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QUARTERLY RETURNS TO TREASURY BILLS:

U.K. AND U.S. 1926-75

by

LUCIEN FOLDES AND PAULINE WATSON

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I) INTRODUCTION

This paper analyses the behaviour of the quarterly time series of returns to U.K. Treasury Bills compiled by the authors in connection with their recent study "Quarterly Returns to U.K. Equities 1919-70", together with comparable series for U.S. Treasury Bills. The basic series relate to quarterly logarithmic returns, $\log_e (1+ r_t)$, the period considered here being 1926-75 instead of 1919-70. Details of sources and data preparation are given in [1].

The present study is limited to statistical time series analysis, the aim being to find simple models which adequately describe the behaviour of the series of Bill returns without seeking explanations in terms of market forces or the movements of economic aggregates. The work proceeds in two stages, the first describing the series for U.K. and U.S. Bills separately by means of auto-regressive models and spectral analysis, while the second examines the inter-relation between the series using cross-spectral analysis. This procedure is applied first to the series of returns in money terms and then to the real series. The analysis has been carried out for the period 1926-75 as a whole and separately for the sub-periods 1926-39, 1939-51 and 1951-75.

The main results are set out in Section II below, while subsequent sections give an account of the methods used and the detailed findings.

II) SUMMARY OF CONCLUSIONS

The main positive finding of this study is that series of Treasury Bill log-returns in money terms fit well to an auto-regressive model whose coefficients have values of the same order of magnitude in both countries and in the inter-war and post-war periods.

A first order auto-regressive model fits quite well, with coefficients of the lagged variable slightly less than one, so that as a first approximation the series of quarterly log-returns is a martingale. This accords with the findings of the detailed study of U.S. Treasury Bills for the dates 1949-64 by Richard Roll. [4]

A second order auto-regression fits slightly better in most cases, with values of R^2 greater than .85. The first order coefficient is now a little greater than one, and the second slightly negative, introducing some stability.

The exception to these results is the sub-period 1939-51 during most of which Bill rates were pegged at low levels in both countries, and which thus cannot be expected to conform.

The auto-regressive models pick up relationships of lag one and two, but ignore longer term effects. The technique of spectral analysis has been used to investigate possible relationships at longer lags and to reveal the behaviour pattern of the series as a whole. Graphs of spectral density have been plotted for the full period and each sub-period (see Graph I (a) (i) - (iv)). The graphs for the basic series are strikingly similar for different periods and both countries, and are typical of auto-regressive processes. Graph I also shows the spectral density curves for the residuals from both types of auto-regression. These curves are seen to be much flatter than those for the basic series. For the full period, 1926-75, the spectra of the residuals are very nearly horizontal, which is what one would expect from a random series or 'white noise' process.

Relationships between the U.K. and U.S. series have been investigated using cross-spectral analysis, and it was found that the coherency (association between cycles of equal frequency) was greatest for cycles with periods greater than 10 quarters and for those with periods of approximately 3 quarters. Where phase differences existed, the U.S. series was found to lead the U.K. by one quarter.

While one might expect a priori to obtain a better fit with models written in real terms, this is not in fact the case with the series used here. Indeed the results in real terms are so poor that we are not able to suggest any adequate time series model, either for the U.K. or for the U.S. A possible explanation of the better fit in money terms is that the variation of the general level of prices is itself the process by which real rates of interest are adjusted to new equilibrium levels; this question cannot be pursued here. A source of difficulties in statistical analysis is that the variance of quarterly changes in the logarithm of the price index is typically much larger than the corresponding variance of log-returns to Bills (by a factor of 4.6 for the U.K. and 4.0 for the U.S. in the period 1926-75 as a whole) so that the results of regressions in real terms tend mainly to reflect random changes in prices. It may also be that an index of retail or consumer prices is not suitable for deflating Bill series. In particular, the presence of annual and perhaps other cycles in the price index introduces into the real returns to Bills components which may be irrelevant to the analysis of rates of interest. We have tried to deal with this problem by preliminary adjustment of the price index but have found no perfect method.

III) ANALYSIS OF THE SERIES IN MONEY TERMS

a) Auto-Regressions

The gross of tax quarterly return to Treasury Bills $1 + r_t$ is simply the ratio of the maturity value to the issue price (i.e. the maturity value less the initial discount). The series of quarterly logarithmic returns, $x_t = \log_e (1 + r_t)$, forms the basis for the analysis. Gross returns have been used throughout since the tax rates available for the U.K. are not particularly suitable for Treasury Bills, and only series of gross returns are available for the U.S.

The present work covers the period 1926-75, and calculations have also been made for the sub-periods 1926-39, 1939-51 and 1951-75. The period 1926-75 was chosen mainly because this is the period covered by the work of Ibbotson and Sinquefield [2] which we used in [1] as the basis for U.S./U.K. comparisons of equity returns. Our earlier study was restricted to the period up to 1970 because suitable data for equities had not been collected beyond that point, but the series for Treasury Bills could be extended more easily. The sub-periods considered here do not coincide with those used in [1] but the break points in August 1939 and January 1951 are the same. Apart from the obvious reason for choosing August 1939, these dates also correspond roughly to the period of pegged Bill rates and other 'wartime' monetary policies.

For the full period and each of the three sub-periods, first and second order auto-regressive equations of the two forms:

$$x_t = ax_{t-1} + c + \varepsilon_t$$

$$x_t = ax_{t-1} + bx_{t-2} + c + \varepsilon_t$$

were fitted to the data using the method of least squares. The results are shown in Table I (a). The notation for regressions is that of Malinvaud [6].

For the first order auto-regression the results are similar in both countries and for all periods. The coefficient of x_{t-1} lies between .92 and .99, while the constant term is virtually negligible. The standard error of the residuals (σ_{ε}^*) is considerably smaller than the standard deviation of the original series (σ_{x_t}) shown at the top of the table, and the value of R^2 is greater than 0.8 in all cases, with a value of .94 in each country for the period 1926-75 as a whole; this indicates that a large part of the variance has been accounted for.

It should be noted that the period 1939-51 is different from the others in that interest rates were pegged at low levels in both countries. Both the mean and the standard deviation of the returns are much smaller in this period than in the others, although the coefficients and statistics relating to the first order auto-regressions are comparable.

Since the coefficient of the lagged variable in the first order auto-regression is in all cases close to 1.0 - more precisely, it is always greater than .92 and falls short of 1.0 by less than two standard errors - each series of Bill returns may be regarded at a rough approximation as a martingale. This means that at any given time, the best forecast (conditional expectation) of any future quarter's return is given by the latest quarterly observation.

A glance at the last line of Table I (a), however, suggests that the auto-regressive properties of the series have not been fully explored. The Durbin-Watson statistic is a measure of the extent to which a series is first-order auto-correlated, and is equal to 2 in the case of zero auto-correlation. The values of this statistic given in Table I (a) are those for the residuals of the auto-regressions. For the first order model they vary between 1.2 and 2.6, indicating that some auto-correlation is still present.

For this reason, the second order auto-regression was carried out, and the results may be found on the right hand side of Table I (a).

The results for 1939-51 now differ considerably from those for the other periods and must be discussed separately. In the remaining periods corresponding coefficients are again very similar, those of x_{t-1} being now somewhat what greater than one and those of x_{t-2} being fairly small and negative. Thus the basic rate of change from one quarter to the next (the coefficient of x_{t-1}) is greater than in the first order model, but this is offset by the stabilising effect of the negative coefficient of x_{t-2}.

For 1939-51 there is in both countries a decreased coefficient of x_{t-1} and a small positive coefficient of x_{t-2}, but not too much significance should be attached to this change since in fact the Bill rates in both countries were virtually constant for long periods. For the U. K. in particular the return was held at one level for the first half of the period and then fell rapidly to a lower level which was maintained to the end. In this case the first order auto-regression provides an excellent (if trivial) model; this is reflected in the fact that the coefficient of x_{t-2} is very small and insignificant. In the U.S., although Government pegging did not end until 1951, Bill rates began to rise at the end of 1947, leading to a more complex situation which is reflected in the larger coefficient of x_{t-2}.

Returning to Table I (a), it is seen that there is in most cases a slight improvement in the values of R^2 and the standard error of the estimate, and that the constant is still negligible. The Durbin-Watson statistic is now in all cases much closer to 2, implying that nearly all the first-order auto-correlation has now been removed from the residuals.

The auto-regressive equations may be used to predict future values of returns, the standard deviation of the predictions depending on that of the residuals. Graph II shows 95% confidence intervals for predictions up to 8 quarters from the end of the full period and the three sub-periods based on the parameters of the first order auto-regressions. Thus for example Graph II (i) shows that for the UK one could forecast up to 8 quarters from November 1975 in the range (.015, .031) with 95% certainty.*

If we consider the auto-regressive process to be a martingale, the standard deviation of the predicted values for the t^{th} quarter is simply $\sigma_{\varepsilon}^{*}\sqrt{t}$. Confidence intervals based on this simplifying assumption are only a little wider than those shown in Graph II.

* As a matter of interest the values actually observed for 1939-41, 1951-52 and 1976-77 (UK only) are also plotted.

b) Spectral Analysis (*)

At an early stage of this study the technique of spectral analysis was used to examine the structure of the time series of Treasury Bills in money and real terms. The method involves splitting a series into cyclical components, each with a different frequency. Such a decomposition of an economic time series cannot be given the same interpretation as in the case of electromagnetic radiation, where a specific physical meaning can be attached to the different components. Nevertheless, the overall shape of the spectrum indicates the behaviour pattern of an economic series and is helpful in the selection of models. Also, in some cases one can measure cycles generated by mechanisms which can be identified in the real world.

Applied to time series the technique of spectral analysis involves estimating the amount of the total variance which may be attributed to each frequency component, known as the 'spectral density' at a given frequency. In a purely random series, or 'white noise' process, the same amount of variance arises at each frequency, so the spectral density curve is simply a horizontal line. A series which has a marked cycle shows a peak in the spectrum at the frequency of that cycle.

Graph I (a), (i)-(iv) shows the spectral density estimates for the basic Treasury Bill series in money terms for the U.K. and the U.S., and for the residuals of first and second order auto-regressions in all the periods considered. The curves for the basic series are strikingly similar in both countries and all periods. In each case a large proportion of the variance comes from low frequency components (long term trends), a pattern typical of auto-regressive processes. After the auto-regressions had been performed, spectral analysis was repeated on the residuals to see whether there were any cyclical features which had been masked by the trends. Graph I (a) (i) for

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(*) A full account of the methods of spectral analysis used here will be found in [3] .

the full period shows that the spectra of the residuals of the auto-regressions are very nearly flat, i.e. the series of residuals are virtually random. There is little difference between the spectra of the first and second order residuals, but that of the second order residuals is flatter. These flat spectra obtained for the residuals imply that the behaviour of the series is described almost completely by the auto-regressive process.

