of all measurements.

It is also interesting to note how these two segments of the time series behave in respect to the entire series; the interest arises in fact from the possibility that the covariation in the cyclical sense or the general correlation may undergo a (possibly systematic) change. One would expect a gradual improvement. Indeed in Table 73 we shall make a specific measurement precisely for that reason (cf. p. 298). Here we can compare both periods, i.e., that without and that with short cycles, with the entire series. For London–New York the first coefficient is 0.346, the second 0.333, both better than $C = 0.323$ for the entire series. For London–Berlin the relations are 0.486 and 0.444 respectively as compared with $C = 0.405$ for the whole series. This second case brings thus a very decided improvement. It is clear, when the coefficient for a shorter (and later) segment of the whole series is markedly better than for the whole, the coefficient for the whole can be depressed only because the correlation was poorer in the earlier segments. In the third case, Paris–Berlin, where the level of significance was not considered satisfactory, the coefficients are nevertheless markedly higher than for the entire series, including the two short subperiods of 67 months only.

Thus, *the disappearance of short cycles is in all likelihood the result of an improvement in the working mechanism which relates the differentials and exchange rates.* There is good reason to assume that the contacts between the money markets improved in the later years before World War I. This is also borne out by earlier observations, notably those relating to the long-term decline in maximal interest rate differentials. An improvement could also have gone on for cycles. The disappearance of cycles may be of deeper significance.

(15) For the *postwar* period uncorrected data were used. The results are so unsatisfactory that no coefficients are computed, since they would not be at acceptable levels of significance. The short-cycle covariation (Table 71) had given the highest value for Paris–Berlin, for which we now have $p > \frac{1}{2}$; the specific cycle covariation (Table 66) showed this same pair as well as Berlin–London scoring negatively. Our present measurement inspires

TABLE 73

Measures of the Relationship between Exchange Rates and Interest Rate Differentials, Great Britain and Germany

Covariation in Direction of Movements, Prewar Period

Period	*Kind of data used*	*C*	p^a
Jan. 1878–July 1914	Seasonally corrected data	0.405	$p < 0.0$
Jan. 1878–July 1914	Seasonally uncorrected data	0.444	$p < 0.0$
Jan. 1878–July 1914	Every second month (Jan., Mar., etc.) seasonally corrected data	0.418	$p < 0.0$
Jan. 1878–July 1914	Every second month (Feb., Apr., etc.) seasonally corrected data	0.393	$p < 0.0$
Jan. 1878–July 1914	Every second month (Jan., Mar., etc.) seasonally uncorrected data	0.418	$p < 0.0$
Jan. 1878–July 1914	Every second month (Feb., Apr., etc.) seasonally uncorrected data	0.470	$p < 0.0$
Aug. 1908–July 1914	Period for which short cycles could not be determined (seasonally corrected data)	0.486	$p < 0.0$
Jan. 1878–July 1914	Interest rate differential leading by 1 month (seasonally uncorrected data)	0.230	$p < 0.0$
Jan. 1878–Dec. 1882	5 year interval (seasonally corrected data)	0.133	$0.5 > p > 0.2$
Jan. 1883–Dec. 1887	5 year interval (seasonally corrected data)	0.417	$0.001 < p < 0.0$
Jan. 1888–Dec. 1892	5 year interval (seasonally corrected data)	0.466	$0.001 > p$
Jan. 1892–Dec. 1897	5 year interval (seasonally corrected data)	0.366	$0.02 > p > 0.0$
Jan. 1898–Dec. 1902	5 year interval (seasonally corrected data)	0.516	$0.001 > p$
Jan. 1903–Dec. 1907	5 year interval (seasonally corrected data)	0.434	$0.001 < p < 0.0$
Jan. 1908–Dec. 1912	5 year interval (seasonally corrected data)	0.417	$0.001 < p < 0.0$
Jan. 1878–Dec. 1882	5 year interval (seasonally uncorrected)	0.184	$0.3 > p > 0.2$
Jan. 1883–Dec. 1887	5 year interval (seasonally uncorrected)	0.484	$0.001 > p$
Jan. 1888–Dec. 1892	5 year interval (seasonally uncorrected)	0.467	$0.001 > p$
Jan. 1892–Dec. 1897	5 year interval (seasonally uncorrected)	0.400	$0.01 > p > 0.0$
Jan. 1898–Dec. 1902	5 year interval (seasonally uncorrected)	0.483	$0.001 > p$
Jan. 1903–Dec. 1907	5 year interval (seasonally uncorrected)	0.600	$0.001 > p$
Jan. 1908–Dec. 1912	5 year interval (seasonally uncorrected)	0.450	$0.01 > p > 0.0$
Jan. 1878–July 1914	Months (41) in which change of interest rate differential was less than ±0.1% (seasonally uncorrected data)	0.268	$0.02 > p > 0.1$
Feb. 1925–Dec. 1931	Gold standard period (seasonally uncorrected data)	[b]	$0.5 > p > 0.2$
Feb. 1925–Dec. 1931	Every second month (Jan., Mar., etc.) (seasonally uncorrected data)	[b]	$p > 0.5$
Feb. 1925–Dec. 1931	Every second month (Feb., Apr., etc.) (seasonally uncorrected data)	[b]	$0.5 > p > 0.2$
		R	p^c
Jan. 1878–July 1914	Prewar period (seasonally corrected data)	0.284	$p < 0.0$
Jan. 1878–July 1914	Prewar period (seasonally uncorrected data)	0.328	$p < 0.01$
Jan. 1878–July 1914	First differences prewar period (seasonally uncorrected data)	0.601	$p < 0.01$

