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The Behaviour of the Canadian Foreign Exchange Market: A Preliminary Time Series Analysis

by

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1. Introduction

The Canadian foreign exchange market has often been studied as a part of various "complete" econometric models of the Canadian economy.[1] So far as we know, however, there has not been extensive study of the behaviour of the time series of price and quantity data generated in the foreign exchange market by trading among the large Canadian banks (the chartered banks, the Montreal City and District Savings Bank, and the Bank of Canada). In contrast to estimation of macro-economic models, such a study can exploit the advantage of very long and precise time series, and may therefore make effective use of tools of time series analysis which are usually difficult to apply to economic data.[2]

The analysis described below is preliminary to a more extensive study of the day-to-day dynamics of the Canadian foreign exchange market (so far as these may be inferred by detailed analysis of time series of foreign exchange data). Nevertheless it seemed to us that a report at this stage might be useful simply as a description of the market's behaviour over the past fifteen years. For the most part, tests of significance and other such statistical tests have been omitted in this first report, which is therefore primarily a descriptive work.

2. The Data

From the Bank of Canada, daily data for the period October 1950 to December 1966 were obtained for the following variables: the spot exchange rate (recorded for the transaction completed nearest to noon on each trading day; quoted in Canadian dollars per U.S. dollar), the 90-day forward exchange rate (similarly defined), and the turnover - i.e., the daily volume of trading in the market - in millions of U.S. dollars. This last series was not available prior to 1955. In addition, we constructed a fourth series, the exchange rate spread, defined as the forward rate minus the spot rate.

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1. For example: Lawrence H. Officer, An Econometric Model of Canada Under The Fluctuating Exchange Rate (Harvard University Press, 1968, forthcoming), Rudolf R. Rhomberg, "A Model of the Canadian Economy under Fixed and Fluctuating Exchange Rates," Journal of Political Economy, vol. 72, (Feb. 1964).

2. For detailed discussion of these techniques see C. W. J. Granger and M. Hatanaka, Spectral Analysis of Economic Time Series (Princeton, 1964) and E. J. Hannan, Time Series Analysis (Londin, 1960).

   For some early applications to economic time series see Irma Adelman, "Long Cycles - Fact or Artifact," American Economic Review, vol. LV (June 1965) and Marc Nerlove, "Spectral Analysis of Seasonal Adjustment Procedures," Econometrica, vol. 32 (July 1964).

Of course, the structure of the exchange market cannot be expected to have remained unchanged under the impact of several substantial changes in policy over this period, the most obvious being the change to a fixed rate in 1962. Moreover, as a mechanical difficulty, available computer programs confined us to time series not exceeding 1,000 observations. Therefore we divided the analysis into sub-periods, as follows.

Since May 3, 1962 government policy (under the International Monetary Fund Agreement) has pegged the spot exchange rate within limits of one per cent on either side of parity (approximately $1.08 Can. under our definition of the exchange rate). Taking 1,000 observations from that date yields a time series for the period May 3, 1962 to April 26, 1966, and this serves as our main record of experience in the fixed rate period.

We desired a record of comparable length for the period of the fluctuating exchange rate. Because of developments following the June 20, 1961 announcement of the Minister of Finance regarding large-scale governmental intervention in the foreign exchange market, we did not consider the period from June 21, 1961 to May 2, 1962 typical of behaviour under a fluctuating rate. Therefore we took the period July 2, 1957 to June 20, 1961 as our main record of experience under the floating rate. The period from June 21, 1961 to May 2, 1962 was considered to represent an exchange market of a nature somewhat intermediate between a freely fluctuating and a pegged rate, say, a managed rate. For completeness we report summary statistics also for the periods 1951-1954 and 1955-1957, but our discussion centres on the two major periods earlier mentioned.

For each of these five periods, the data were standardized. (Adequate precision in the presence of very small variances was obtained by use of double-precision arithmetic in the standardization routines. Computations were performed on Harvard University's IBM 7094.) Summary statistics are reported in Table 1. Of course, the statistics pertain to the original data, as the standardized series have mean 0 and variance 1.

Naturally, the coefficients of variation for the exchange rates decrease significantly in the period of the managed rate, and do so very sharply when the rate is formally pegged. Conversely, the statistic for the turnover series rises in the

TABLE 1

SUMMARY STATISTICS OF TIME SERIES

Period	Number of Observations	Number of Lags (for spectral analysis)	Turnover		
			Mean	Standard Deviation	Coefficient of Variation
Apr. 26, 1951-Dec. 31, 1954	1000	199	----	----	----
Jan. 3, 1955-June 27, 1957	630	60	5.0372	2.7143	0.5389
June 28, 1957-June 16, 1961	1000	130	7.1846	4.3822	0.6099
June 19, 1961-May 2, 1962	222	30	8.6822	8.1494	0.9386
May 3, 1962-April 20, 1966	999	130	8.0633	9.1624	1.1364

Period	Spot Rate			Forward Rate		
	Mean	Standard Deviation	Coefficient of Variation	Mean	Standard Deviation	Coefficient of Variation
Apr. 26, 1951-Dec. 31, 1954	0.9942	0.03250	0.03268	0.9957	0.03003	0.03016
Jan. 3, 1955-June 27, 1957	0.9796	0.01505	0.01536	0.9813	0.01370	0.01396
June 28, 1957-June 16, 1961	0.9683	0.01298	0.01341	0.9700	0.01226	0.01264
June 19, 1961-May 2, 1962	1.0391	0.008757	0.008428	1.0391	0.008881	0.008547
May 3, 1962-April 20, 1966	1.0784	0.003144	0.002915	1.0793	0.003191	0.002957

Period	Exchange Rate Spread		
	Mean	Standard Deviation	Coefficient of Variation
Apr. 26, 1951-Dec. 31, 1954	0.001489	0.002957	1.9857
Jan. 3, 1955-June 27, 1957	0.001639	0.001917	1.1696
June 28, 1957-June 16, 1961	0.001760	0.001745	0.9913
June 19, 1961-May 2, 1962	0.00003238	0.0004849	14.9790
May 3, 1962-April 20, 1966	0.0009187	0.001595	1.7358

first period mentioned, and still more in the second. This is to be expected, as less variation in price should entail greater variation in the volume of transactions. It is also not surprising that the forward rate has slightly lower variance than the spot rate when the latter is free, and slightly higher when the latter is managed or pegged. What is interesting is the decreasing variability of the exchange rates over time (and the consequent increasing variability of the turnover series), involving all five periods in the case of the exchange rates and the four for which information exists in the case of the turnover. This uniformity does not extend to the exchange rate spread. However, the maximum coefficient of variation occurs in the period of greatest uncertainty (the managed rate), and this is to be expected; but both the mean and standard deviation are inordinately small during this period.

Finally, the coefficients of variation show - not surprisingly - that the turnover and spread are much more variable series than the spot and forward rates.

For more detailed study, let us first turn to the individual series within the two main periods. Later we consider possible cross-relationships.

3. Comparison of the Two Main Periods: Behaviour of the Individual Series

For each of our four series - turnover, spot rate, forward rate, and spread - we consider several characteristics: the trace of the series, its autocorrelation function, its power spectral density, and some autoregressive equations estimated by ordinary least squares. The results are presented for the 1957-1961 and the 1962-1966 periods.

a. Traces

The trace of each series in standardized form is set out in Figure 1. There need be little comment on these traces. The exchange rate and spread series have considerably smoother graphs than does the turnover.

Some periods of unusual activity in the market may be identified. These may sometimes be associated with external events which can plausibly be taken as responsible. Examples are the announcement of the United States interest equalization tax and the assassination of President Kennedy. These events are reflected in disturbances in the series on July 19 and November 22, 1963. The turnover has outlying

observations on both these dates, the price series only on the first. In general, the turnover is far more susceptible to such disturbances than the other three series.

b. Autocorrelation Functions

Since we deal with standardized variables, the autocovariance function is automatically normalized to have unit value at zero lag. Thus we may plot the autocorrelation functions directly as in Figure 2.

Looking first at the turnover series, we see that the autocorrelation function in both periods is roughly consistent with the exponentially decaying form characteristic of a first-order autoregressive process. The decay is perhaps slightly faster in the 1957-1961 period, and that period also displays a pronounced relative maximum at a lag of 4 days, which is absent in the later period. Both periods show some evidence of "monthly" (20-22 day) regularities.

Turning to the spot rate, the autocorrelation function for each period is strikingly regular. For the 1957-1961 period the function is essentially linear, declining to .1 only after a lag of 130 days. In the 1962-1966 period, by contrast, the function falls off much more sharply, reaching zero after about 69 days, and declining to -.4 at 130 days. A pronounced change in curvature occurs around 23 days, consistent perhaps with a "monthly" cycle.

For the forward rate, the autocorrelation functions exhibit essentially the same behaviour, though the contrast is slightly less pronounced, and the change in curvature in the 1962-1966 period is also less pronounced.

The autocorrelation functions of the exchange rate spread are close to linear. Unlike the two variables from which this series is constructed, the earlier period exhibits the greater rate of decline. In 1957-1961 the function falls to zero after a lag of 127 days, whereas in 1962-1966 it is .2 at that interval.

c. Spectral Density Functions

The autocorrelation function (which is a function of a time lag) may be transformed into a function of frequency (cycles per day). For some purposes this latter function is more convenient than the autocorrelation function itself; one such purpose is the identification of important periodicities in the data. In Figure 3 such a transformed function is plotted for each of our four series for the two basic periods.

For the turnover series, the spectrum gives evidence of an annual (250 trading day) component in the 1957-1961 period which is absent in the 1962-1966

period. However, the pervasive difficulty with trend domination throughout this analysis may in fact be responsible for this result. Evidence of a 30 (trading) day cycle is also given by the spectrum for the turnover series in the 1957-1961 period. The primary periodicity in the 1962-1966 period seems to be closer to a 22-24 day cycle.

The spectrum of the spot rate in 1962-1966 falls only slightly at the very low frequencies, before exhibiting the rapid decline characteristic of all the spectra - a property of the conventional spectrum of economic time series. The hesitation in the decline at the low frequencies is not so acute for the forward rate in this period, but it still exists. For both rates the 1957-1961 spectra have the standard shape.

Again, for both the spot and forward rates, what evidence there is of a dominant periodicity in the 1957-1961 period seems to indicate a cycle of about 30 trading days. (This is suggested by a transformation of the spectra to log scale - not plotted here.) On the other hand, there is sharp evidence in the spectra of both the spot and forward rates in the 1962-1966 period for a cycle of about 22 trading days - the "monthly".

Thus, to summarize this evidence from spectral analysis for the three basic series, there appears to be some indication of a significant cycle of about 30 trading days (6 calendar weeks) for the 1957-1961 period, and rather stronger indication of a significant cycle of about 20-24 trading days (a "monthly") during the 1962-1966 period. (Our grid is too coarse to catch glimpses of any business cycle components at this stage.) What is perhaps more surprising is the indication that the autocovariance functions and spectra for the spot and forward rates in each period are almost identical to one another. This suggests that the spot and forward rates are almost indistinguishable, having very little independent variation.

The spectra of the exchange rate spread give indications of both support for and opposition to this assertion. True, these spectra have the standard shape; but they reach zero at lower frequencies than the corresponding spot and forward series. On the other hand, for each period the spectrum in log scale (not plotted) exhibits a fairly definite "monthly" cycle.

d. Regression Analysis

We have estimated some autoregressive equations by ordinary least squares, although it is probably true that all the foregoing suggests that equations in level form are not the most appropriate. More complete models will be discussed later.

Let S_t = spot exchange rate in day t

F_t = forward exchange rate in day t

D_t = exchange rate spread in day t

For each period we estimated the following equations (ignoring the constant term, since it was always insignificant):

1. $S_t = a_1 S_{t-1}$
2. $S_t = a_2 S_{t-1} + b_2 S_{t-2}$
3. $F_t = a_3 F_{t-1}$
4. $F_t = a_4 F_{t-1} + b_4 F_{t-2}$
5. $D_t = a_5 D_{t-1}$
6. $D_t = a_6 D_{t-1} + b_6 D_{t-2}$

The estimates are presented in Tables 2 and 3. The t-value is given below the estimated coefficient. The Durbin-Watson statistic is denoted as d. w. and the standard error of estimate as s. e. e.