The results for the sub-periods are similar, but not so conclusive. There is still a certain amount of variation in the spectra of the residuals in 1926-39 and, for the U.S., in 1939-51. For the U.K. the greater stability of the return in 1939-51 is reflected in the very flat spectra obtained for both sets of residuals in that period. The results for the longest sub-period, 1951-75, are closer to those for the full period.

It may thus be concluded that, particularly over long periods, the series of returns to Treasury Bills in money terms is very well described, both in the U.S. and the U.K., by the second-order auto-regressive relationship with the coefficients set out in Table I (a).

c) <u>Cross-Spectral Analysis</u>

The next aspect of the study was the investigation of the interdependence between the series in the U.S. and in the U.K. The first statistic calculated was the cross-covariance function, $C(x_{1,t}, x_{2,t+k})$, which measures the covariance between the value $x_{1,t}$ of the U.K. series at time t, and the value $x_{2,t+k}$ of the U.S. series at time t+k. Graph III (i)-(iv) shows the cross-covariance function for up to 15 lags (i.e. k= -15 to k= +15) for the basic series and for the first differences in the four periods under consideration. The basic series shows a high degree of cross-correlation, but this is mainly due to the similar long term auto-regressive properties of the two series. The presence of such long term trends can give rise to spurious results in cross-spectral analysis. The calculations have therefore been carried out using the first differences, whose cross-covariance function approaches zero much more quickly than that of the basic series in all periods.

Cross-spectral analysis has been applied to all periods using the cross-covariances of the first differences up to lag 10 i.e. between -10 and +10. If higher lags are used instability begins to creep in. The results for 1926-75 are shown in Graph IV. The coherency spectrum shows peaks in the range f = 0 to 0.1 and f = 0.35 (corresponding to cycles of more than 10 quarters and approximately 3 quarters respectively), indicating that most of the cross-correlation between the series is confined to these wavebands. The phase spectrum shows a peak of height nearly $\pi/2$ about frequency f = 0.25 (corresponding to components of period 4 quarters). This means that these components are out of phase by a quarter of a cycle, i.e. one quarter, and from the sign of the phase spectrum we deduce that the U.K. series lags behind the U.S.

Apart from 1939-51, the sub-period coherency spectra are very similar to that of the full period. The 1951-75 phase spectrum also differs little, but for 1926-39 it is the short term components of period 2 quarters which are out of phase, again with the U.S. leading the U.K. by one quarter.

The peculiarity of the sub-period 1939-51 is again shown in Graph III (iii) where the cross-covariances between the two basic series are all negative. This happens because the U.S. Treasury Bill rate is held down below the U.K. rate in the first part of the period, but later rises above it, so that over the whole period the U.K. rate falls while the U.S. rate rises, producing negative cross-correlation. Graph III (iii) also shows that the largest value of the cross-covariance of the first differences occurs at lag 11 rather than at lag 0 as in the other periods. This means that in order to obtain a good cross-spectral estimate, a large number of lags should be considered, since the computation should be centred on the largest cross-covariance value. Since the results for this sub-period are of limited interest because of the way in which rates were pegged, these further computations have not been carried out.

IV) ANALYSIS OF THE SERIES IN REAL TERMS

a) Price Index

It was the intention to use for the conversion of U.K. series to real terms, the Index of Retail Prices described in [1] and for the U.S., the Consumer Price Index tabulated in [2]. However, spectral analysis of these indices showed a marked annual cycle in the U.K. index and a lesser one for the U.S. Several methods of smoothing were tried to remove these cycles, since they re-appeared in the series for Treasury Bills in real terms.

It was relatively easy to find a suitable method of smoothing the U.S. series, but the U.K. series proved more intractable. The method finally chosen involved smoothing the series separately over the three sub-periods 1926-39, 1939-51 and 1951-75. For consistency, the same method of smoothing was applied to the U.S. index.(*)

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(*) The obvious first attempt at smoothing was to use a four-quarter moving average, which, while it removed the annual cycle, created neighbouring peaks in the spectrum and also increased disproportionately the contribution to the total variance of the long term trends. The second attempt involved adjusting the data so that the means of the four sub-series obtained by taking all the quarters beginning in the same month were equal. This simply meant adding to each element the difference between the overall mean of the series and the mean of the sub-series containing that element. This worked well for the U.S. index, but when applied to the U.K. data the cycle was not removed. The reason for this appeared to be that the largest sub-series mean occurred at different times of the year in different parts of the period. In the early years, the largest values occurred in the quarters beginning in August, later in those beginning in November and finally in those beginning in February. Thus, adjusting the sub-series mean to the overall mean of the period improved the situation in some sub-periods but exacerbated it in others. Accordingly, the

Footnote (cont.)

smoothing process was applied separately to each of the three sub-periods 1926-39, 1939-51 and 1951-75. This removed the cycle in each sub-period quite well, and was also effective for the period as a whole.

b) Auto-Regressions

The results of first and second order auto-regressions applied to the series in real terms are set out in Table I (b). These results are much less consistent than those for money terms; the coefficients of x_{t-1} vary considerably and the values of R^2 are very small. Comparing the standard error of the estimate (σ_{ϵ}^*) with the original standard deviation (σ_{x_t}) shows that very little of the variance has been accounted for. The Durbin-Watson statistic is in all cases close to 2, but this mainly reflects properties of the price series.

c) Spectral Analysis

Graph I (b), (i)-(iv) shows spectral estimates for the real terms series. The spectra for the basic series are similar to those for the 'money' case in that they all show a peak at low frequencies, although this is now much less marked. Other features, particularly peaks around $f = .3$ to $.4$ are evident. The dramatic difference between the spectra of the basic series and those of the residuals which occurs in the 'money' case is absent, although the residual spectra do tend to show a little less variation, particularly for the U.S. over the full period. It would not, however, be appropriate to suggest that in this case the auto-regressive model gave any sort of satisfactory explanation of the behaviour of the series.

d) Cross-Spectral Analysis

The cross-covariance function of the real terms series was in all periods found to be very similar to that of the price index, presumably because the changes in the Treasury Bill rates are relatively small. Thus any cross-spectral analysis would reflect the properties of the price index rather than those of the Treasury Bill series, and although the interdependence between price indices is of considerable interest, it will not be discussed here.

TABLE I (a)

Results of first and second order auto-regressions

for quarterly log-returns to UK and US Treasury Bills in MONEY terms

	First order auto-regression $x_t = ax_{t-1} + c$								Second order auto-regression $x_t = ax_{t-1} + bx_{t-2} + c$							
	1926-75		1926-39		1939-51		1951-75		1926-75		1926-39		1939-51		1951-75	
	UK	US	UK	US	UK	US	UK	US	UK	US	UK	US	UK	US	UK	US
μ_{xt}	.00809	.00562	.00539	.00360	.00195	.00106	.01260	.00892	.00816	.00566	.00523	.00349	.00192	.00114	.01284	.00905
δ_{xt}	.0066	.0052	.0046	.0042	.0006	.0009	.0058	.0047	.0067	.0052	.0046	.0042	.0006	.0009	.0059	.0047
a	.9815	.9746	.9246	.9321	.9204	.9625	.9436	.9510	1.1387	1.1562	1.3015	1.0619	.8528	.6644	1.0124	1.1850
σ_a	.0174	.0174	.0509	.0480	.0649	.0699	.0324	.0308	.0715	.0703	.1307	.1373	.1101	.1472	.1042	.1017
T_a	56.45	55.96	18.18	19.41	14.18	13.77	29.17	30.90	15.93	16.45	9.96	7.73	7.75	4.52	9.71	11.65
b									-.1565	-.1824	-.4021	-.1214	.0966	.3628	-.0659	-.2391
σ_b									.0723	.0706	.1297	.1363	.1114	.1566	.1037	.1014
T_b									-2.19	-2.58	-3.10	-.89	.87	2.32	-.64	-2.36
c	.00020	.00016	.00023	.00008	.00015	.00011	.00091	.00053	.00022	.00019	.00046	.00012	.00006	.00007	.00090	.00058
σ_c	.00018	.00013	.00037	.00027	.00013	.00009	.00044	.00031	.00018	.00013	.00034	.00026	.00010	.00009	.00046	.00031
T_c	1.13	1.24	.62	.31	1.10	1.23	2.06	1.74	1.24	1.47	1.33	.46	.63	.87	1.96	1.87
σ_ε^*	.00159	.00126	.00169	.00145	.00027	.00037	.00186	.00142	.00159	.00124	.00157	.00141	.00010	.00035	.00189	.00140
R^2	.942	.941	.869	.883	.827	.819	.900	.909	.945	.945	.888	.892	.912	.857	.898	.913
D-W	1.65	1.62	1.24	1.68	1.65	2.60	1.82	1.55	1.96	1.89	1.69	1.81	1.81	1.89	1.98	1.92

TABLE I (b)

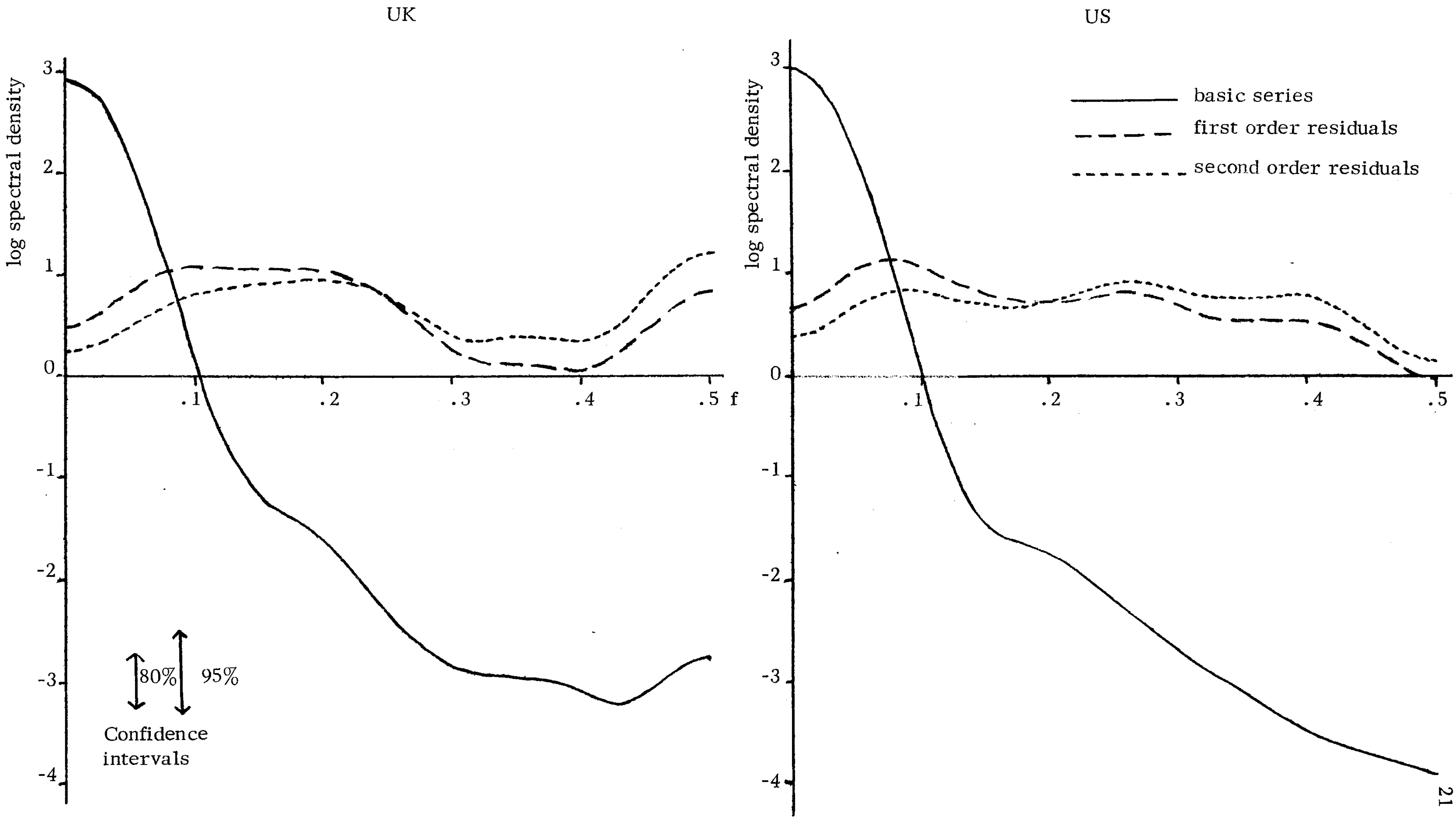
Results of first and second order auto-regressions
for quarterly log-returns to UK and US Treasury Bills in REAL terms