C = Coefficient of covariation. R = Correlation coefficient. p = Probability.

[a] Probability that a deviation from the expected value as great or greater is due to chance.

[b] Not significant.

[c] Probability that a coefficient of correlation as great or greater is due to chance.

greater confidence, because with it a probability estimate can be made, for which a basis is lacking in the domain of the ordinary cycle technique. The evidence suggests the view that the postwar gold standard functioned less well and regularly than the prewar standard did (or was supposed to do). Of course we have other evidence to support this view, but it is important to be able to strengthen it as a result of different approaches. When there is no one outstanding reason for a scientific view, then its support from various sides is the next best situation. But it must be borne in mind that the latter form of reasoning is definitely a sign of weakness in an argument and, in scientific matters, of the absence of a well-established theory.

Section 6. Discussion of a Specific Example

(16) We now turn to a specific example where a number of further measurements is made in the hope of increasing our understanding appreciably. It will be found that there are again limits, but that at least we shall be able to judge the whole problem posed in Chapter V and in the present chapter more adequately.

The example is the relation between the two series for London–Berlin. These are the reasons for this particular choice: it should not be a pair involving New York, because of the special factors that often appear when this money market is introduced;[9] rather, it should be a European pair, but not London–Paris, which was generally found to consist of those markets with the highest degree of interaction. Of the remaining two London–Berlin was the better, because the fact that it involved London gave it greatest international significance, and the volume of transactions was probably larger between these two markets than between Paris and Berlin.

Table 73 gives the whole series of measurements, some of which are merely repeated from the two preceding tables for the sake of completeness. For the first seven entries we find the best correspondence with $C = 0.486$ for the short period August 1908–July 1914, when no short cycles could be detected (in the seasonally corrected data). This compares with $C = 0.405$ for the corresponding whole series. The next item involves a lag; from the interpretation of the mechanism it was clear that only one lag could reasonably be considered, i.e., that of the exchanges lagging

[9] Quite aside from the complication of the call money rate versus the commercial paper rate.

behind the differentials (for uncorrected data). The result is entirely in the negative; a $C = 0.230$ only is obtained, one of the lowest values in all tables. This strengthens the belief, therefore, that the speed of adjustments between these factors is very high, at least so great that one month is a sufficiently long period of observation.

The next hypothesis is not without interest, and was partly indicated in some preceding remarks: it is possible that the degree of correspondence or correlation changes over time. Indeed the disappearance of short cycles was tentatively interpreted as meaning just that, i.e., an improvement of the correlation (cf. p. 297). To expect a decrease up to 1914 would contradict all previously gained indications. The statistical result, though not fully conclusive, supports the hypothesis fairly well. It was obtained by splitting the entire period from January 1878 to July 1914 into arbitrary five-year periods. The successive values for C are shown in Table 73.

To conclude this series of different measures for the same pair of series, three *correlation coefficients* were computed by the standard technique. The first two require little comment; the one for the uncorrected data is substantially higher (0.328) than that for the corrected data (0.284). This was to be expected; both are significant though low. The third one is of greater interest. It is computed, not like the others for the given data as such, but for the *first differences* formed from month to month for each series from the seasonally uncorrected data. The reasons for correlating first differences—a well-known mathematical device—are practically the same as those for sign correlation. The coefficient is 0.601, a very significant value indeed, which can be directly compared with the other two mentioned above. We are therefore inclined to accept the fact that there is a high degree of interaction between the two economic factors.