We notice that all second-order autoregressive coefficients are significant in the 1957-1961 period, but only the one for the exchange rate spread is significant - and that barely - in the 1962-1966 period. A comparison of regressions 1 and 3 demonstrates again the near-equivalence of the spot and forward series. This holds for each time period. Regressions 2 and 4 are also similar (though not as strikingly) in 1957-1961; but less so in 1962-1966, when the insignificant second-order coefficient is present.

The second-order equations (2, 4, and 6) suggest particular types of autoregressive relationships. Both the spot and forward rates change from a moving-average process in 1957-1961 to an "over-correction" process in 1962-1966. It will be seen that the same kind of over-correction occurs in the other three periods. On the other hand, the spot rate appears as essentially a first-order process in the differences in both 1957-1961 and 1962-1966, and this result does not hold true for any other period.

TABLE 2

AUTOREGRESSIVE EQUATIONS IN 1957-1961

Equation	a	b	a+b	R^2	d.w.	s.e.e.
1	.9897 (198.68)			.98	2.32	.1571
2	.7339 (23.98)	.2596 (8.47)	.9935	.98	1.83	.1518
3	.9893 (194.14)			.97	2.29	.1607
4	.7528 (24.47)	.2401 (7.79)	.9929	.98	1.83	.1561
5	.9937 (277.53)			.99	1.63	.1132
6	1.1641 (37.30)	-.1715 (5.50)	.9926	.99	1.98	.1116

TABLE 3

AUTOREGRESSIVE EQUATIONS IN 1962-1966

Equation	a	b	a+b	R^2	d.w.	s.e.e.
1	.9844 (176.25)			.97	1.87	.1765
2	1.0400 (32.86)	-.0564 (1.78)	.9836	.97	1.98	.1763
3	.9842 (174.34)			.97	1.95	.1784
4	1.0022 (31.62)	-.0183 (0.58)	.9839	.97	1.99	.1785
5	.9947 (301.84)			.99	1.86	.1041
6	1.0623 (33.60)	-.0680 (2.15)	.9943	.99	2.00	.1040

4. Comparison of the Two Main Periods: Cross-Relationships

We now turn from the study of the individual series to consideration of relations between them. The main tool will be cross-spectral analysis; some additional regression equations will also be of interest.

The relations that will be considered are the following: (i) turnover and spot exchange rate, (ii) turnover and forward exchange rate, (iii) spot exchange rate and forward exchange rate, (iv) spot exchange rate and exchange rate spread.

a. Cross-Correlation Functions

Cross-correlation functions were computed, and are plotted in Figure 4. The first series named is the base series; the second is crossed with it. Thus, where $T \leq 0$ the second series leads, and where $T \geq 0$ the first series leads.

Examining the cross-covariance functions, it appears that the timing relationships are quite different in the two periods. In 1957-1961 the turnover series appears to lead both the spot rate and the forward rate by about 12 trading days - i.e., the strongest correlation is between the turnover at one point and the spot (or forward) rate about 12 days later. In 1962-1966, by contrast, the turnover series appears to lag both the spot and forward rates by about 18 days - i.e., the strongest correlation appears between the turnover at one point and the exchange rates about 18 days (almost one month) earlier.

In both periods the cross-correlation functions between the spot and forward rates suggest that these rates behave almost as if they were the same series. This phenomenon, which persists throughout all periods, casts some doubt on the significance of any expectational content in the forward rate. (It should be recalled, however, that finer tests do show regularities in the spread between the forward and spot rates.)

The cross-relationship between the spot exchange rate and the spread is unique in that it is radically different in the two periods. In 1957-1961 the cross-correlation hovers around -.48 when the spread leads the spot rate ($T \leq 0$). As T takes on positive values - the spot rate now leading - the cross-correlation increases (in algebraic value), and almost linearly. Zero cross-covariance does not occur until T is about 105, and the correlation continues to increase, reaching a value of .15 at T = 130.

In the 1962-1966 period this cross-correlation has both an algebraic minimum and maximum. The minimum value of about -.35 occurs at T = -25; the maximum value of about .34 occurs at T = 90.

b. Phases of Cross-Spectra

Phase diagrams are presented in Figure 5. These are plotted in fractions (θ) of a circle against frequency (cycles per day). Where $\theta < 0$ the second series leads; where $\theta > 0$ the first series leads.

The phase diagrams confirm that for the low frequencies the turnover series leads the exchange rate series in the 1957-1961 period and lags in the 1962-1966 period. The two rate series are coincident in the 1957-1961 period, but the diagram suggests that the spot rate may have led the forward rate slightly in the 1962-1966 period.

Regarding the spot rate and the spread, the former series leads for the lowest frequencies in each period. However, this consistent lead ends at a frequency of only .012 in the 1957-1961 period, while it persists until .031 in the 1962-1966 period.

c. Regression Analysis

As a further step in the study of cross-relationships, we consider some regression equations involving both exchange rate variables. We altered the purely autoregressive form of equations 3 and 4 by introducing the spot exchange rate as an explanatory variable, and thus estimated the following equations:

7. $F_t = a_7 F_{t-1} + b_7 S_t$

8. $F_t = a_8 F_{t-1} + b_8 S_{t-1}$

Results are presented in Tables 4 and 5.

Equation 7 for the 1957-1961 period is unlike any other regression estimated thus far. On the one hand, it has high t-values for each of its coefficients, and the lowest standard error of estimate yet encountered. On the other hand, it is the first regression to have a Durbin-Watson sufficiently small to suggest autocorrelated residuals. These features distinguish it from equation 7 in the 1962-1966 period. Furthermore, the relative sizes of the estimates of a_7 and b_7 are reversed in 1962-1966. However, the sum of the coefficients does not change radically in the later period.

5. Other Periods

Let us now consider how the other periods fit into the detailed comparison above.

a. 1951-1954

In this period there are no daily turnover data available. Both the spot and the forward rate exhibit a strong downward trend over the period, and this feature dominates the constructed functions. The autocovariance function declines slowly, to

TABLE 4

REGRESSION EQUATIONS IN 1957-1961

Equation	a	b	a+b	R^2	d.w.	s.e.e.
7	.3791 (24.33)	.6216 (39.99)	1.0007	.99	0.90	.0996
8	.9596 (23.70)	.0299 (0.74)	.9895	.97	2.29	.1607

TABLE 5

REGRESSION EQUATIONS IN 1962-1966

Equation	a	b	a+b	R^2	d.w.	s.e.e.
7	.8735 (87.89)	.1301 (13.10)	1.0036	.97	1.78	.1649
8	.9625 (83.20)	.0249 (2.15)	.9874	.97	1.96	.1781

about . 4 after a lag of 130 days. The spectrum has all its power concentrated in the low frequencies, though some harmonics of the "monthly" appear weakly. This is true for both the spot rate and the forward rate, between which the cross-covariance is essentially a repetition of the common autocovariance function, while the phase diagram strongly suggests that the series are identical. Nevertheless, we do find evidence of a "monthly" and a "two-monthly" cycle in the exchange rate spread, and evidence that the spread is about one-half circle out of phase with the spot rate. (This result, however, should not be emphasized. Algebraic relationships require that the spread be negatively correlated with the spot rate, and this is one further aspect of that relationship.)

Regressions for this period are presented in Table 6.

We notice that the exchange rate spread is definitely not a first-order process. The second lag is highly significant, unlike the spot and forward rates. Also, the current spot rate is extremely significant in explaining the forward rate, albeit there is a low Durbin-Watson in the equation.

b. 1955-1957

The autocorrelation function for the turnover decays rapidly, exhibiting relative peaks at lags of 7 and 19 days and also around 10-12 days. The power spectrum displays a peak at a frequency close to the 22 day "monthly", and a sharp peak at the first harmonic of this.

The exchange rate series both show autocorrelation functions similar to those associated with the 1962-1966 period, with definite changes in curvature around the 22 day lag, and again at the 44 day lag. Their power spectra have a peak at the first harmonic of the 22 day cycle.

The cross-covariance functions between the turnover and the exchange rate series are rather striking, and the one involving the spot rate is therefore plotted in Figure 6. (The turnover-forward relationship is virtually identical to the turnover-spot.) It is clear that the basic 22 day cycle is entering significantly into this relationship, but the function seems difficult to interpret precisely.

The phase diagrams suggest that at the low frequencies the spot and forward rates lag the turnover series somewhat. This is broadly consistent with the timing behaviour described for the 1957-1961 period.

The autocorrelation function for the spread exhibits a pattern not radically different from those of the exchange rates, with a change in curvature at the "monthly"

TABLE 6

REGRESSION EQUATIONS IN 1951-1954

Equation	a	b	a+b	R^2	d.w.	s.e.e.
1	.9972 (394.71)			.99	1.10	.0799
2	1.0713 (33.92)	-.0744 (2.35)	.9969	.99	1.25	.0797
3	.9972 (390.29)			.99	1.09	.0808
4	1.0845 (34.37)	-.0877 (2.78)	.9968	.99	1.26	.0805
5	.9392 (86.44)			.88	2.81	.3436
6	.5225 (18.41)	.4437 (15.63)	.9662	.91	2.17	.3081
7	.2593 (15.43)	.7405 (44.08)	.9998	.99	0.68	.0471
8	1.0335 (21.14)	-.0364 (0.75)	.9971	.99	1.09	.0808

cycle and a slightly delayed change after the "two-monthly" cycle. The cross-correlation of the spread and the spot exchange rate is small (always below .08) at all lags, but it has an interesting bimodal property. There are peaks when the spot rate leads by both 34 and 44 days, the second reflecting a "two-month" cycle again. The transfer function shows a consistent lead of the spot rate for all low frequencies until .1 cycles per day. Thus this lead persists even more than in the 1962-1966 period.

Regression results for 1955-1957 are given in Table 7. In contrast to the 1951-1954 period, the exchange rate spread moves closer to a first-order autoregressive process.

c. 1961-1962

The 1961-1962 period is too short for spectral analysis to be very revealing. The autocorrelation function of the turnover series has a peak at a lag of 23 days (the "monthly"). The functions for the exchange rates change curvature once at a lag of about half the monthly cycle and again slightly before the monthly itself. The spot and forward rates continue to move together.

Cross-correlations of the turnover with the exchange rate are more scattered than usual, but exhibit peaks where the exchange rates lead by 24 days. In this respect behaviour is similar to the 1962-1966 period.

The autocorrelation function of the spread declines to .09 after a lag of 30 days, while those for the spot and forward rates do not fall below .66. The cross-correlation of the spot exchange rate and the spread has a peak where the spot rate leads by 3 days.

Regressions for the 1961-1962 period are presented in Table 8.

As in the 1951-1954 period, the current spot rate is very significant in explaining the forward rate, but again the Durbin-Watson is low. The exchange rate series do not give evidence of going beyond a first-order process - this result is again similar to 1951-1954. However, the significance of the second-order term in the spread equation is considerably reduced, compared to that period.

6. Concluding Comments

As noted at the outset, this is a preliminary report intended only to describe the main features exhibited by the exchange market data. In assessing the results of the study, several qualifications should be kept in mind.

First, relatively strong trends are evident in several of the periods examined. Filtering or de-trending techniques may be necessary in later analysis. We have not used

TABLE 7

REGRESSION EQUATIONS IN 1955-1957

Equation	a	b	a+b	R^2	d.w.	s.e.e.
1	1.0004 (376.10)			.99	1.46	.0666
2	1.1216 (28.29)	-.1218 (3.07)	.9998	.99	1.70	.0662
3	1.0002 (337.94)			.99	1.50	.0741
4	1.1040 (27.79)	-.1044 (2.62)	.9996	.99	1.71	.0737
5	.9928 (204.27)			.99	2.23	.1220
6	.8776 (22.12)	.1161 (2.93)	.9937	.99	2.01	.1212
7	.6225 (32.93)	.3794 (20.13)	1.0019	.99	1.04	.0578
8	.9041 (29.35)	.0965 (3.13)	1.0006	.99	1.50	.0736

TABLE 8

REGRESSION EQUATIONS IN 1961-1962

Equation	a	b	a+b	R^2	d.w.	s.e.e.
1	.9353 (38.14)			.87	1.16	.3641
2	1.0122 (15.03)	-.0829 (1.23)	.9293	.87	1.25	.3637
3	.9604 (54.25)			.93	1.42	.2649
4	1.0610 (15.79)	-.1038 (1.55)	.9572	.93	1.55	.2641
5	.9489 (44.06)			.90	1.71	.3205
6	1.0856 (16.19)	-.1442 (2.15)	.9414	.90	1.98	.3179
7	.0553 (4.42)	.9452 (75.19)	1.0005	.99	0.19	.0513
8	1.5258 (4.62)	-.5666 (1.71)	.9592	.93	1.40	.2638

such techniques at this stage because of the difficulty in interpreting results after complicated manipulation of the data.