	First order auto-regression $x_t = ax_{t-1} + c$								Second order auto-regressions $x_t = ax_{t-1} + bx_{t-2} + c$							
	1926-75		1926-39		1939-51		1951-75		1926-75		1926-39		1939-51		1951-75	
	UK	US	UK	US	UK	US	UK	US	UK	US	UK	US	UK	US	UK	US
μ_{xt}	-.00188	-.00001	.00696	.00857	-.0105	-.01185	-.00146	.00135	-.00190	-.00016	.00689	.00803	-.01061	-.01269	-.00114	.00134
σ_{xt}	.0165	.0141	.0168	.0160	.0129	.0169	.0129	.0046	.0165	.0139	.0168	.0157	.0128	.0170	.0126	.0046
a	.3397	.6500	.2890	.4936	-.1235	.5972	.4336	.2290	.2472	.4713	.2578	.3416	-.1104	.5677	.3538	.1839
σ_a	.0670	.0544	.1357	.1230	.1152	.1239	.0883	.0963	.0692	.0680	.1415	.1309	.1539	.1569	.1022	.0982
T_a	5.07	11.94	2.13	4.01	-1.07	4.82	4.91	2.38	3.57	6.93	1.82	2.61	-.72	3.62	3.46	1.87
b									.2666	.2663	.1276	.3174	.1276	.0597	.1058	.2811
σ_b									.0689	.0680	.1419	.1309	.1165	.1570	.0985	.0949
T_b									3.87	3.92	.90	2.43	1.10	.38	1.07	2.96
c	-.00130	-.00005	.0477	.00435	-.01197	-.00481	-.00071	.00105	-.00098	-.00017	-.00413	.00238	-.01024	-.0053	-.00044	.00073
σ_c	.00111	.00077	.0248	.00221	.00238	.00253	.00119	.00047	.00108	.00073	.00257	.00213	.00300	.0027	.00118	.00046
T_c	-1.17	-.06	1.92	1.96	-5.03	-1.90	-.60	2.23	-.91	-.24	1.60	1.12	-3.41	-1.96	-.38	1.57
σ_ε*	.0155	.0107	.0163	.0140	.0129	.0137	.0116	.0045	.0150	.0102	.016	.0130	.0128	.0139	.0116	.0043
R^2	.116	.422	.083	.244	.027	.356	.203	.056	.178	.468	.101	.338	.047	.360	.180	.144
D-W	2.19	2.32	2.05	2.24	1.96	2.04	2.14	2.03	2.12	2.03	2.06	2.11	2.06	1.91	2.02	2.16

Graph I (a)

Spectra of basic series of quarterly log-returns to UK and US Treasury Bills in MONEY terms and spectra of residuals from first and second order auto-regressions. Parzen window, truncation point 15.

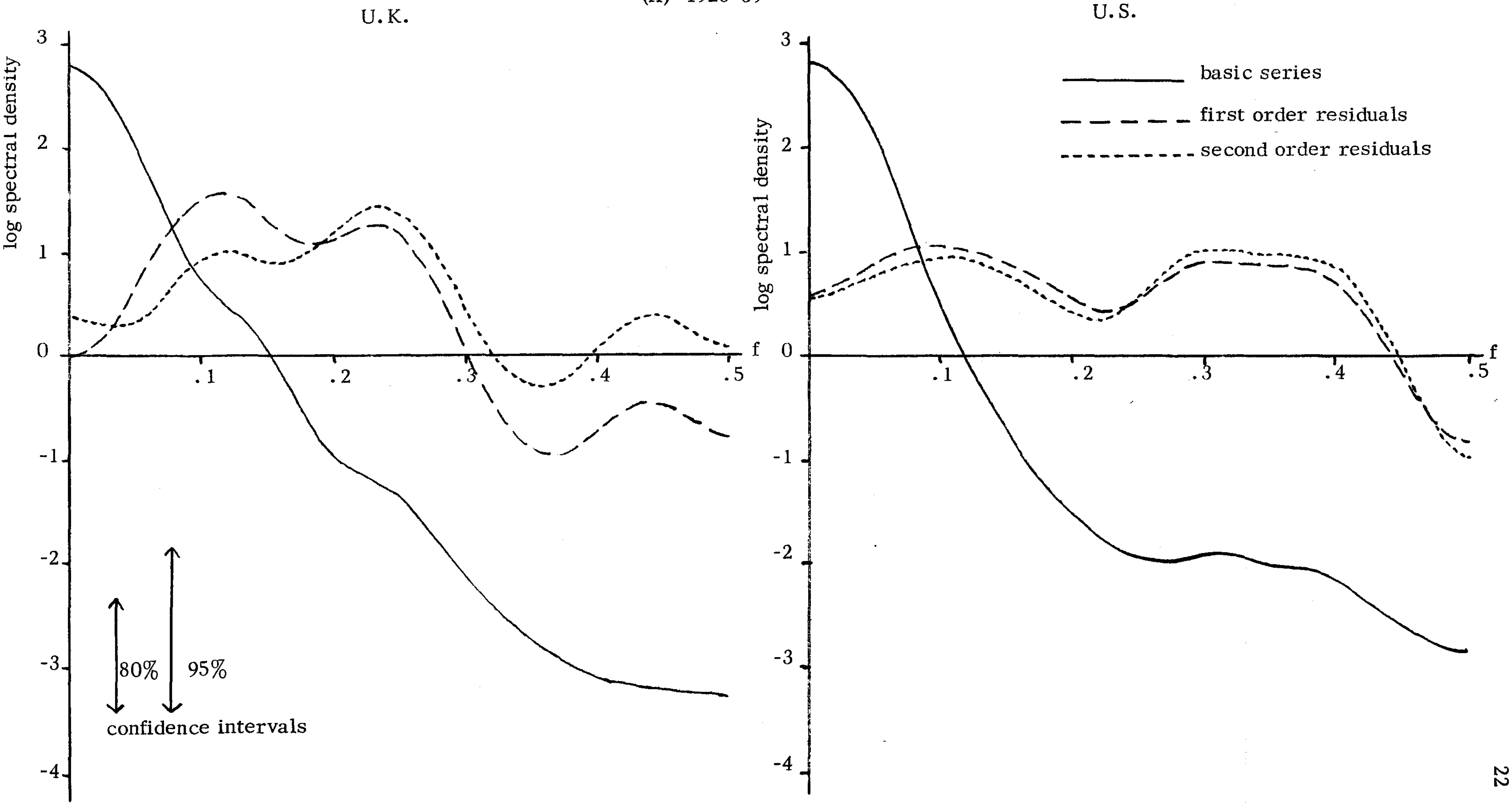
(i) 1926-75



GRAPH I(a)

Spectra of basic series of quarterly log-returns to U.K. and U.S. Treasury Bills in MONEY Terms and spectra of residuals from first and second order auto-regressions.
Parzen window, truncation point 15

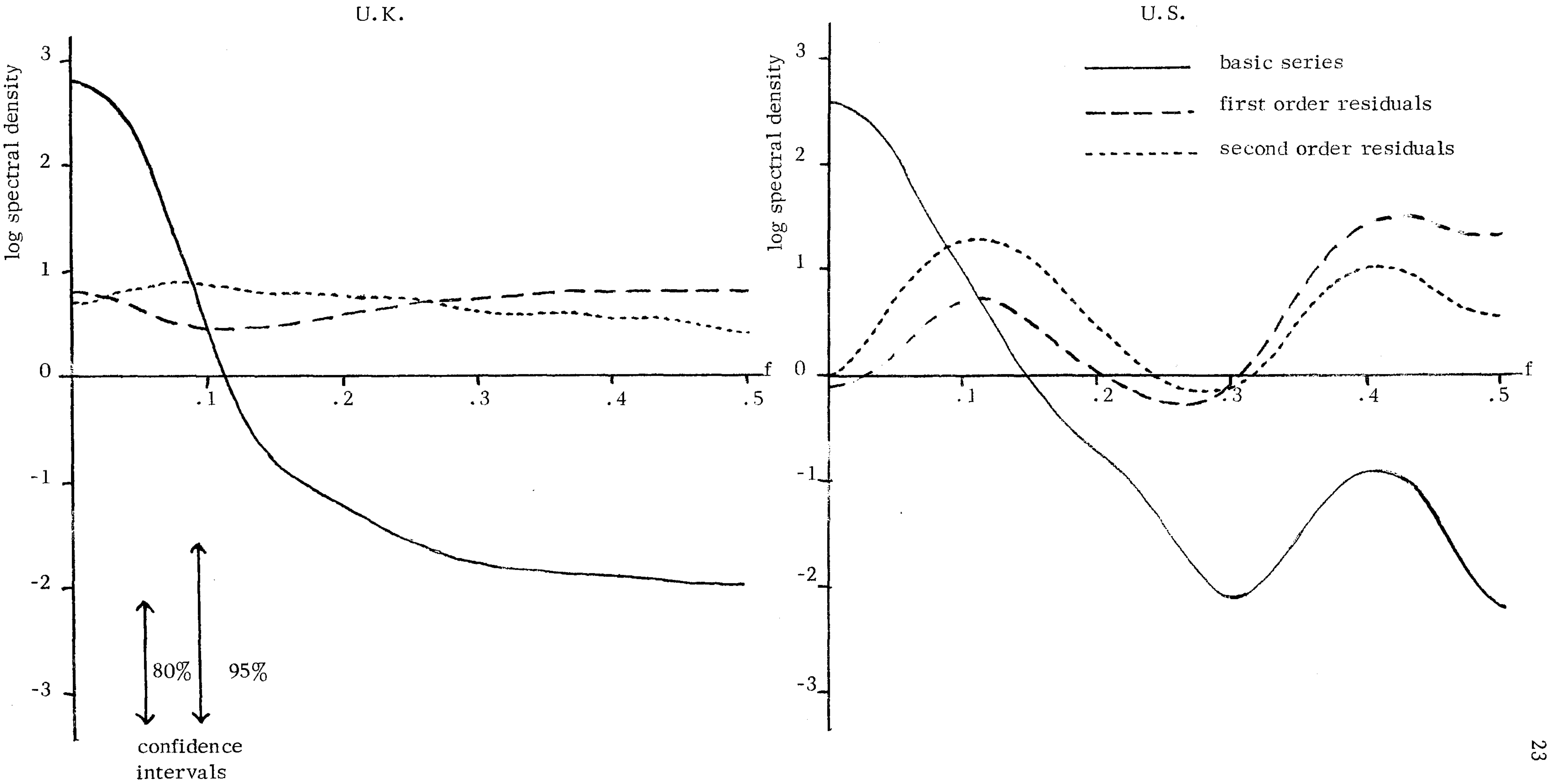
(ii) 1926-39



GRAPH I(a)

