

a sense of the vitality of the Indian villages and a wish that the author had given us a book on India and had foregone rather less profitable general sociological surveys, though his knowledge of countries outside India compares more than favourably with the knowledge of some noted European writers concerning peoples outside Europe. Mukerjee's book is inspired by the hope of a planned economy in which durability of relationship will once more increase, and intimate touch with the land and personal loyalties shall have their chance.

H. J. FLEURE.

A PROBLEM IN ECONOMETRICS

The Analysis of Economic Time Series

By Harold T. Davis. (Cowles Commission for Research in Economics, Monograph No. 6.) Pp. xv+620. (Bloomington, Ind.: The Principia Press, Inc.; London: Williams and Norgate, Ltd., 1941.) 5 dollars.

ECONOMETRICS may be described as the application of mathematics to statistics for the elucidation of economic forces and the measurement of their effects. Since these actions are dynamic the principal data are successive records in time, or time series, and in recent years many mathematical economists have made them the subject of intensive study. Mr. Harold T. Davis has brought together and criticized the theories and methods employed in this region, and illustrated them with a wealth of new material. His summary of his subject is (p. 59): "The problem of single time series is concerned with three things: first, the determination of a trend; second, the discovery and interpretation of cyclical movements in the residuals; third, the determination of the magnitude of the erratic element in the data. This preliminary problem, once solved, leads immediately into the more complex one of discovering valid interactions of one time series with another. Upon the discovery of such relationships the hope of establishing a firm science of economics inevitably rests. From them will come ultimately the power of prediction, which is the final test of any mature science."

The Trend. If there are causes of a permanent or organic nature that affect the whole series, we may expect that their effects can be expressed by mathematical formulæ, or by some smoothing process. Thus a straight line, parabola or polynomial, applied to the terms or their successive ratios, may give a general picture of the movement over a long period, and leave residuals the algebraic averages of which over short periods are zero. Continual growth, as of population or production, may require an exponential expression, usually with a damping term; that most used is the

'logistic', the equation of which is $\frac{dy}{dt} = \frac{y}{a} \left(1 - \frac{y}{L}\right)$

In the author's opinion such curves can be successful only if they are based on some a priori theory. Failing any successful choice of an equation, the alternative is the device of the moving average, or some other arithmetical method of smoothing.

Cyclical movements. The mathematician naturally turns to harmonic analysis to determine the existence of, and to measure, regular periodic movements, and Mr. Davis devotes a great deal of his book to the nature and use of the periodogram and to the periods indicated by it in a number of selected series. The periods most generally found are seasonal, which require no logical explanation, and the 'trade cycle' for the genesis of which many ingenious theories are

considered in Chapter 8. There is also a persistent 40-months cycle in stock exchange and allied series, for which no cause has been assigned. It is a weakness of harmonic analysis as applied to economic series, that it can reveal only waves of uniform length, whereas the length of the trade cycle has perhaps varied from seven to eleven years during the past hundred years; if the effect of a nine-year period is removed, new and irregular residuals are introduced.

Residuals. The effect of the removal of the trend and cyclical movements is measured by the reduction of the 'variance' of the series. Thus, if s is the original standard deviation, we may write

$$s^2 = s_t^2 + s_h^2 + s_v^2,$$

where s_t, s_h, s_v are the standard deviations attributable to the trend, the harmonics and the residuals respectively. The relative sizes of these squares are taken as measuring the 'energy' of the three factors. The residuals, though free from systematic movements, may nevertheless have some structure; as for example, an increase may be followed by a further increase more often than by a decrease, and autocorrelation (correlation between one term and a later term) may be present. The author devotes an interesting chapter to the study of random series, with reference also to the possibility of forecasting movements when there is autocorrelation. But perhaps the main importance of s_v is as a measurement of the magnitude of the variation that may be expected from unassignable causes. The behaviour of a series as regards trend, cycle and nature of the residual is clearly an important subject of observation; but study of the relationship between two or more series is more fundamental for econometrics. For this purpose the correlation of the residuals, x_t and y_{t+s} , from two series is computed for various values of s , the number of terms lagged (s zero is itself important). The usual process, followed by Mr. Davis, is to compute the correlation coefficient for several values of s , and select the maximum; thus we have the following coefficients between stock-market quotations (the Dow-Jones averages) and pig-iron production (s in months)

s	r	s	r	s	r
- 12	- 0.182	- 3	0.166	+ 6	0.563
- 9	- 0.130	0	0.515	+ 9	0.369
- 6	- 0.036	+ 3	0.684	+ 12	0.130

From this, Mr. Davis's conclusion (p. 105) is: "This means that pig-iron production follows by three months the industrial averages", and later (p. 235), this becomes, "It was established that pig-iron production moves three months after the stock price averages". Surely this is too strong a statement; the correlation coefficient is only an average, only one of several possible averages; a relationship is no doubt shown, but action based on it would by no means always be successful.

Space does not permit even allusion to all of the many topics discussed, or criticism of the less mathematical chapters on wealth and other economic subjects, which are less guarded than the purely analytical studies. Parts of the book are very difficult reading, and only possible to a qualified mathematician, who should be prepared to refer to the originals of studies where results are only summarized. The whole is a very valuable account of the work that has already been done in this important region, while at the same time many indications are given of promising lines of approach towards the basing of some parts of economic theory on a quantitative basis. A. L. BOWLEY.