Second, we have not made use of formal tests of significance in this preliminary study. Autocovariance and cross-covariance functions are clearly not significantly different from zero for all lags, nor are spectral densities or phase diagrams significantly different from zero for all frequencies. In general, only relatively low frequencies, or low order lags, should be taken seriously at this stage.

Third, the regression equations employed here are estimated naively, without correction for problems of autocorrelated errors or other biases. Later estimation will require more attention to these issues.

Finally, of course, our breakdown of the data into sub-periods may not prove to be the only appropriate, or most appropriate, decomposition of the data. Different subdivisions might be adopted later.

Nevertheless, despite these obvious qualifications some conclusions of interest do emerge from this survey of the data. The following are the most important.

(1) A cycle of approximately a month's duration occurs often as a dominant frequency. Occasionally it is supplemented by a two-month cycle, less frequently by a half-month cycle. (The latter may be simply a harmonic of the monthly.) Perhaps the "monthly" is plausible as a result of payment or billing habits in the export and import markets; at any rate the point appears to warrant some further consideration.

(2) The spot and forward exchange rates appear, on the basis of autocovariance and spectral density functions, to be essentially identical variables. However, examination of the exchange rate spread reveals that it definitely contains systematic components. Moreover, the cross-covariance functions suggest that the timing relationships are definitely different as between the fixed and floating rate periods.

(3) In predicting the spot and forward rates (and their spread) under the existing exchange rate system, our results suggest that a second-order autoregressive process is applicable only to the spread. Furthermore, the use of both the forward and spot rates appears to give a better equation for the forward rate than a pure autoregressive process. However, it should be noted, of course, that the three variables are connected by a simple identity and hence should not be predicted independently.

These results suggest that specification of an adaptive predictor in the form of a low-order autoregressive process would be fruitful in the study of exchange

rate data, and that more careful examination of the relationship between forward and spot rates, separately in the two main periods, is desirable.