Spectra of basic series of quarterly log-returns to U.K. and U.S. Treasury Bills in MONEY Terms and spectra of residuals from first and second order auto-regressions. Parzen window, truncation point 15.

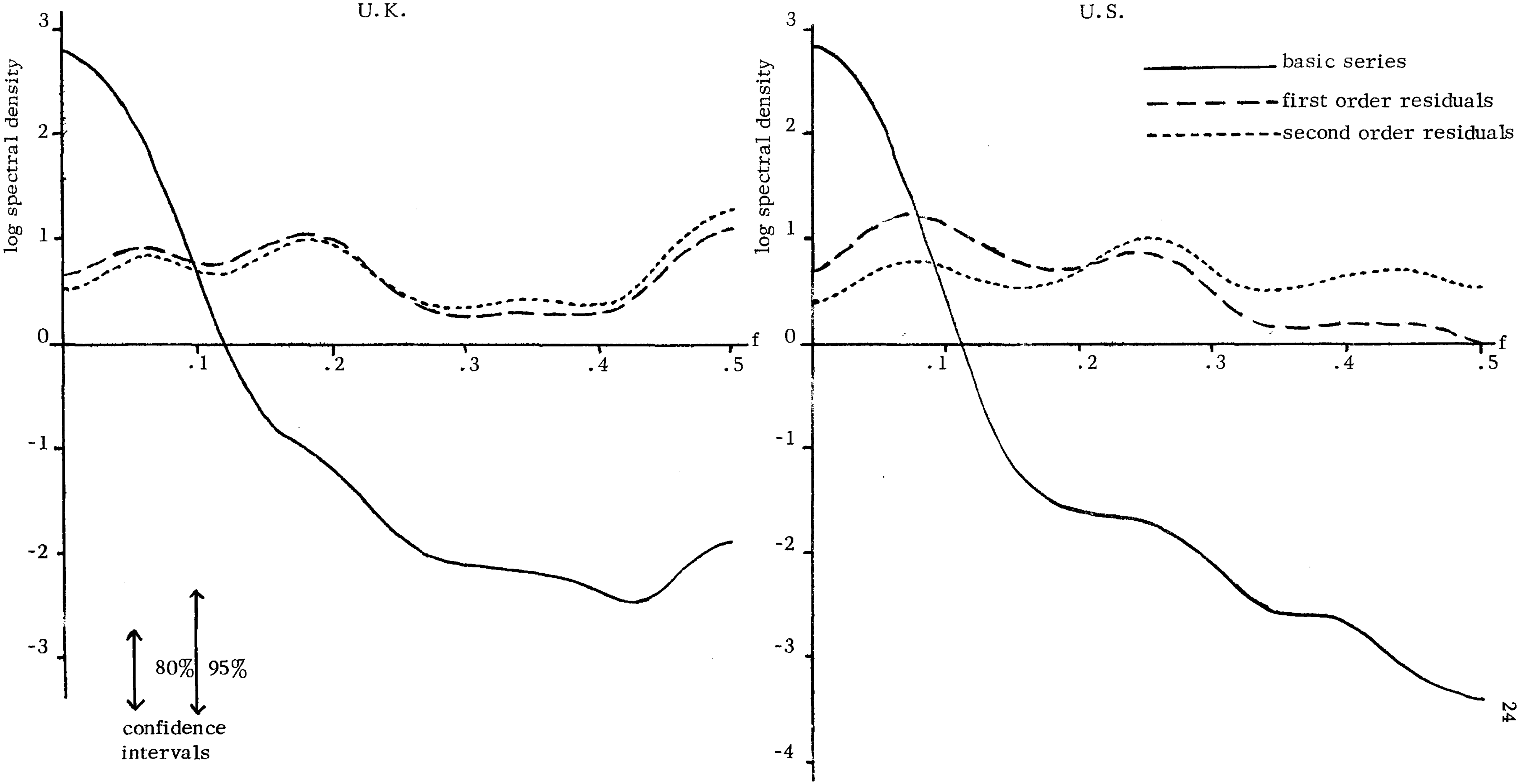
(iii) 1939-51



GRAPH I(a)

Spectra of basic series of quarterly log-returns to U.K. and U.S. Treasury Bills in MONEY Terms and spectra of residuals of first and second order auto-regressions.
Parzen window, truncation point 15

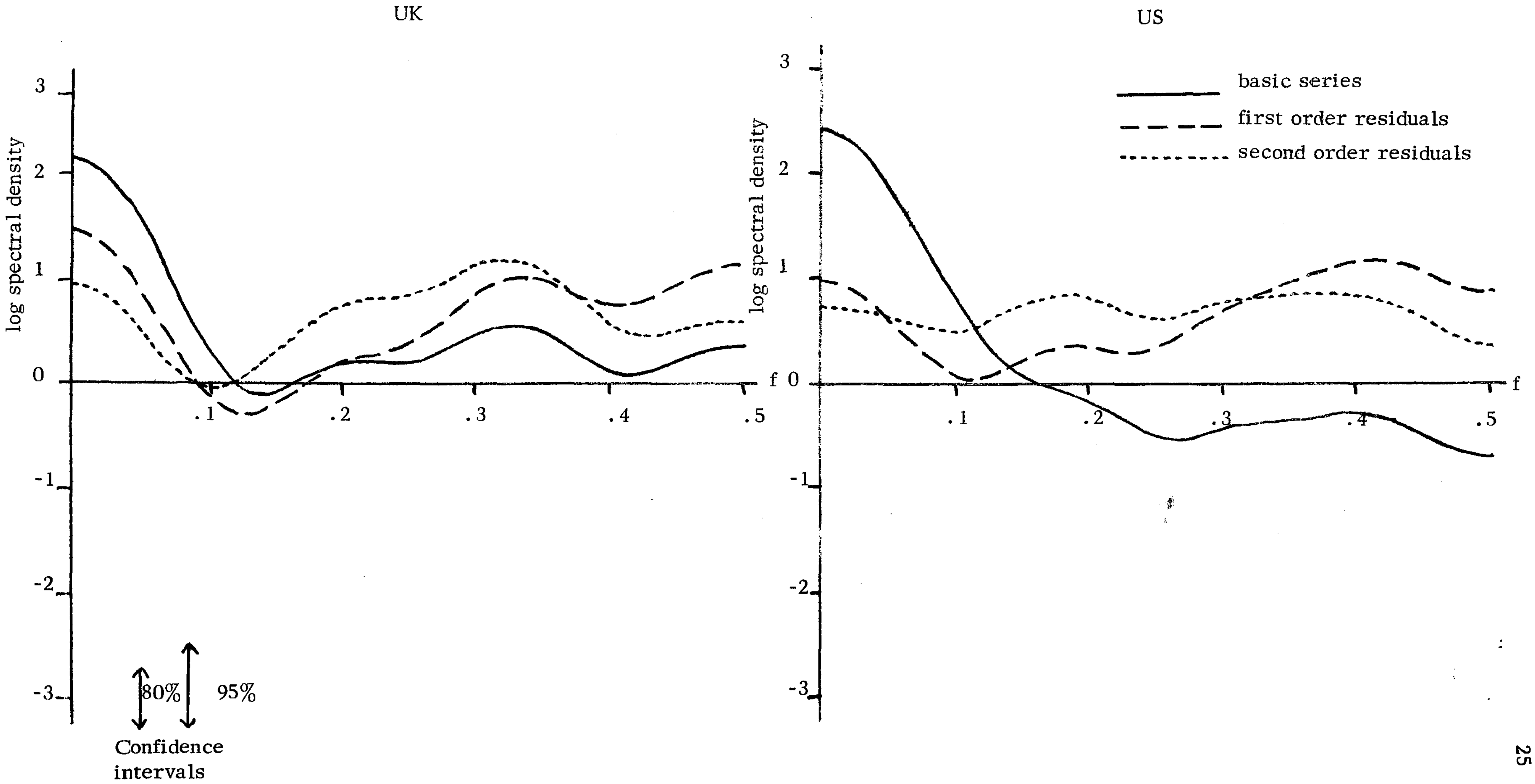
(iv) 1951-75



GRAPH I(b)

Spectra of basic series of quarterly log-returns to UK and US Treasury Bills in REAL terms and spectra of residuals from first and second order auto-regressions.
Parzen window, truncation point 15.