Figure 1
STANDARDIZED SERIES

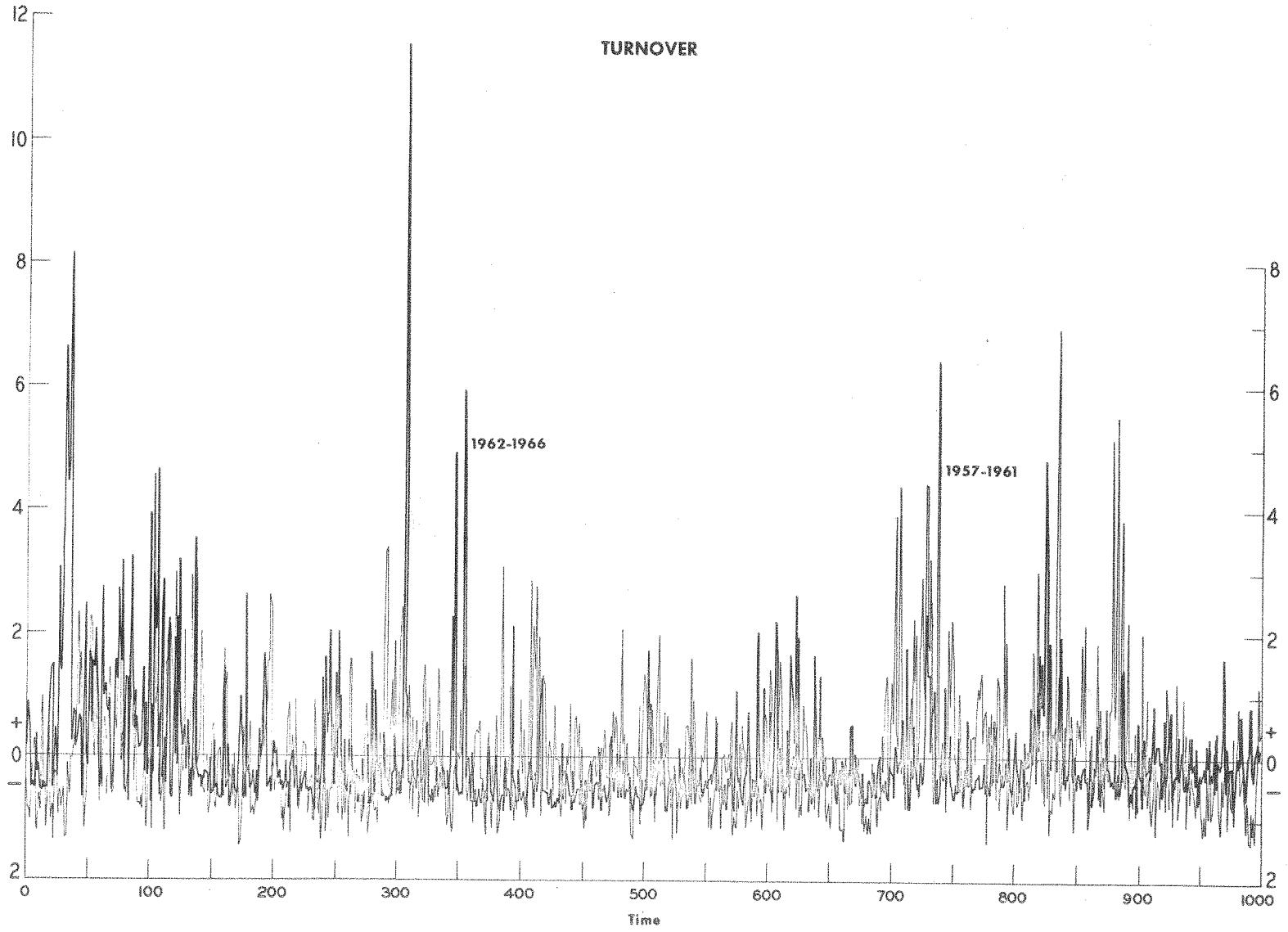

Figure 1
STANDARDIZED SERIES

SPOT EXCHANGE RATE

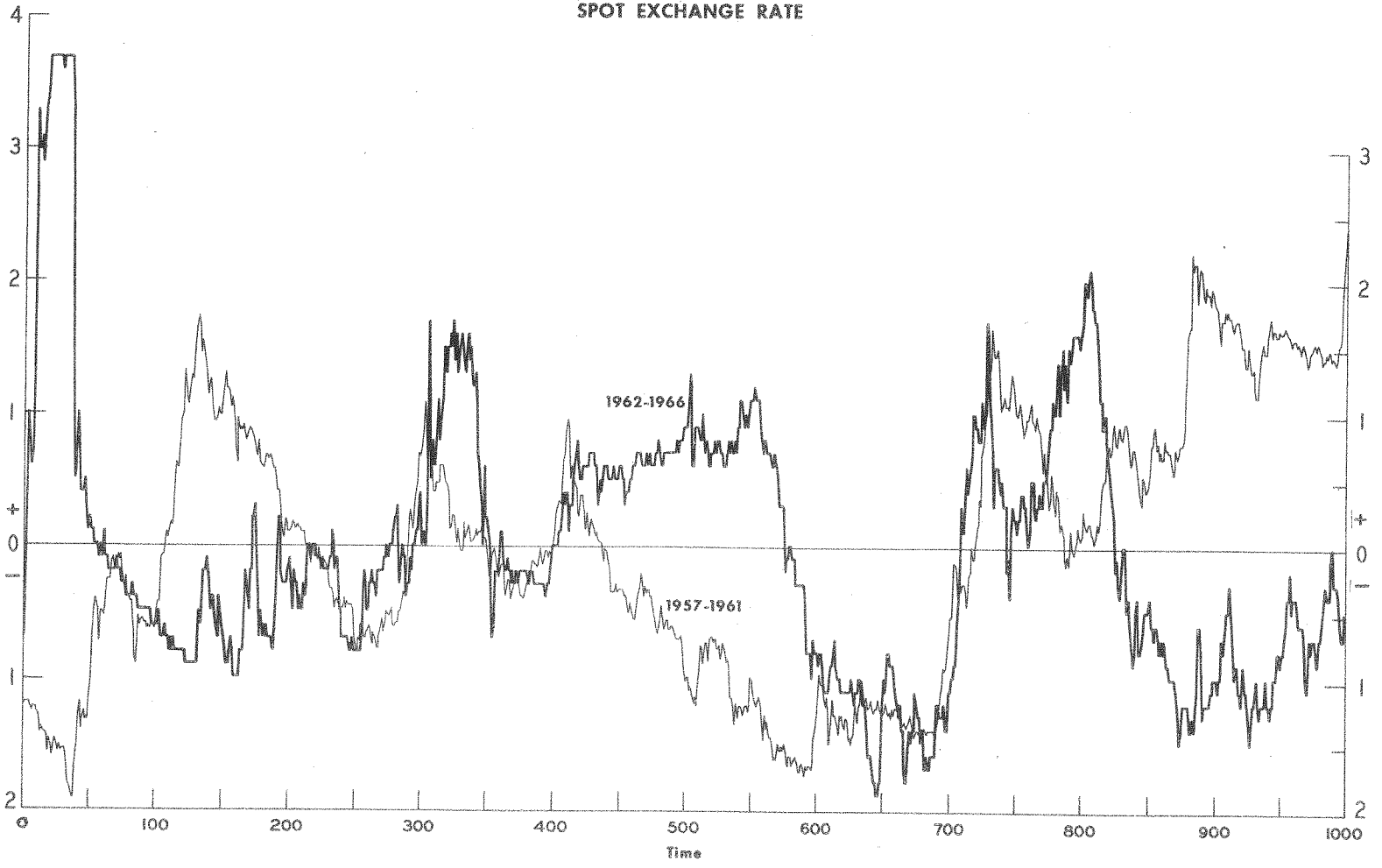

Figure 1
STANDARDIZED SERIES

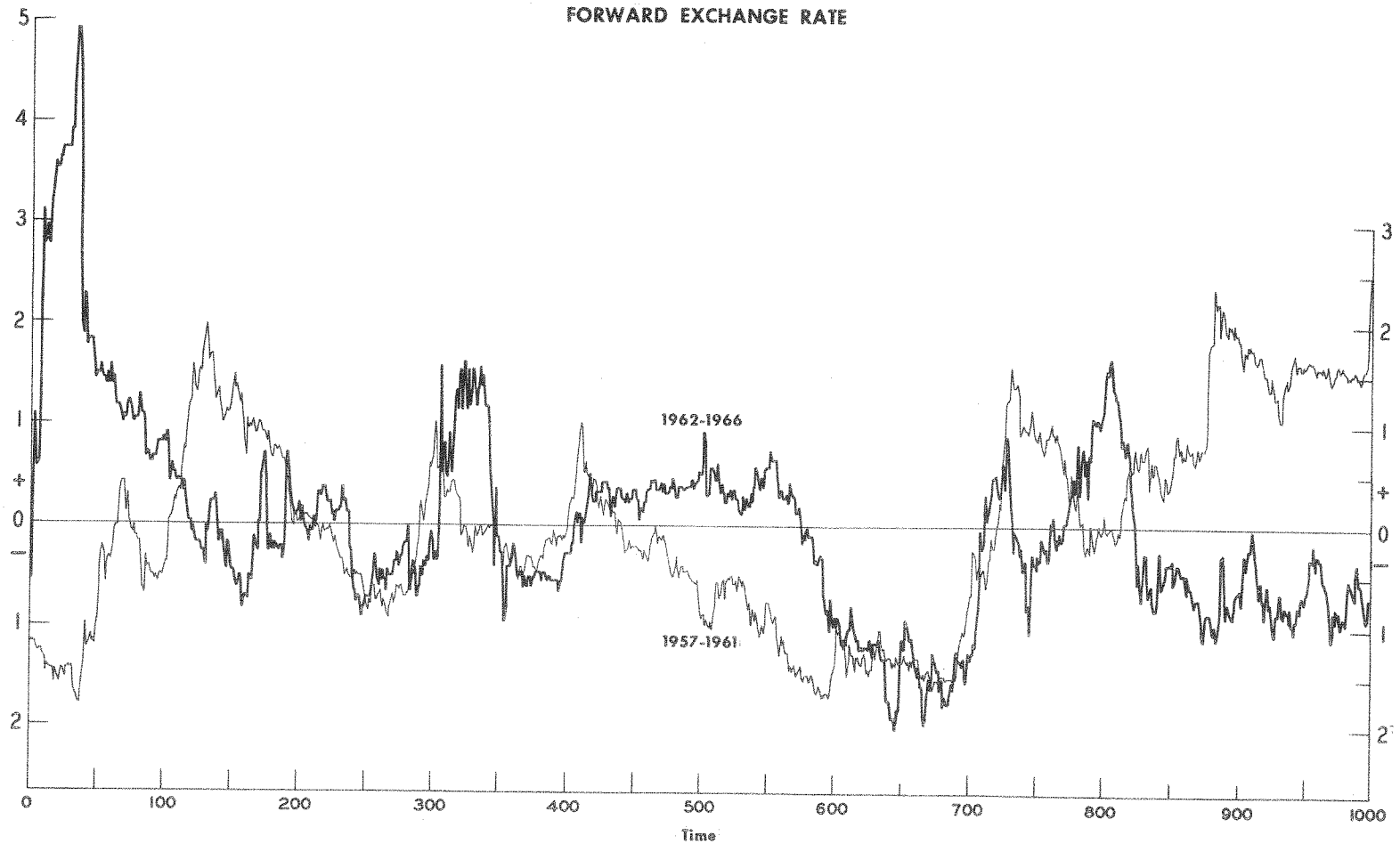

Figure 1
STANDARDIZED SERIES

Figure 2

AUTOCORRELATION FUNCTION

SPOT EXCHANGE RATE

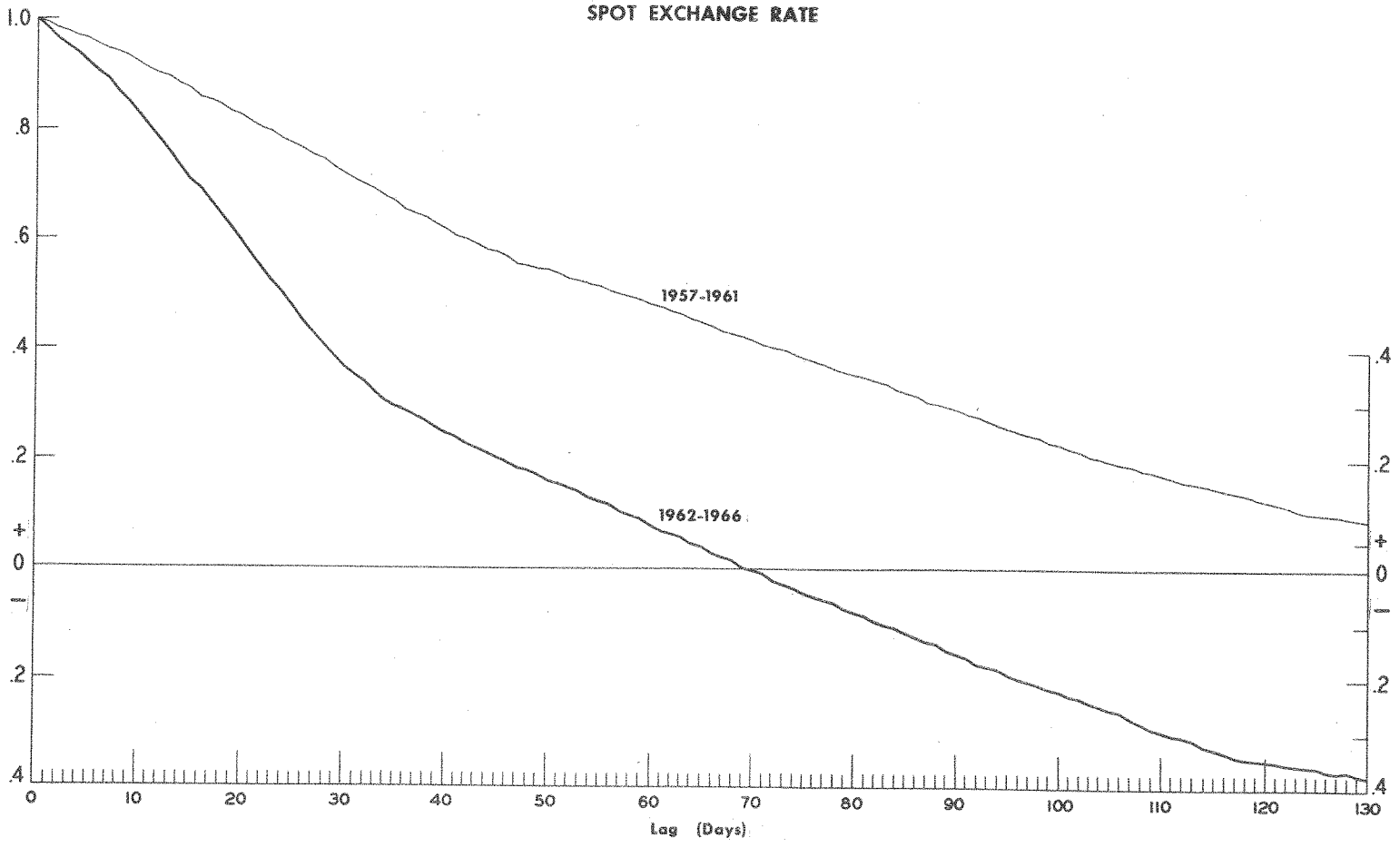