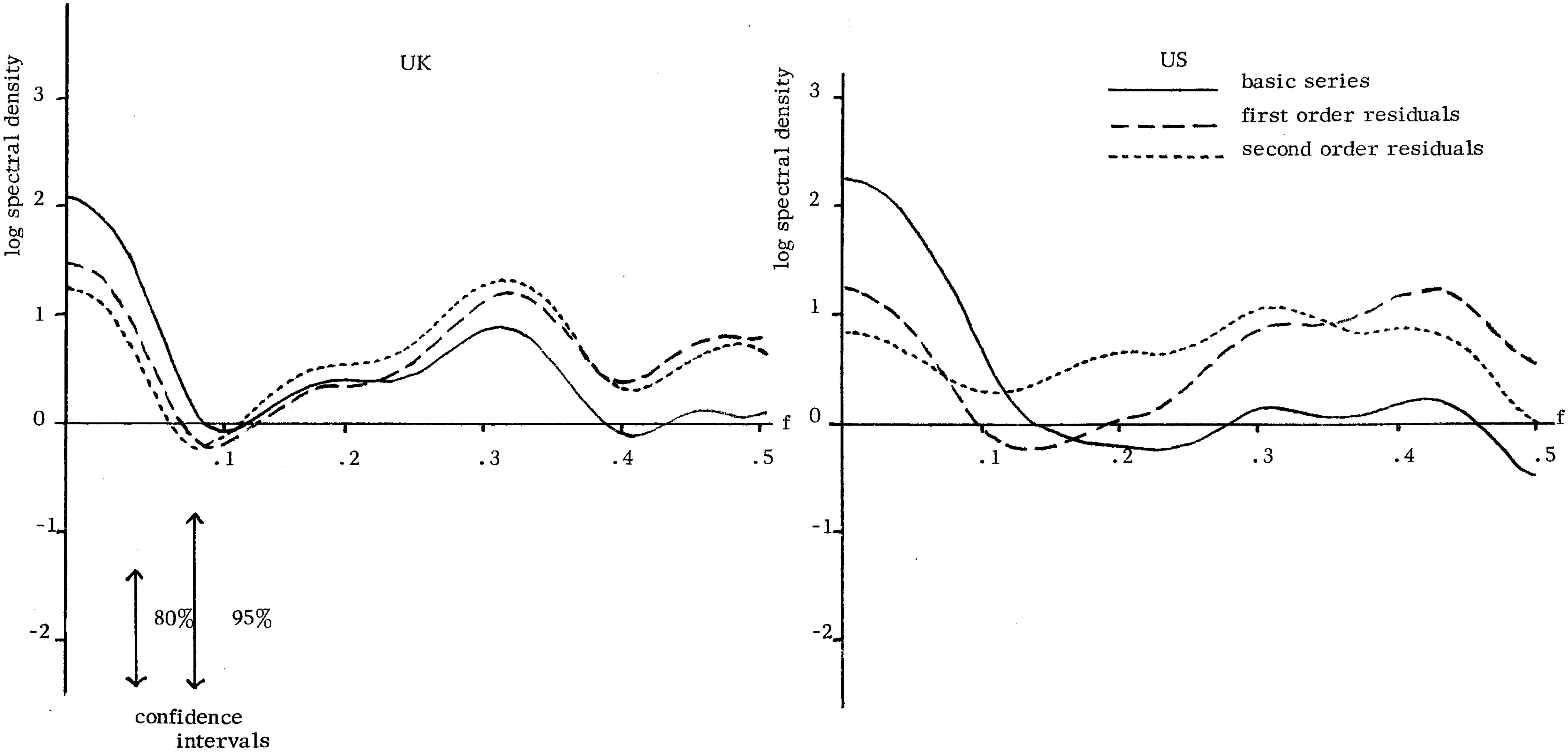
(i) 1926-75



GRAPH I(b)

Spectra of basic series of quarterly log-returns to UK and US Treasury Bills in REAL terms and spectra of residuals from first and second order auto-regressions.
Parzen window, truncation point 15.

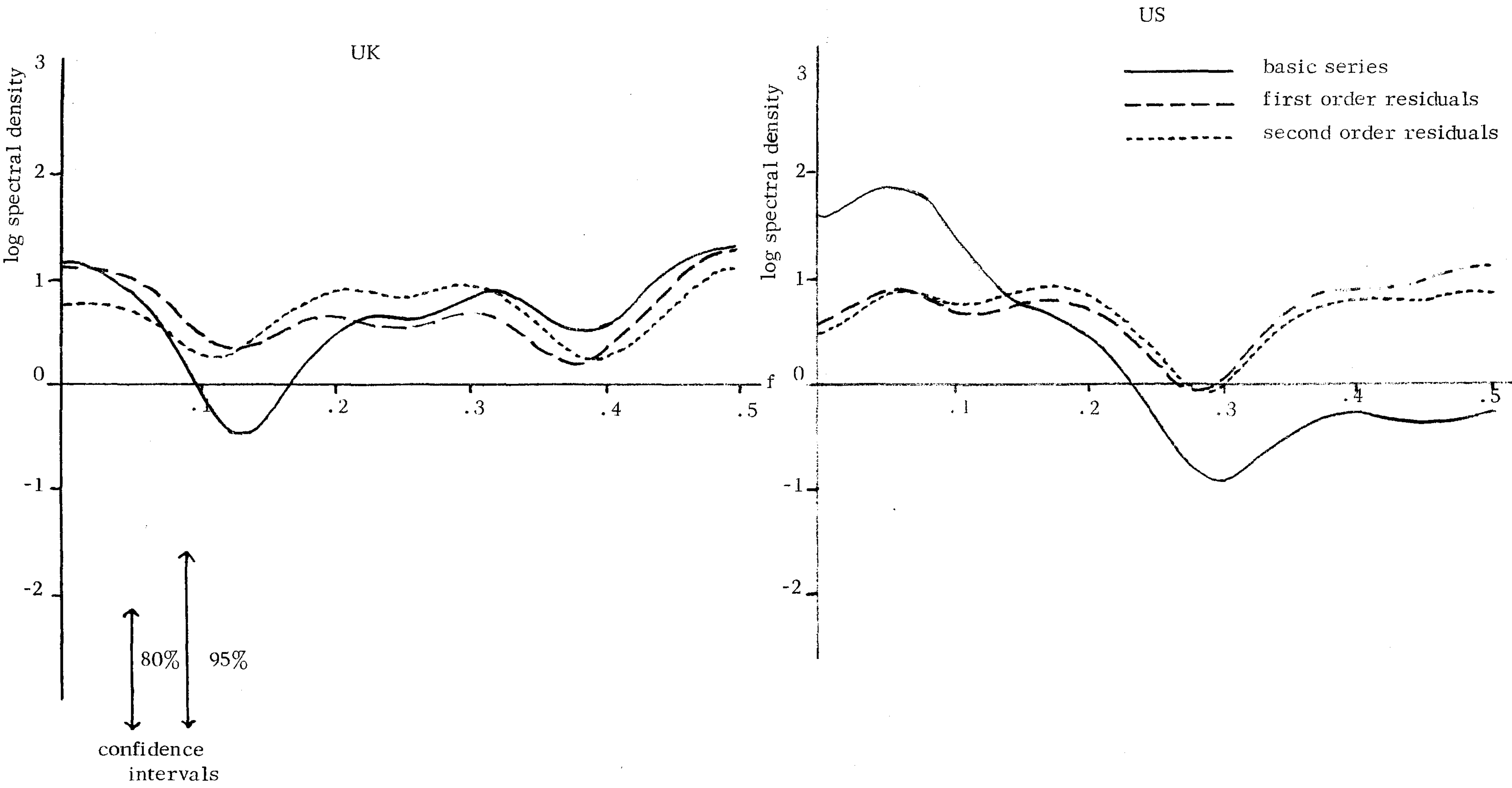
(ii) 1926-39



GRAPH I(b)

Spectra of basic series of quarterly log-returns to UK and US Treasury Bills in REAL terms and spectra of residuals from first and second order auto-regressions. Parzen window, truncation point 15.

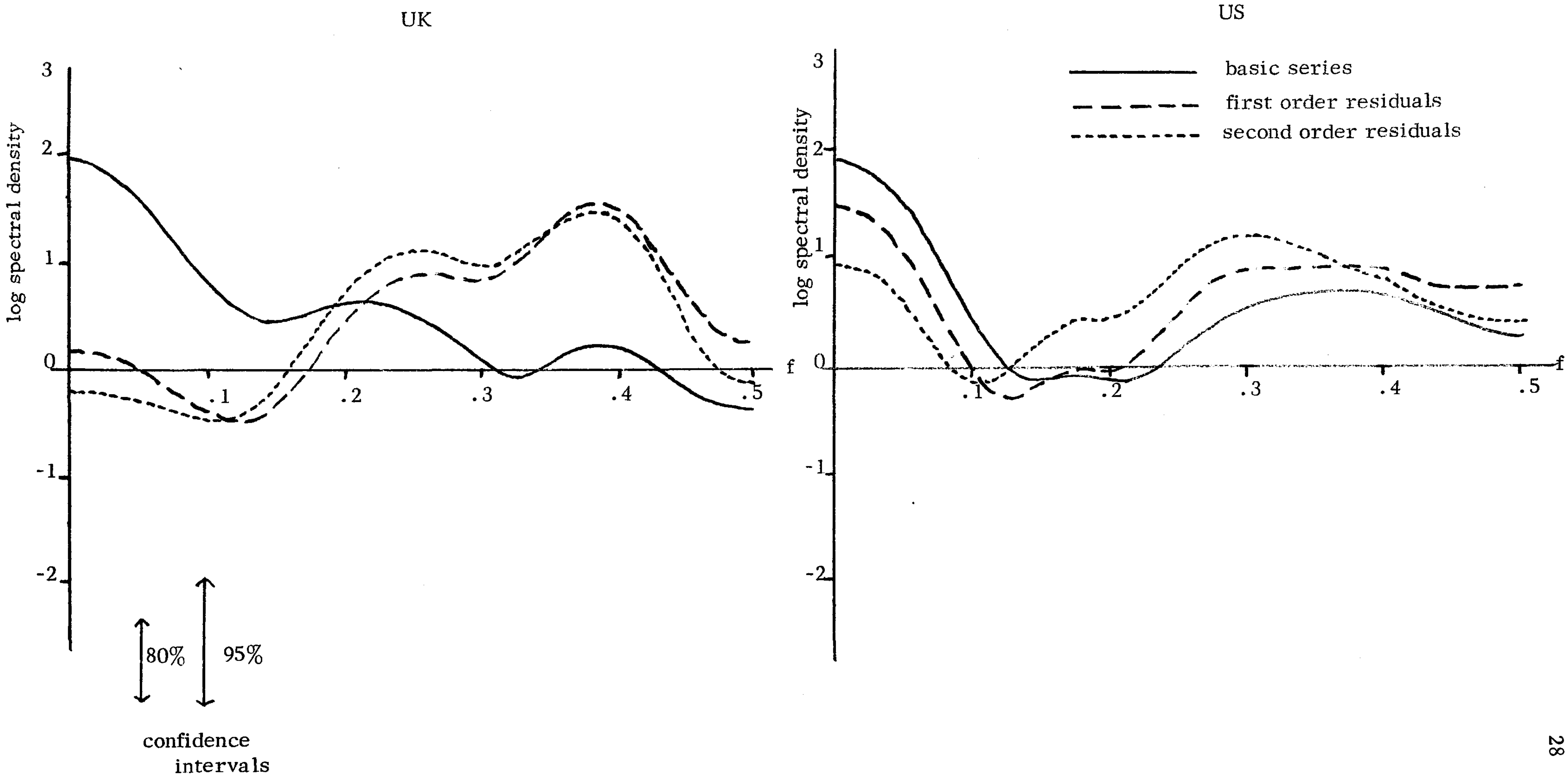
(iii) 1939-51



GRAPH 1 (b)

Spectra of basic series of quarterly log-returns to UK and US Treasury Bills in REAL terms and spectra of residuals of first and second order auto-regressions. Parzen window, truncation point 15.

(iv) 1951-75

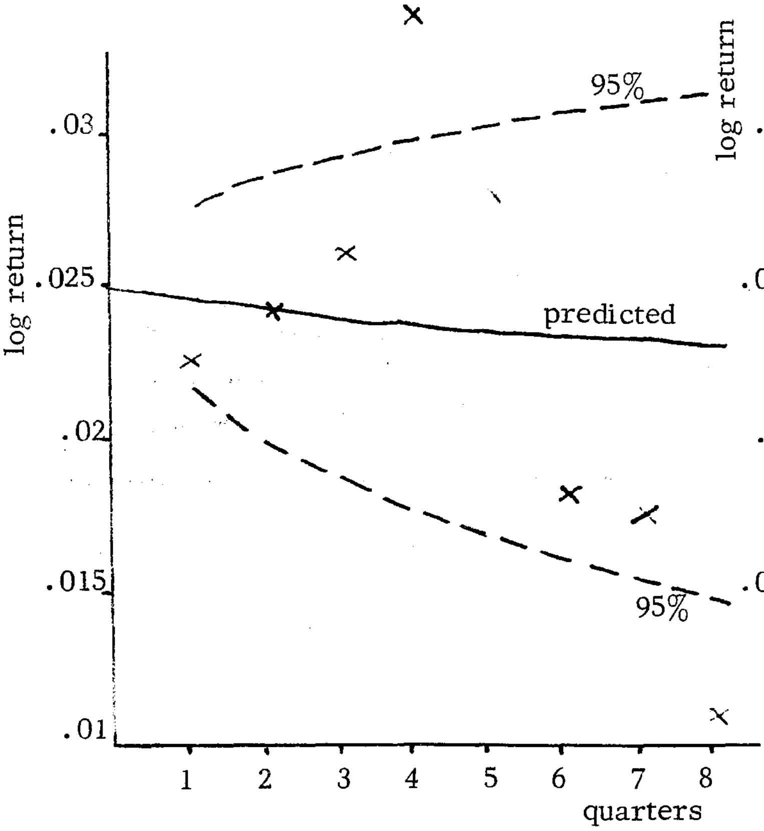


GRAPH II (i) & (ii)

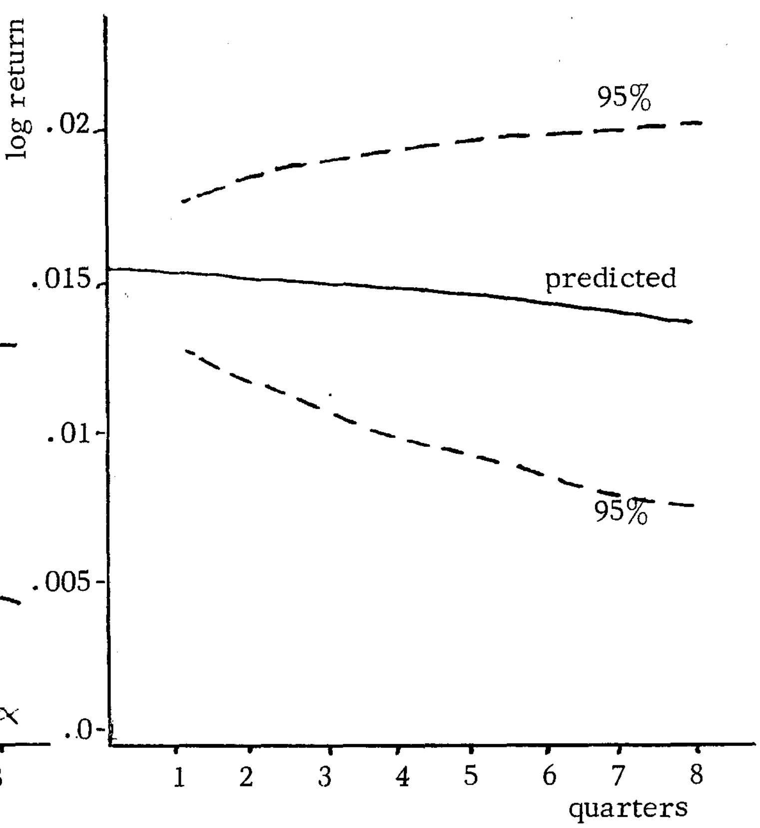
95% confidence intervals based on first order auto-regressions for predictions up to 8 quarters from end of period.
Quarterly log-returns to Treasury Bills in MONEY terms.

(i) 1926-75

(a) U.K.

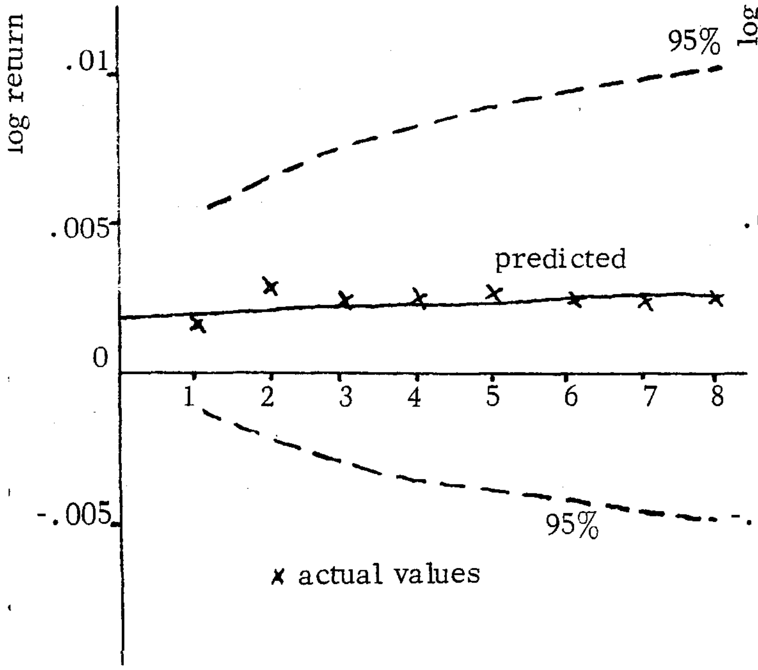


(b) U.S.

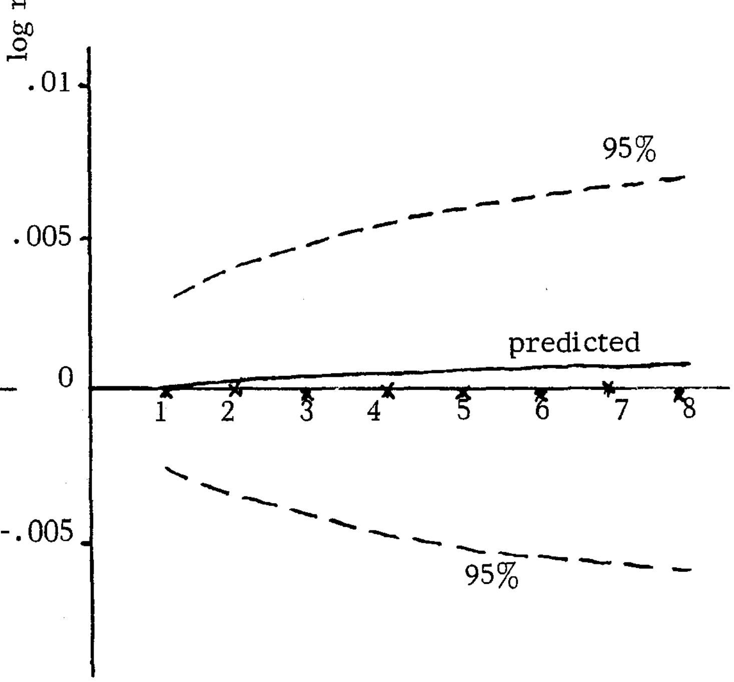


(ii) 1926-39

(a) U.K.



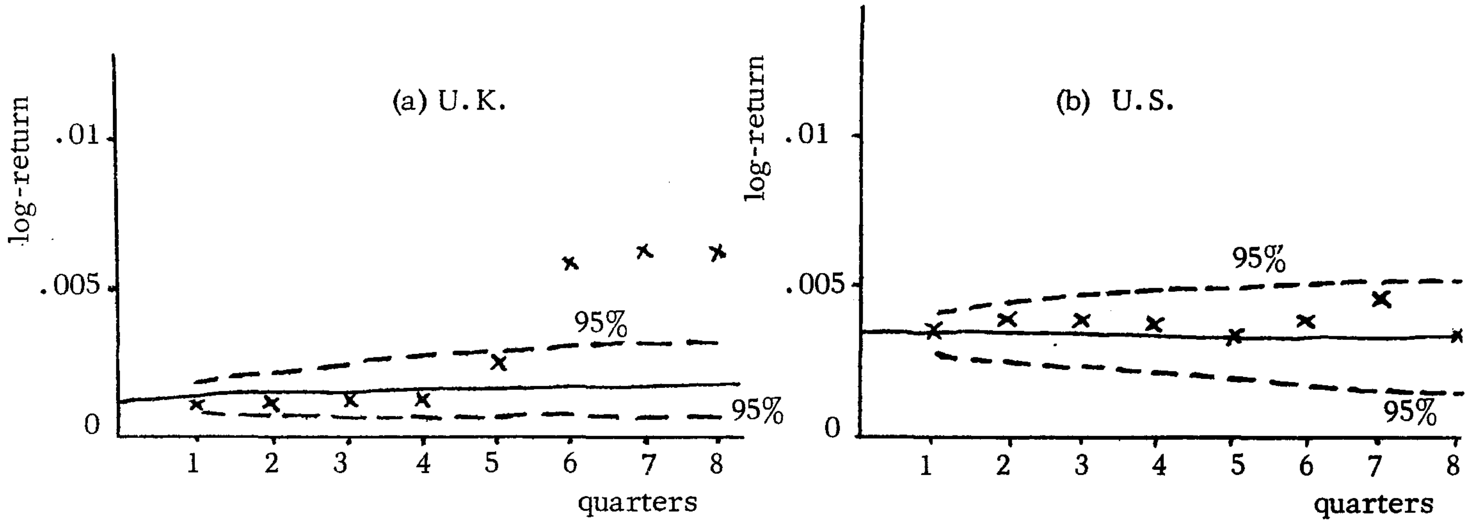
(b) U.S.



GRAPH II (iii) & (iv)

95% confidence intervals based on first order auto-regressions for predictions up to 8 quarters from end of period.
Quarterly log-returns to Treasury Bills in MONEY terms.