Figure 2

AUTOCORRELATION FUNCTION

FORWARD EXCHANGE RATE

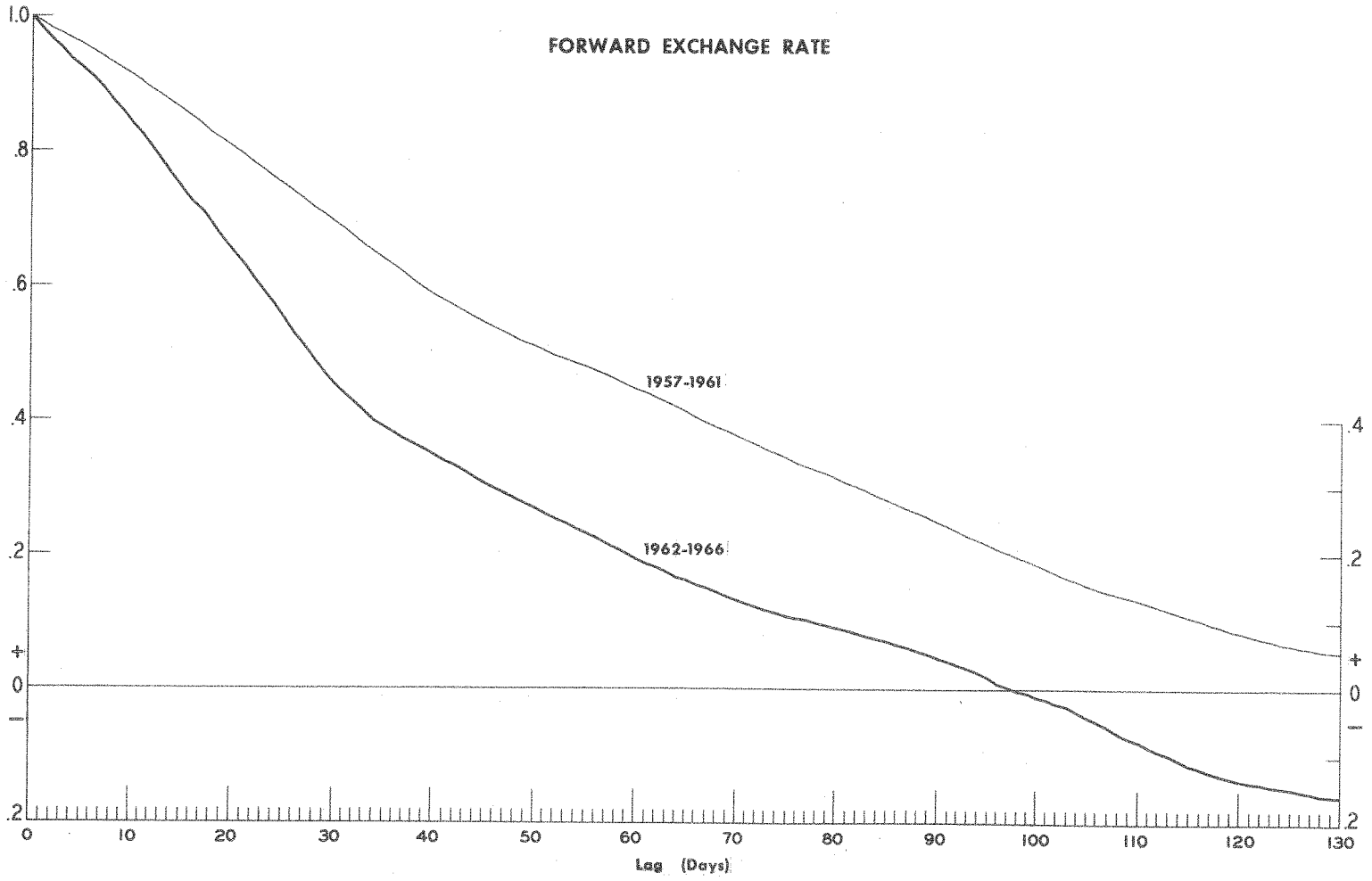

Figure 2
AUTOCORRELATION FUNCTION

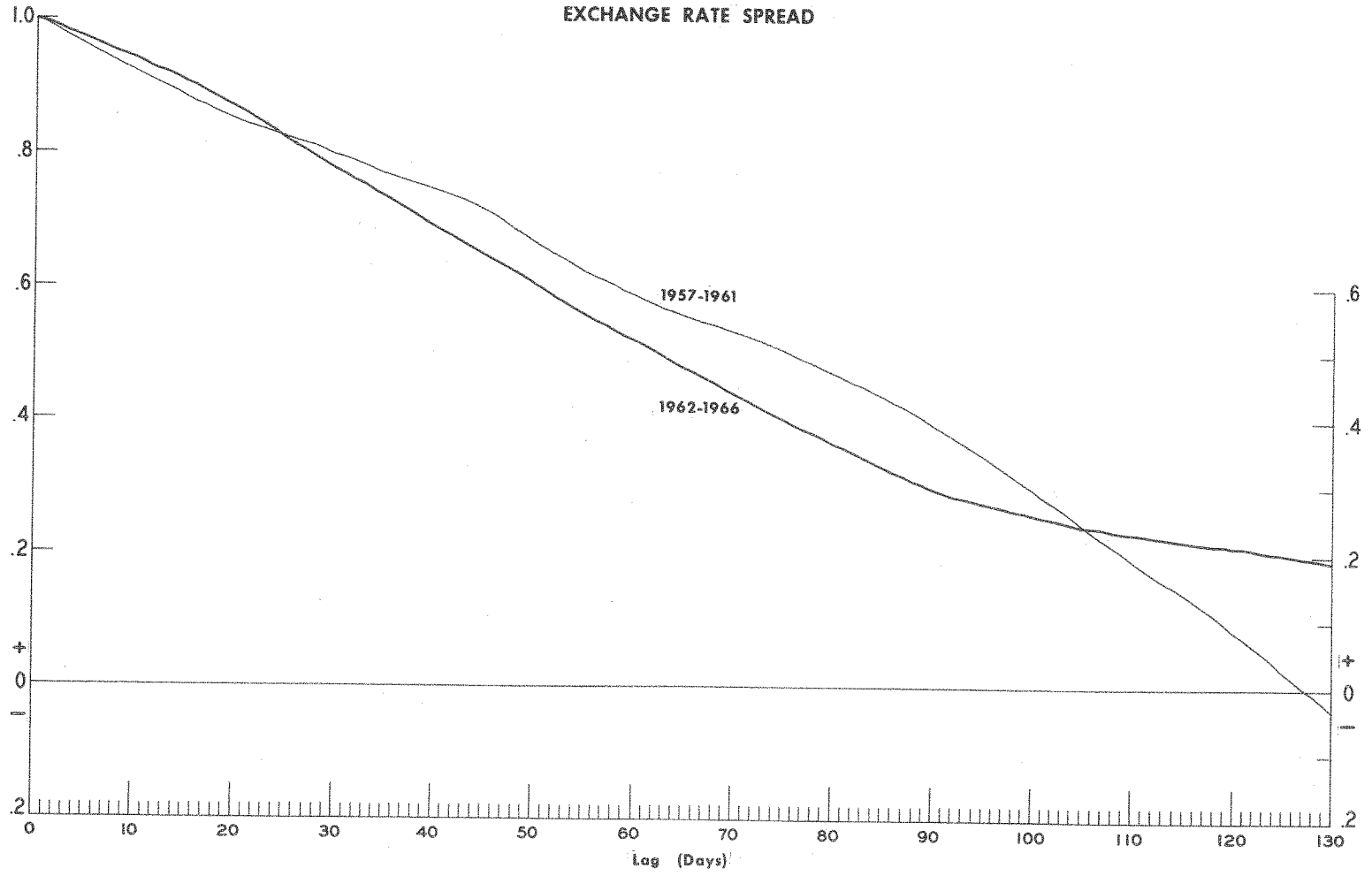

Figure 3
POWER SPECTRAL DENSITY

TURNOVER

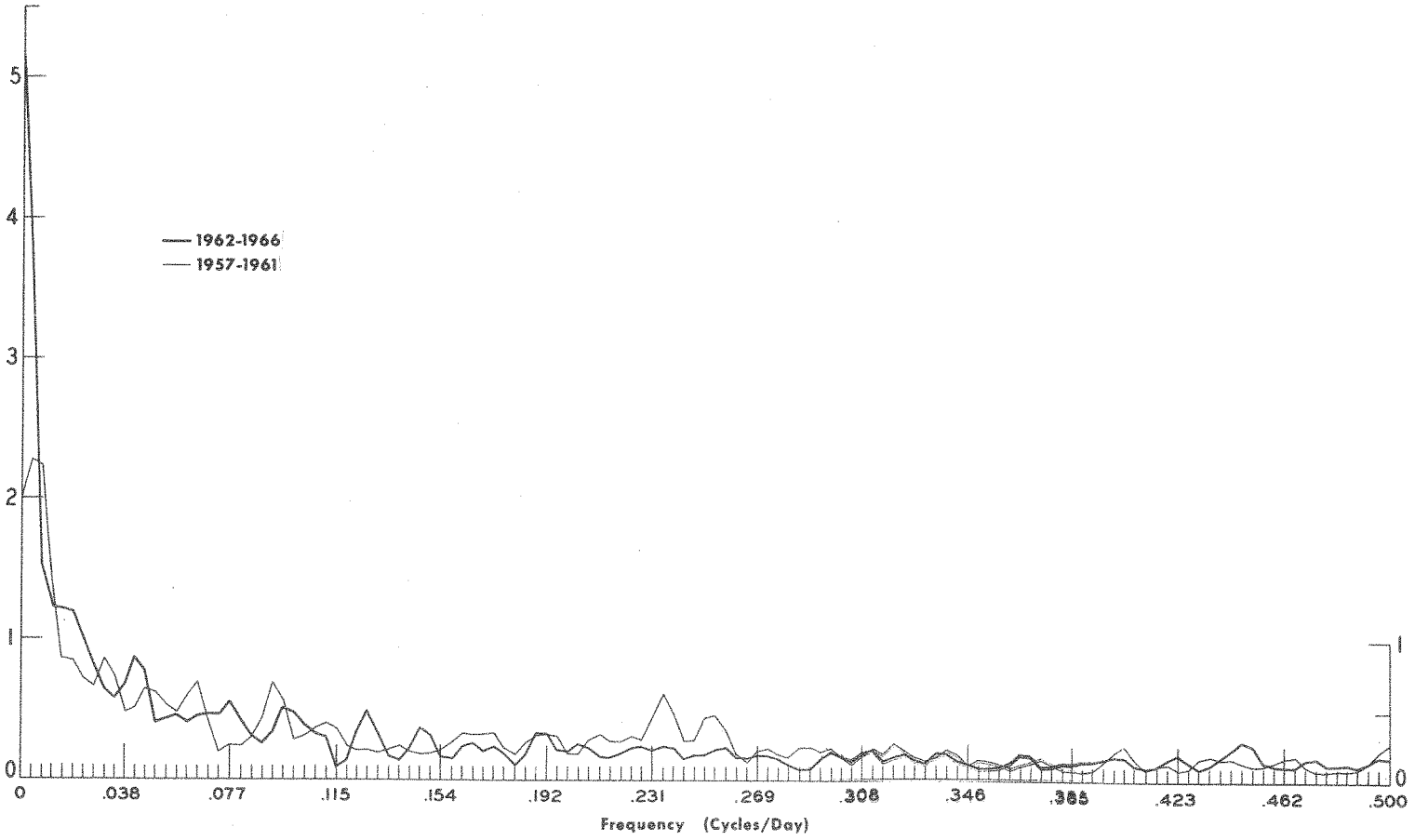

Figure 3
POWER SPECTRAL DENSITY

SPOT EXCHANGE RATE

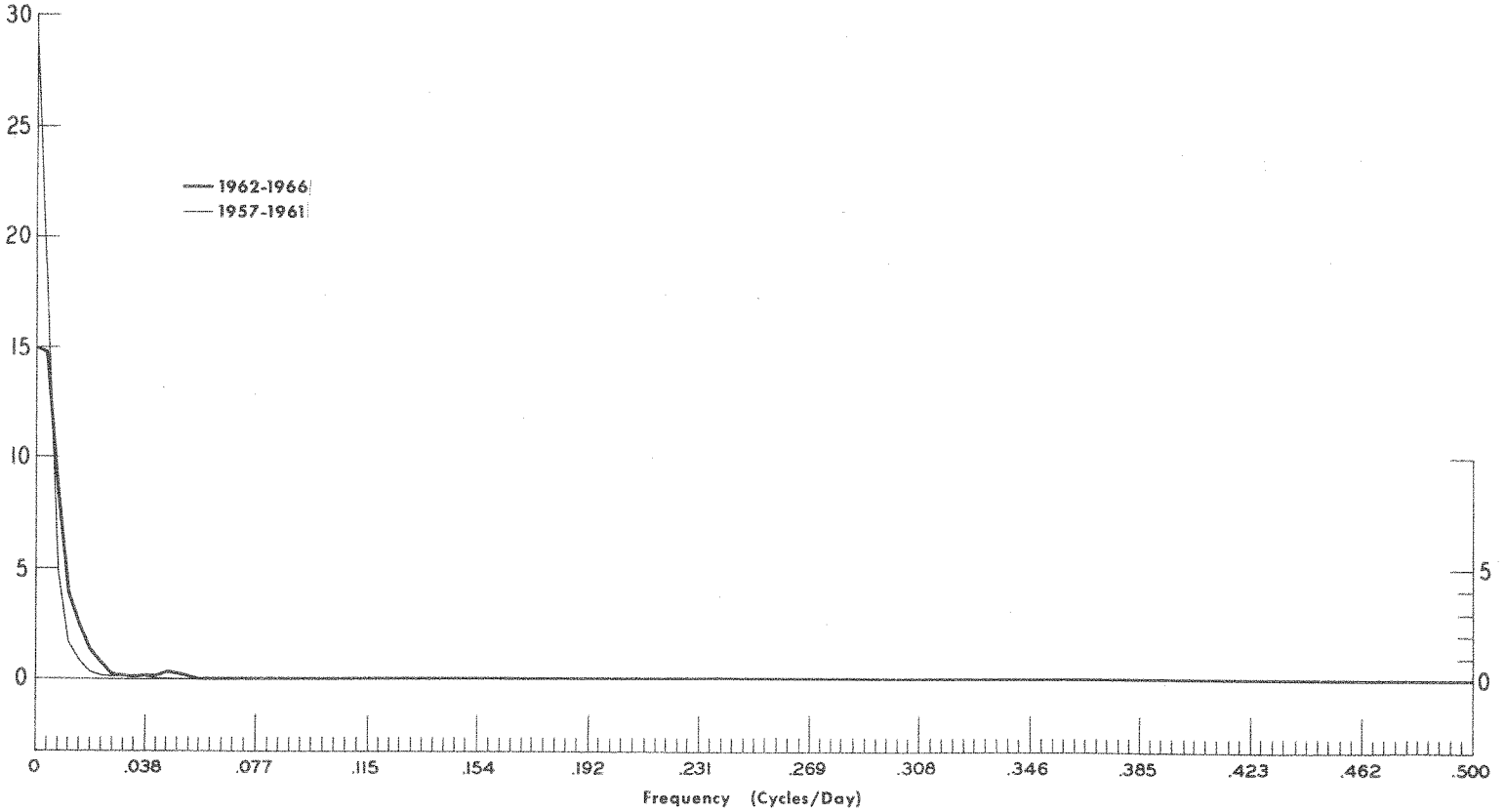

Figure 3