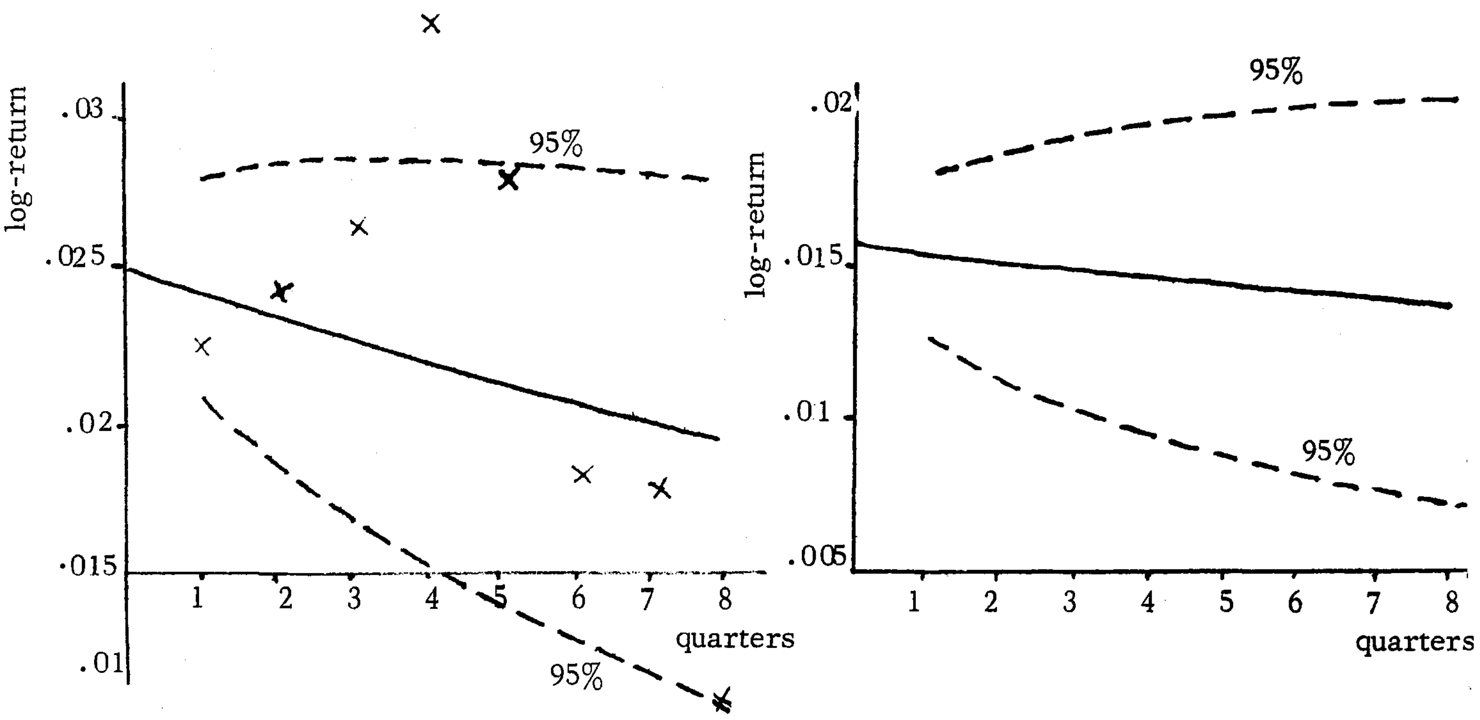
(iii) 1939-51



✗ actual values

(iv) 1951-75

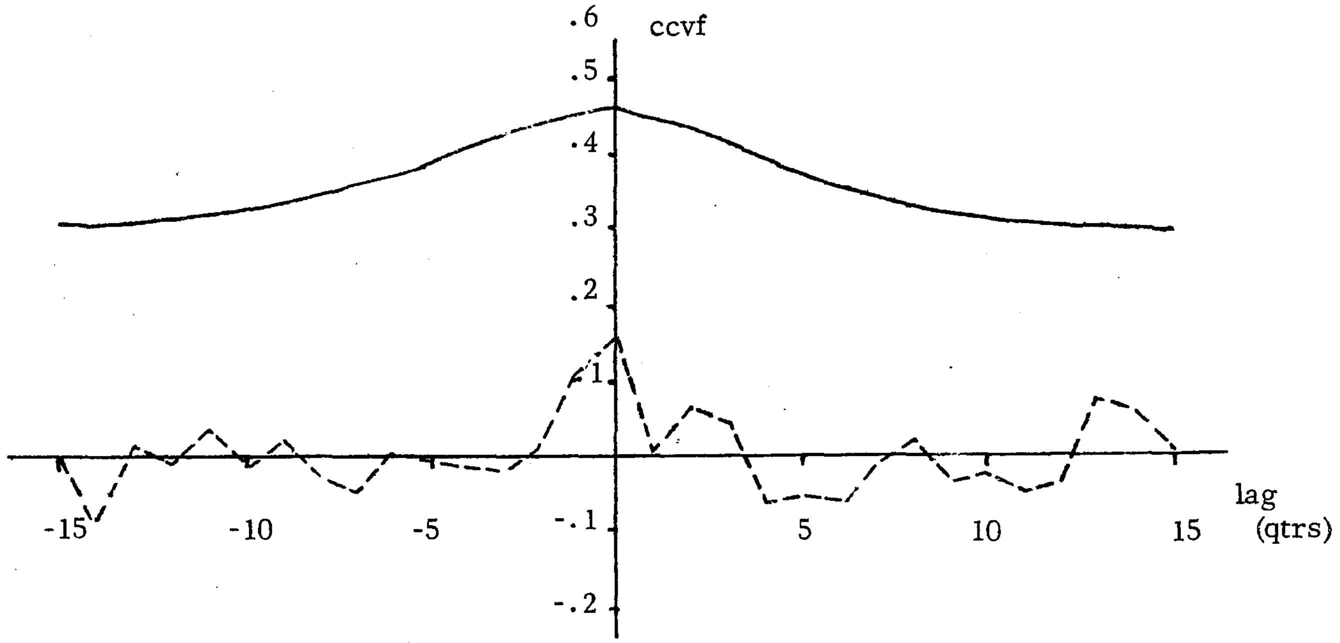
(a) U.K. (b) U.S.



GRAPH III (i) & (ii)

Cross-covariances of quarterly MONEY log-returns to U.K. and U.S. Treasury Bills. Cross-covariance function to lag 15 for basic series and first differences.