POWER SPECTRAL DENSITY

FORWARD EXCHANGE RATE

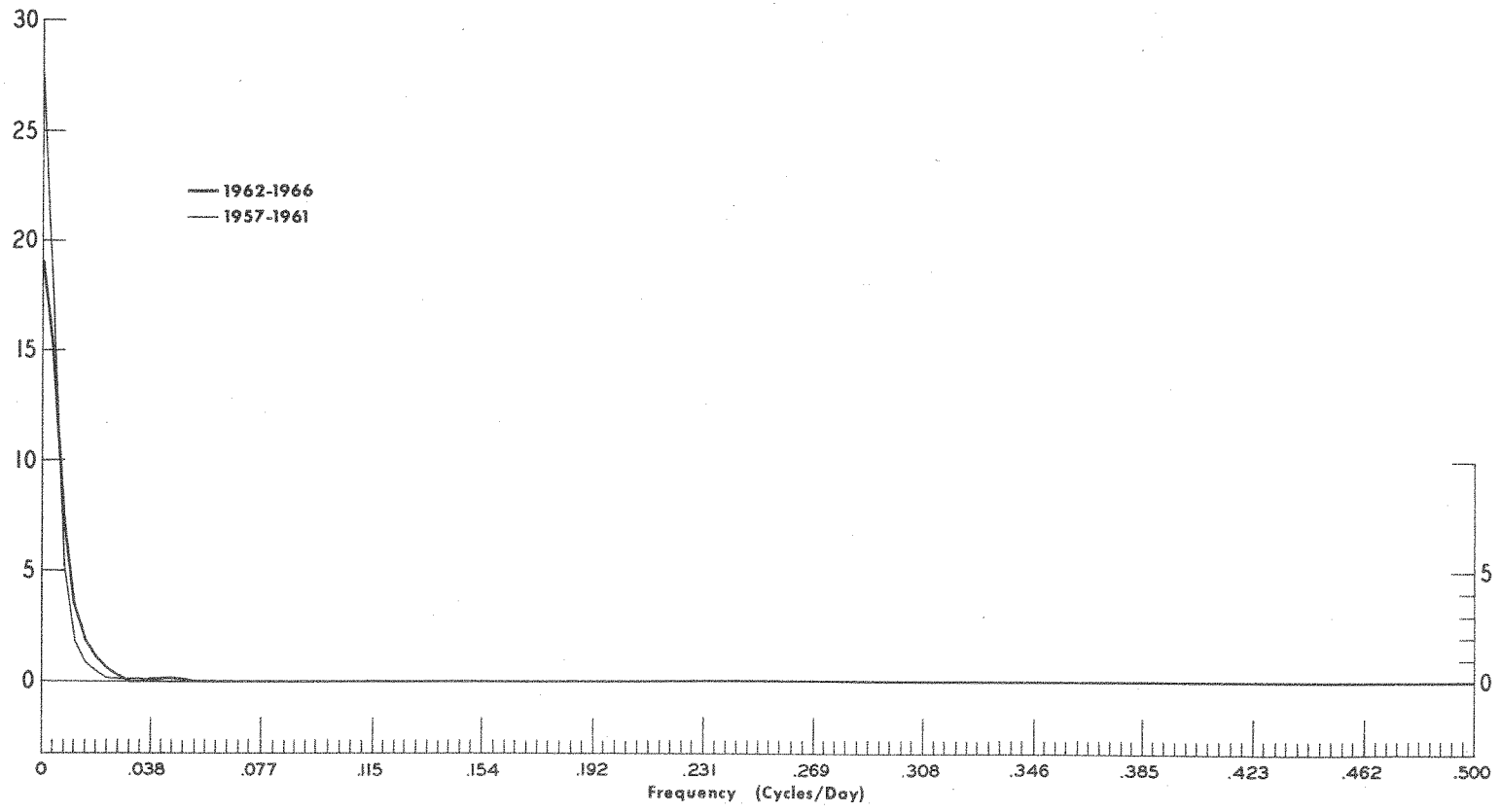

Figure 3

POWER SPECTRAL DENSITY

EXCHANGE RATE SPREAD

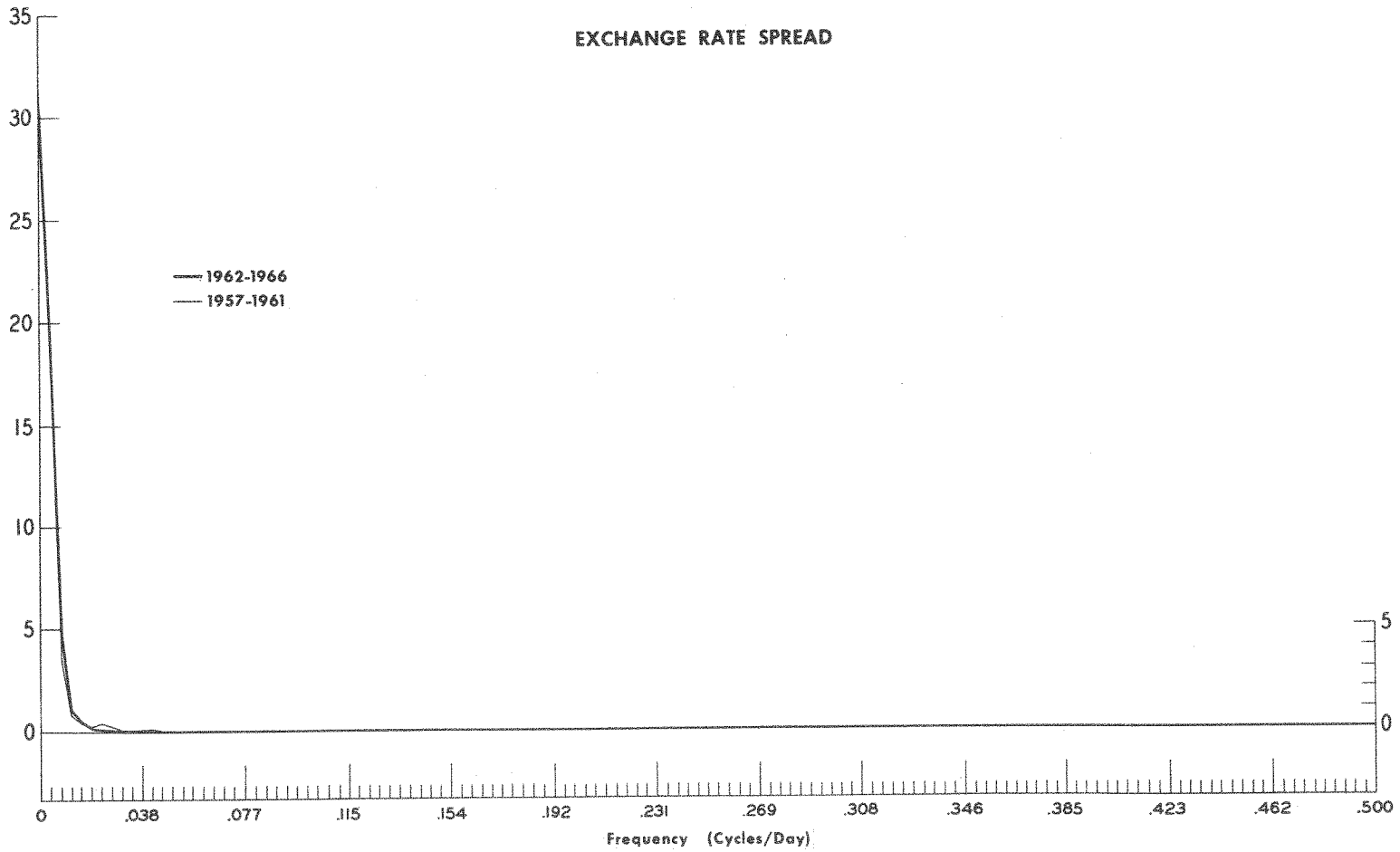

Figure 4
CROSS-CORRELATION FUNCTION

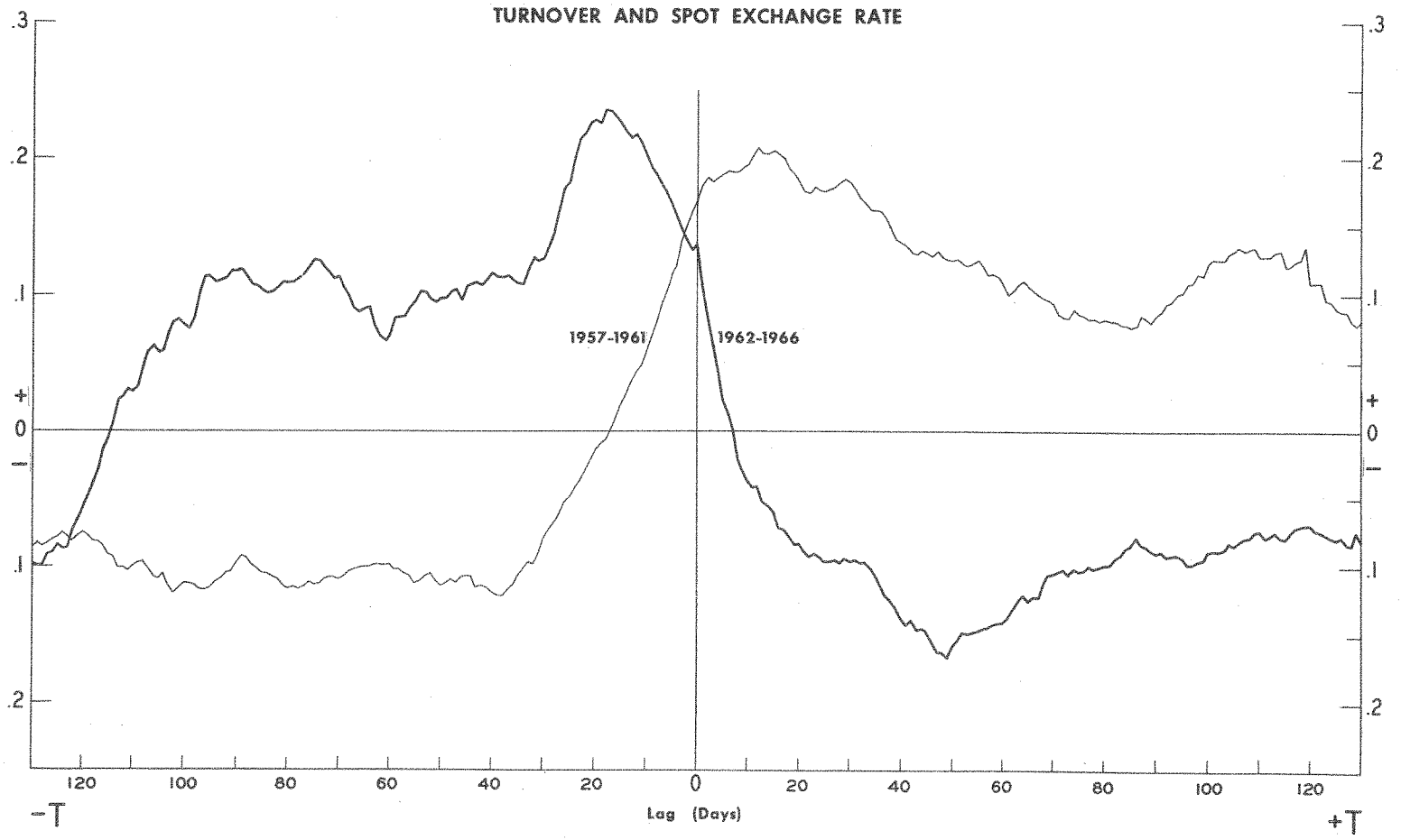

Figure 4
CROSS-CORRELATION FUNCTION

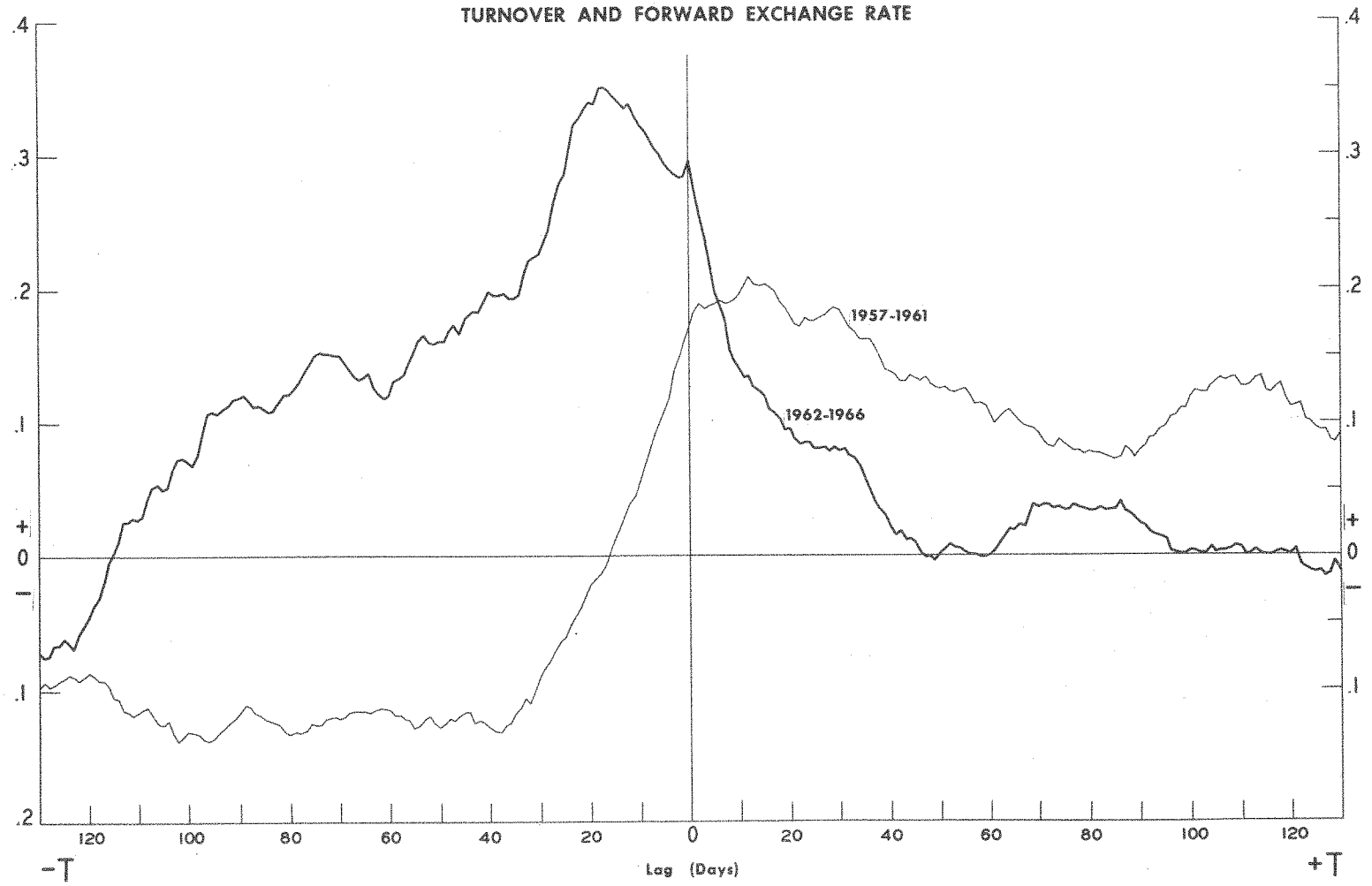

FIGURE 4