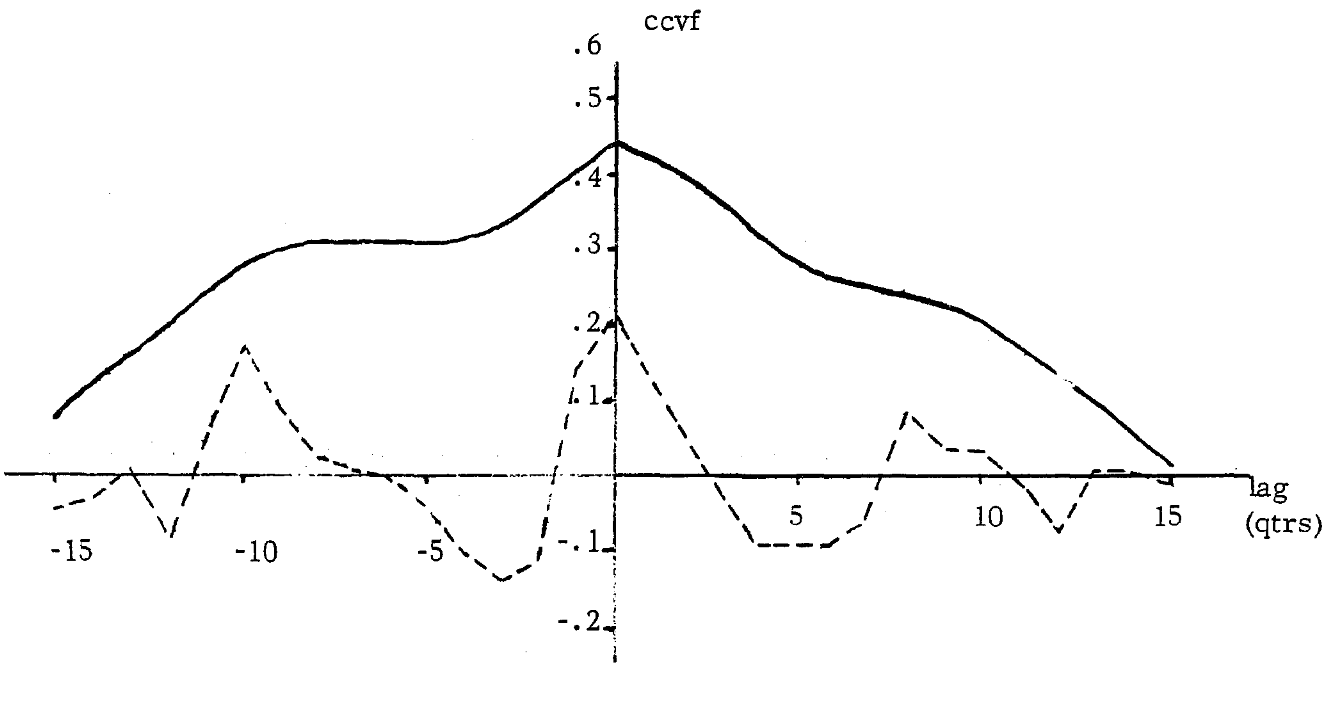
(i) 1926-75



(ii) 1926-39

——— basic series

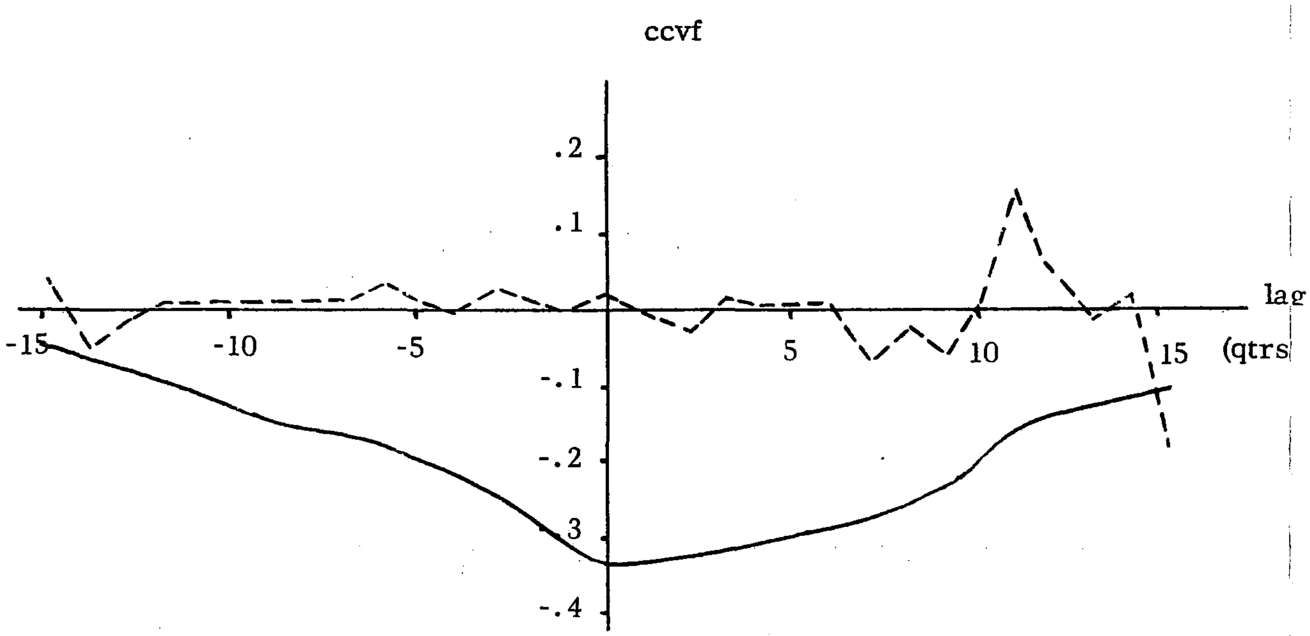
– – – – first differences



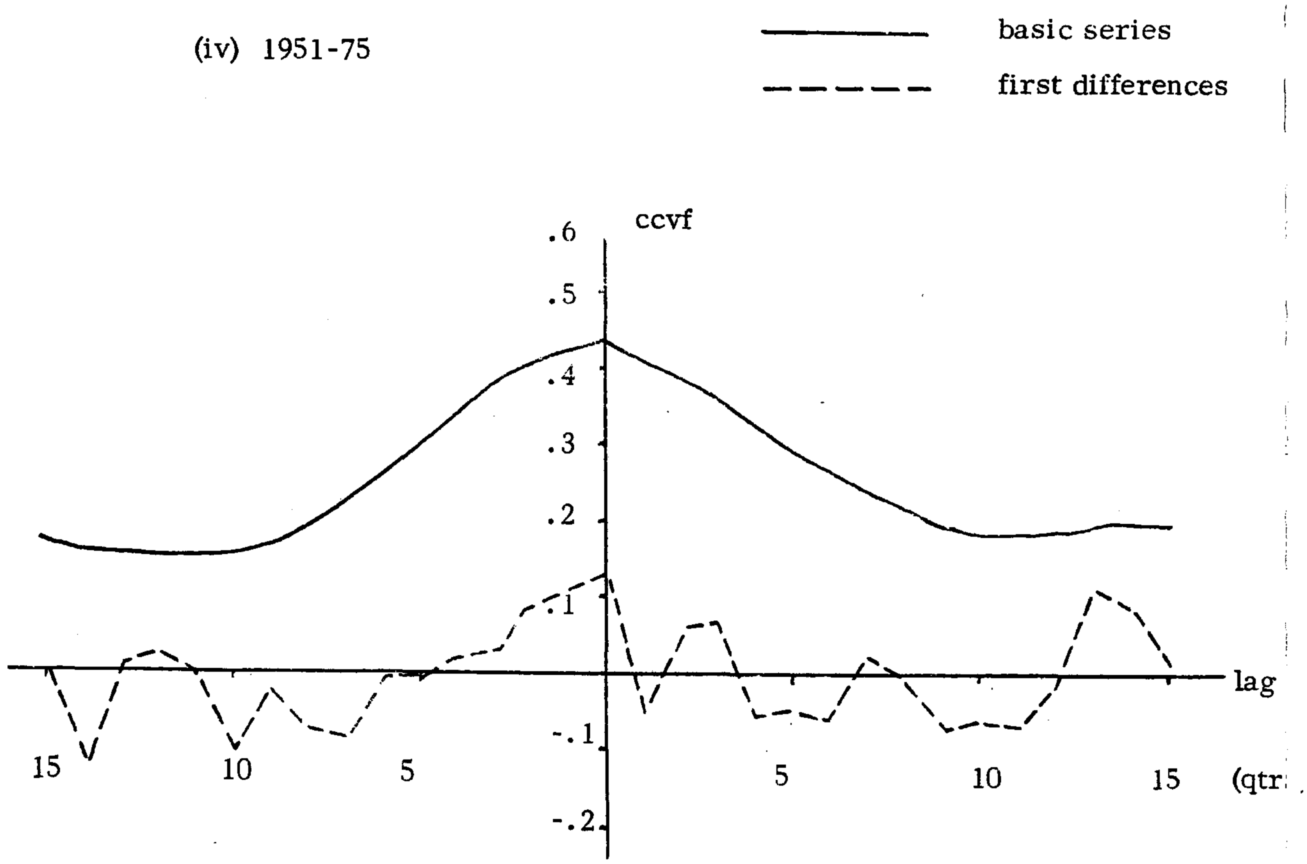
GRAPH III (iii) & (iv)

Cross-covariances of quarterly MONEY log-returns to U.K. and U.S. Treasury Bills. Cross-covariance function to lag 15 for basic series and first differences.

(iii) 1939-51



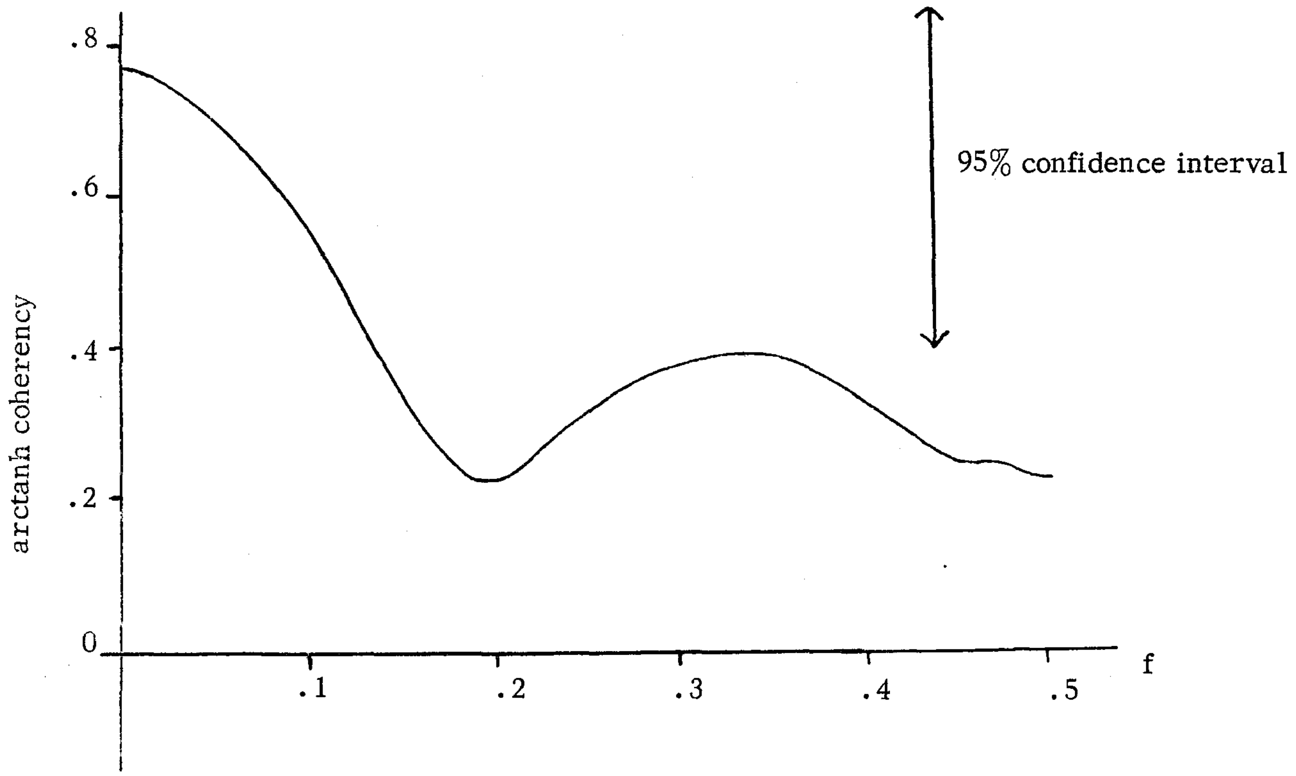
(iv) 1951-75



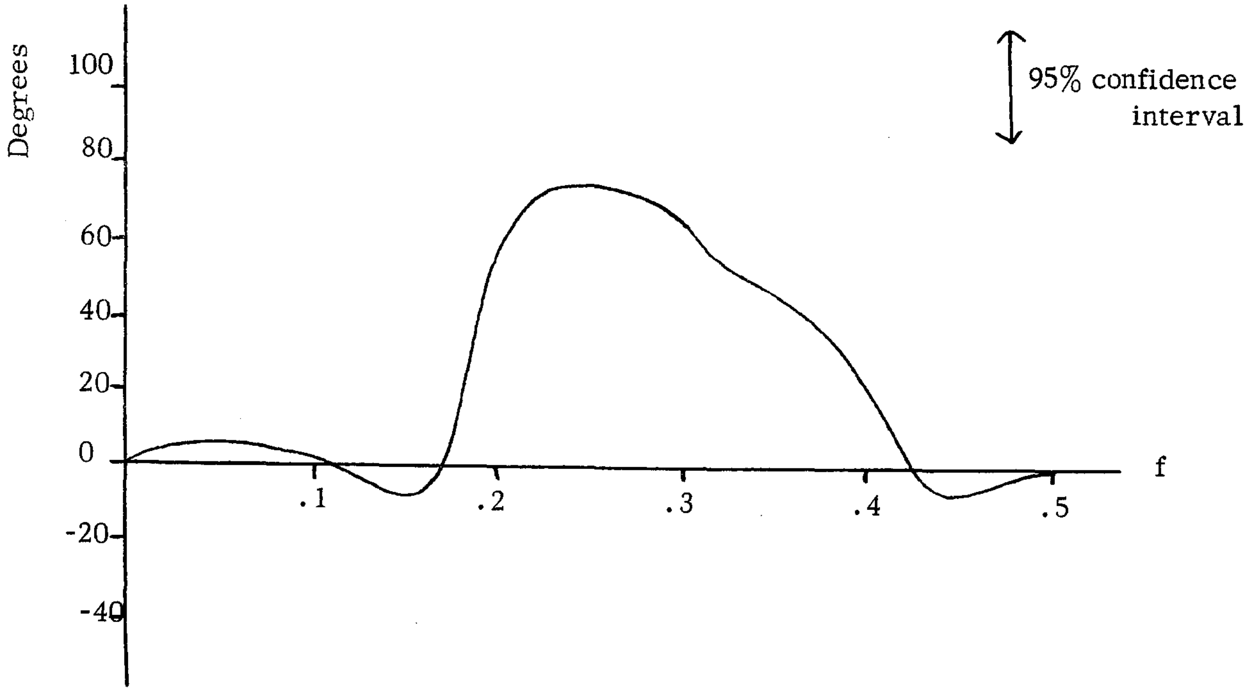
GRAPH IV

Cross-spectrum of first differences of quarterly MONEY log-returns to U.K. and U.S. Treasury Bills 1926-75. Parzen window, truncation point 10.

(a) Coherency spectrum



(b) Phase spectrum



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