CROSS CORRELATION FUNCTION

SPOT EXCHANGE RATE AND FORWARD EXCHANGE RATE

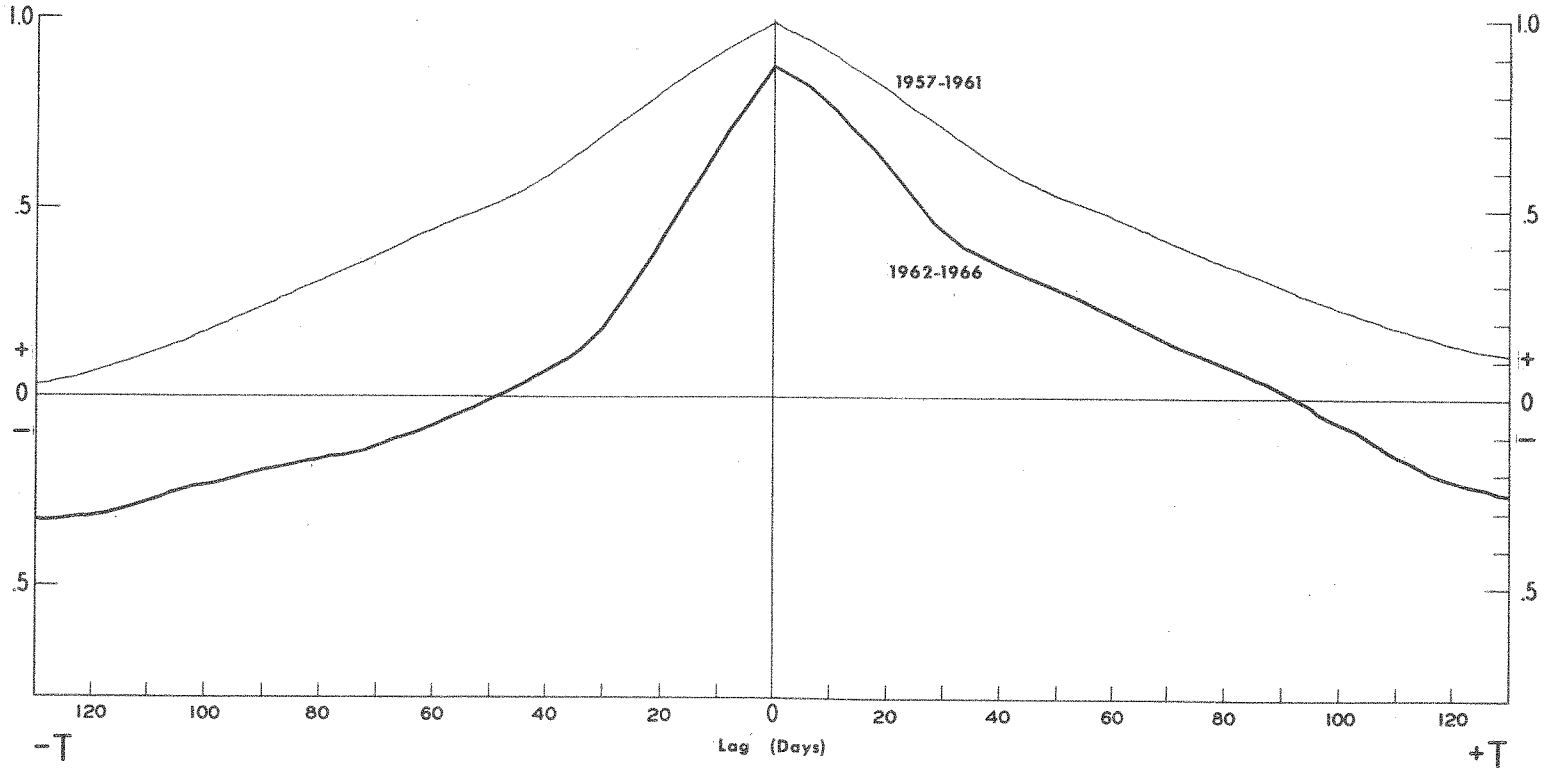

Figure 4
CROSS-CORRELATION FUNCTION

SPOT EXCHANGE RATE AND EXCHANGE RATE SPREAD

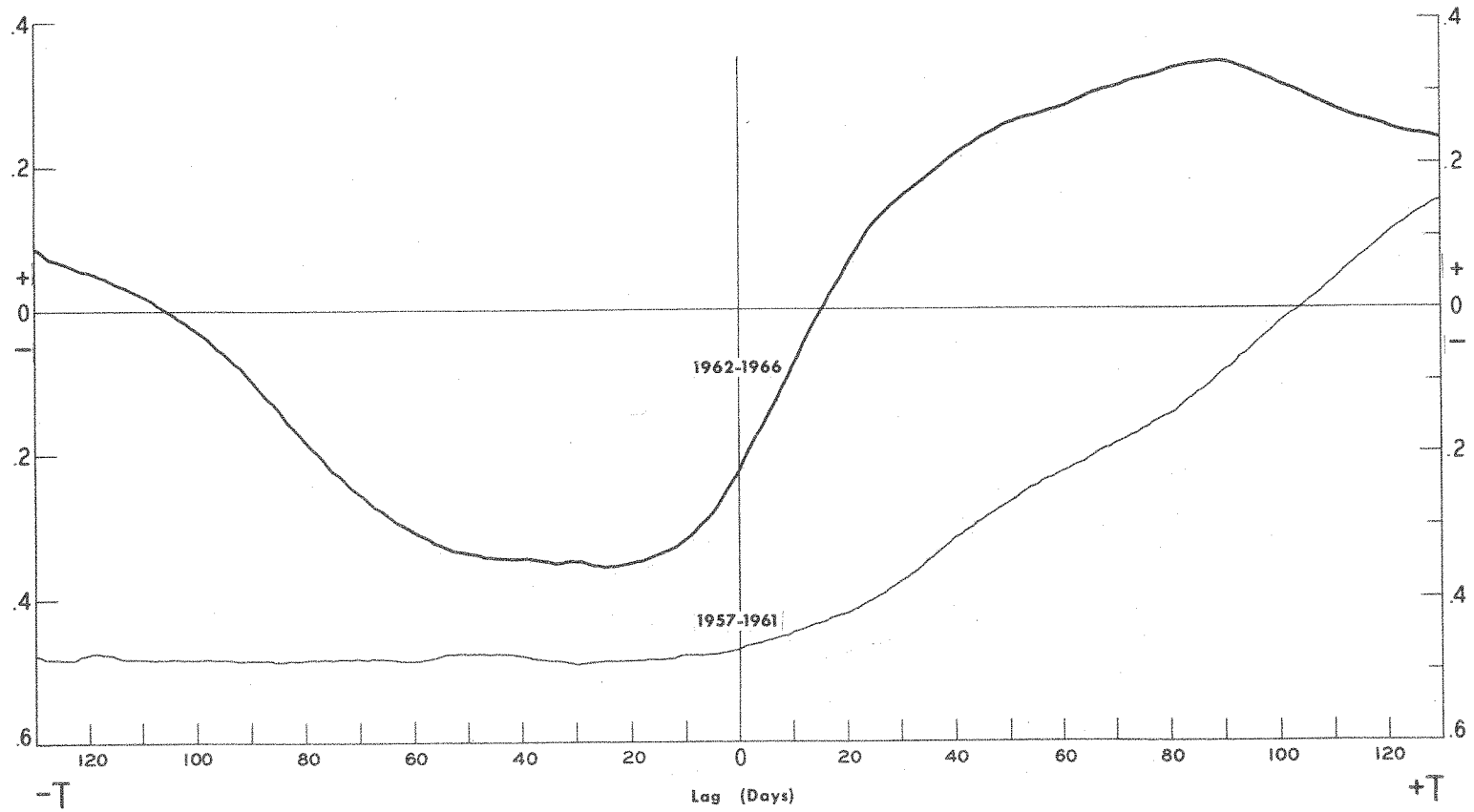

Figure 5
PHASE OF CROSS-SPECTRUM

TURNOVER AND SPOT EXCHANGE RATE

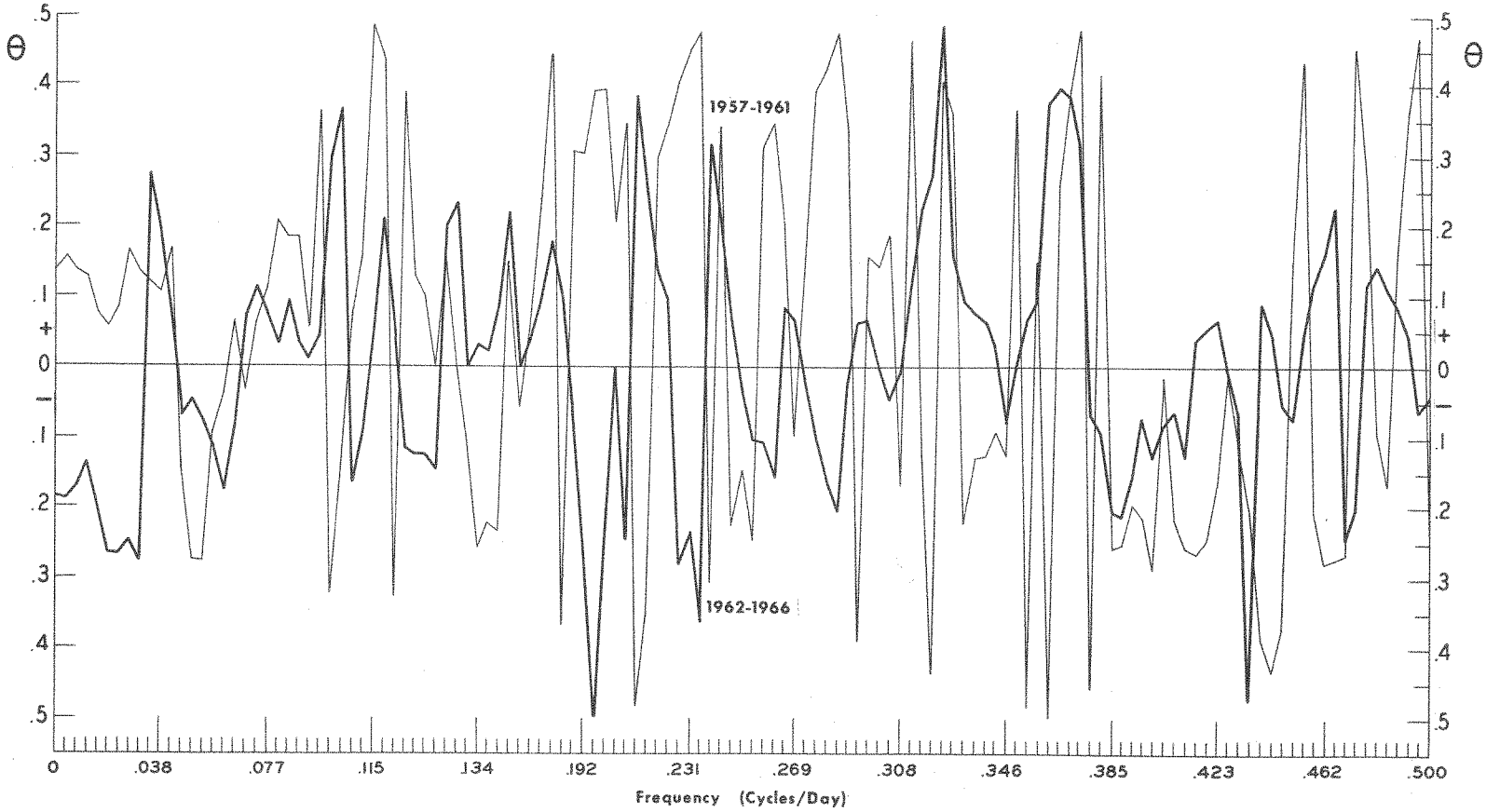

Figure 5

PHASE OF CROSS-SPECTRUM

TURNOVER AND FORWARD EXCHANGE RATE

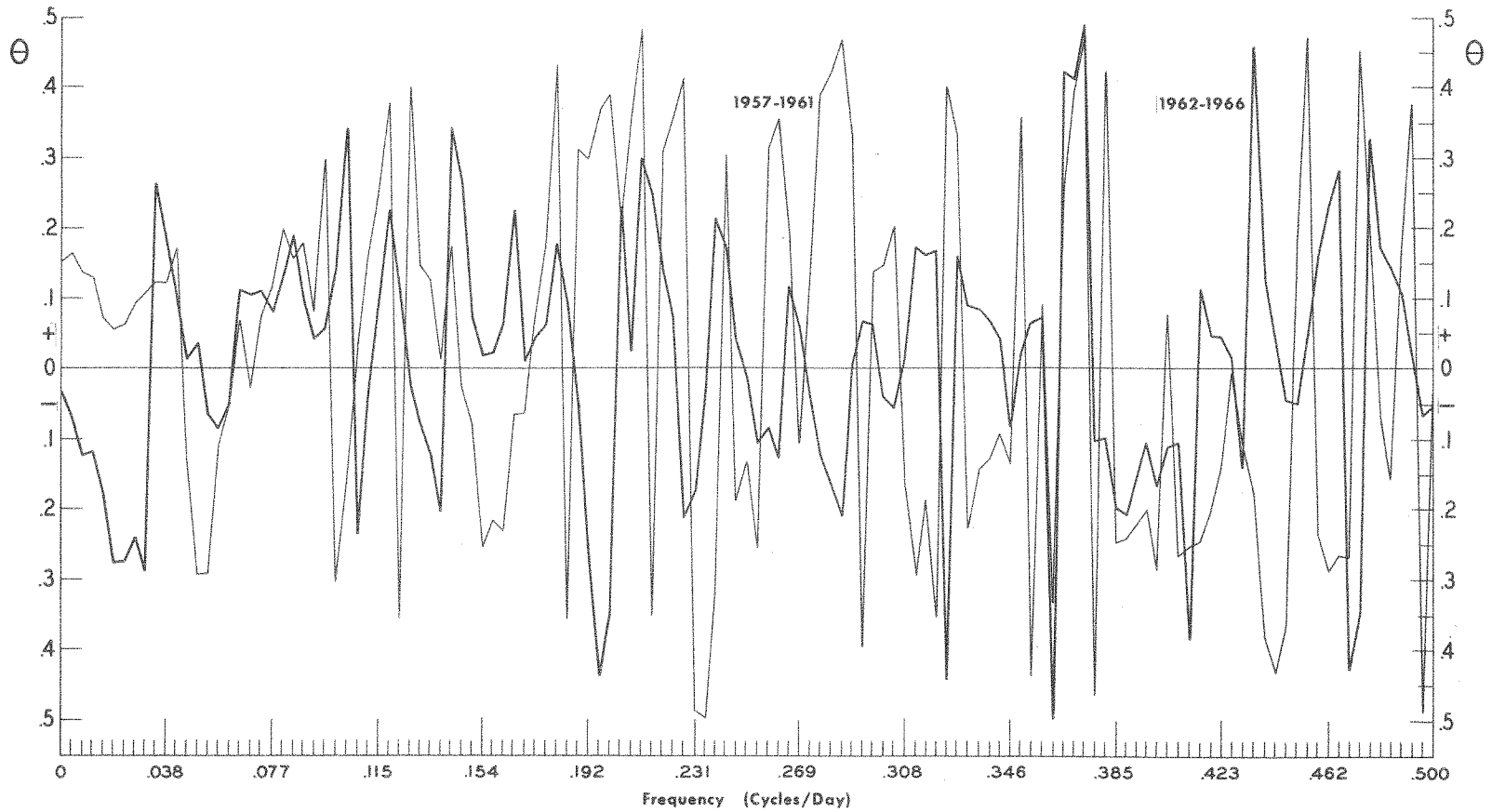

Figure 5
PHASE OF CROSS-SPECTRUM

SPOT EXCHANGE RATE AND FORWARD EXCHANGE RATE

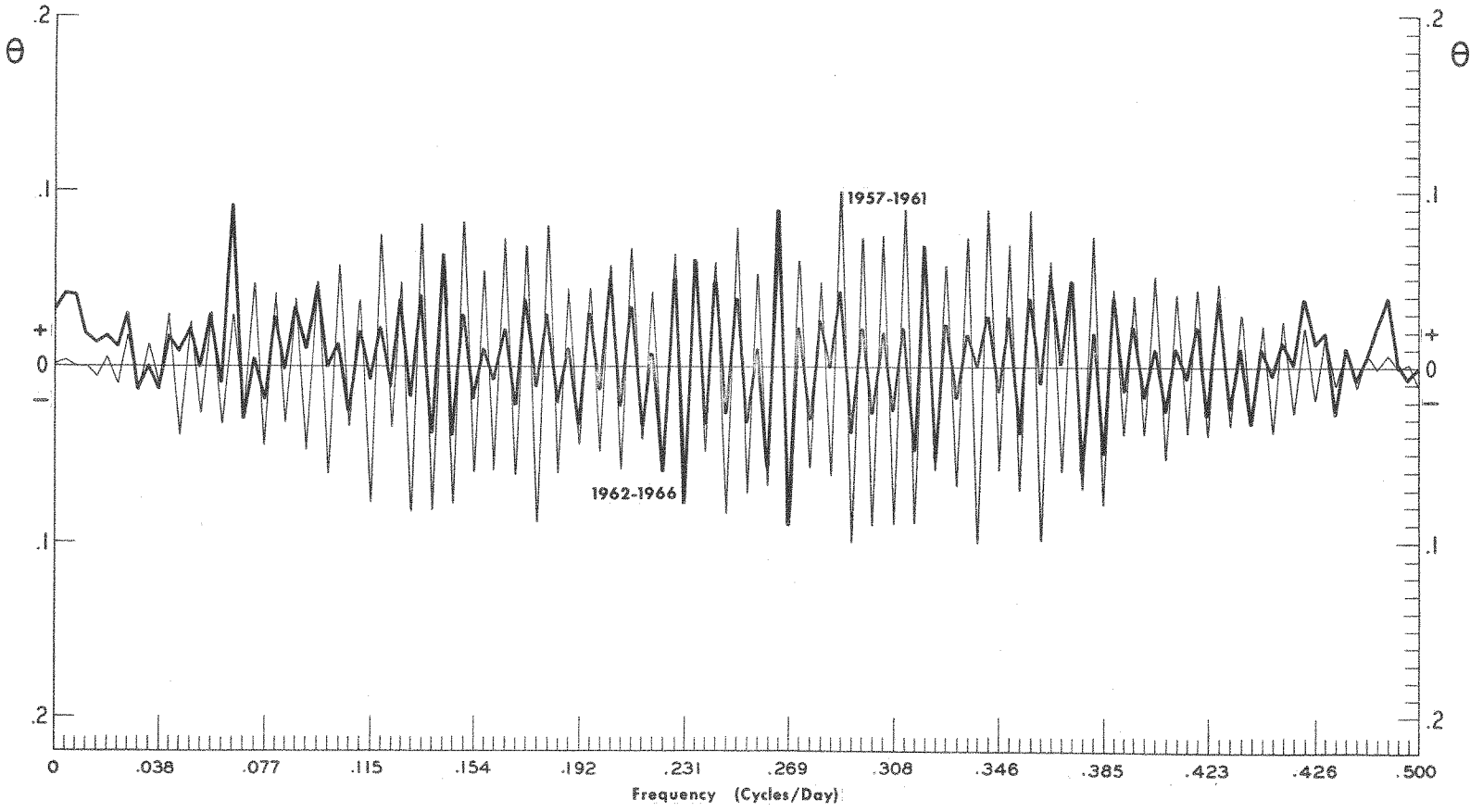

Figure 5
PHASE OF CROSS-SPECTRUM

SPOT EXCHANGE RATE AND EXCHANGE RATE SPREAD

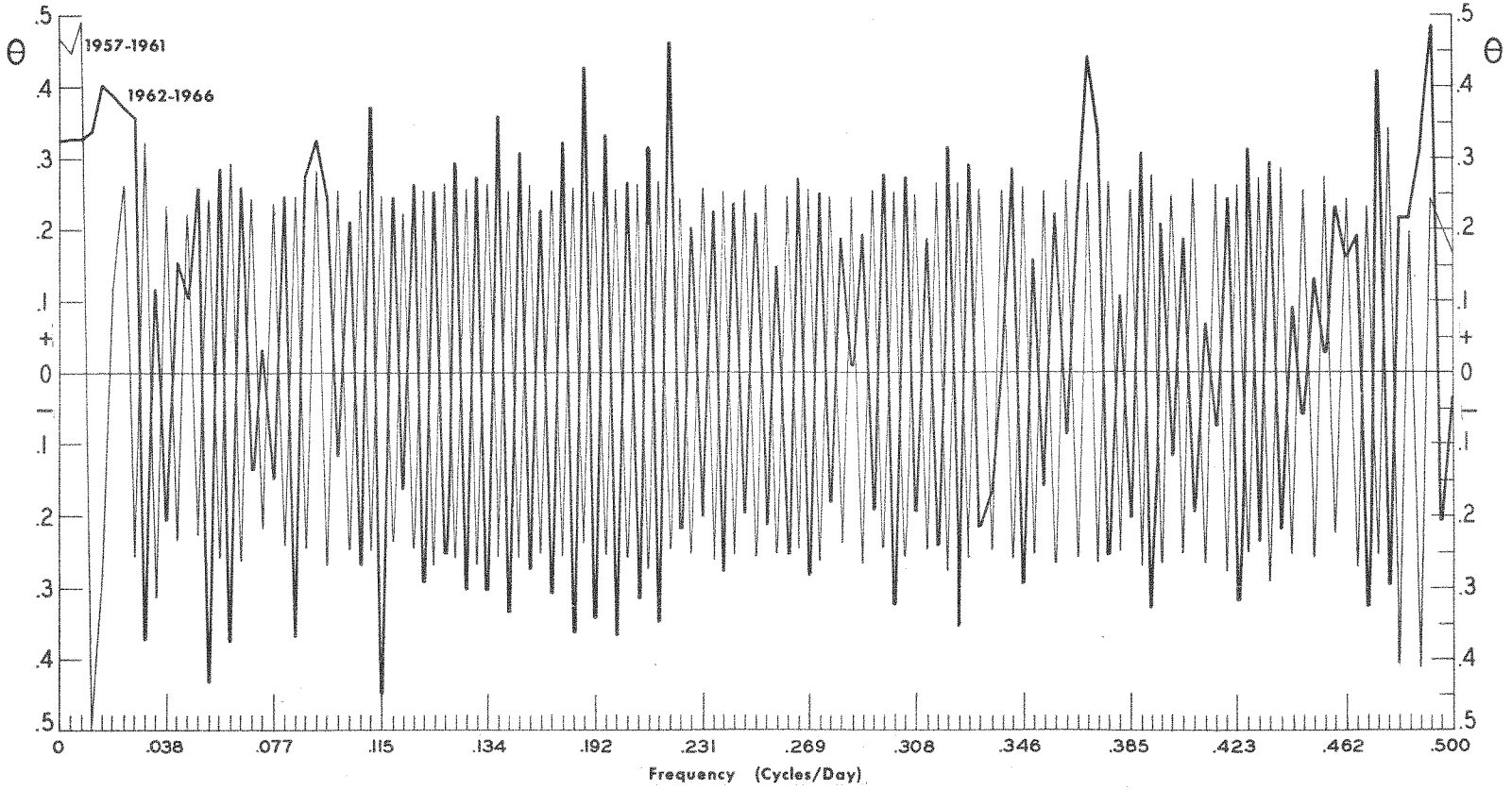

Figure 6
CROSS-CORRELATION FUNCTION