STATISTICS FOR ECONOMIC DEVELOPMENT

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Friends,

I am glad to have this opportunity of being with you today. I consider it a great honour to follow on the lecture given by Sir Ronald Fisher on "Statistics for the Acquisition of Knowledge of the Real World". I shall make certain observations which may perhaps be considered to be supplementary or complimentary to some of his observations this afternoon.

I have selected the topic, "Statistics for Economic Development". The title I think indicates the point which I shall be continually stressing, namely, that statistics has two aspects, one, which is utilitarian or economic; and the other, which is scientific, or as Sir Ronald has called it, aesthetic, in the sense of giving intellectual satisfaction.

The utilitarian or economic phase of statistics had its origin in time immemorial, from the colletion of information relating to social and economic conditions to help in making policy and administrative decisions. The English word "statistics" is indeed connected with statecraft, the business of the State or of Government or Administration.

In every country whenever there has been an upsurge of social

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1) A series of Bibliographical References are given in an Appendix; the reference number 1, 2, 3 etc. correspond to the serial number of these Bibliographical References.

and economic and political activities, there has also been a rapid advance of statistics. In my own country, in India, during a period of great national prosperity in the 3 rd or the 4 th century B. C., in the time of the Emperor Asoka, we find a most elaborate system of statistics of which an account is given in the *Arthasastra* of *Kautilya*[2]. Nearly two thousand years later in the 16 th century, in the time of the great Muslim Emperor Akbar, we find again a very elaborate system of statistics in the comprehensive survey of the country called *Ain-i-Akbari*[3]. In the British period in India, at the time of renewed countrywide economic activities, there were great advances in statistics of which one striking example was the survey of East India by Francis Buchanan in the first decade of the 19 th century.[4] Again, during the last ten or twelve years since independence, there has been a great deal of expansion of statistical activities in India.

I have given a few examples from my own country to illustrate the point that the advance of statistics has accompanied or has been an essential factor in social and economic progress. This is equally true for other countries[5].

The concept of random events emerged much later, as Sir Ronald Fisher has pointed out today. It came in connexion with games of chance, for example, in rules for the equitable division of stakes which I believe were given by Cardan and by Galileo in the 16 th century. The theory of 'mathematical probability' in fact was developed in connexion with problems of games of chance; this, I venture to suggest, had both a motivation which is utilitarian or economic (in estimating the chance of winning a stake) and another, which in Sir Ronald's sense, is aesthetic and which may perhaps be also called mathematical or logical.

This dual aspect of motivation in statistics led, later on, to a dichotomy in the organization of teaching and research in statistics, one portion being included under 'economics' and the other portion under 'pure mathematics'. This has had some unfortunate consequences. The attempt to teach and treat statistics as a branch of pure mathematics has led to sterile exercises in abstract mathematical symbols which have no relation to the real world.

This point deserves a little elaboration. I shall accept Bertrand Russell's description of pure mathematics, as all reasoning of the form: "If P, then Q", with the essential condition that one must not enquire

what P and Q are, or whether they are real. And yet, my friends, I think you will not dispute that statistics is very much concerned with observations, classification, measurement, and experimentation in the world of physical reality, in all the sciences, both natural and social. Statistics in fact, has to deal with the raw data of all the sciences, natural and social, and therefore must deal with the word of reality. I submit, statistics cannot possibly be considered to be a branch of pure mathematics (in the sense of "if P, then Q").

Also, we do know that the statistical approach has had a tremendous impact on the progress of science. Let me give some examples. Consider the concept of a normal distribution of statistical variates. It had its origin in the mathematical theory of games of chance, but it also supplied the foundation for the theory of errors of observations in the hands of Gauss and other famous scientists. This still remains the basic method for the adjustment of physical observations in all the sciences.

Again, the same normal distribution was applied with great success in the kinetic theory of gases, in studying the distribution of velocities of molecules in three dimensions, which led to spectacular results in physics. I may also mention the development of "statistical mechanics" with the emergence of the concept of entropy linked with probabilty and the level of randomness of distribution of physical states.

In this way the great second law of thermodynamics has a statistical foundation. And it is this second law alone, among the so-called laws of physics developed in the 19th century or even during the last half a century, which still survives in its original form. Newton's laws of gravitation had to be modified, even Einstein's theories are being modified; but the second law still stands, perhaps, may I venture to suggest, because of its essentially statistical nature?

Sir Ronald has referred to the need of some kind of axiom of ignorance in statistics. We find this also in physics in the principle of uncertainty enunciated by Heisenberg.

I shall not try to give further examples from physics. In biology I should like to mention that it was Sir Francis Galton who first got the concept of statistical correlation between biological variates such as the height of fathers and the height of sons. Now, this concept was entirely new in a physical sense, although much earlier the great Gauss

himself had dealt with the mathematics of correlation in the form of the cross product of errors of observation without, however, being aware of the physical notion of correlation[6]. Thus even Gauss missed the statistical concept of correlation although he had handled its pure mathematics. I think this supports the point which I made earlier, namely, that statistics deals with the world of reality while mathematics is concerned with the world of abstraction in which the question of physical reality is entirely meaningless.

However, mathematics has to be used continually in dealing with the real word, but as a tool. There is a wide gulf between the "world of reality" and the "world of pure mathematics", and Sir Ronald Fisher has shown the way to bridge this gulf with the help of the concept of "fiducial probability."

Perhaps I may give a very simple example. Let us consider the tossing of a coin. If it can be assumed axiomatically that the coin is unbiassed then, of course, statements about results of repeated tossings of the coin would be a part of deductive mathematics, in which the concept of "repeated sampling" would be of crucial importance.

But, in the world of reality when we have a real coin, the axiom is not written on it that it is unbiassed. It now becomes a problem of statistics to find out, from an observed series of observations of tossings of the coin, whether the coin is unbiassed; or, if it has a bias, to estimate the bias. This is a problem of statistics, that is, of inductive inference and not of deductive mathematics.

On this view, statistics must be treated as an applied science or a technology with a dual motivation, one utilitarian and economic and the other, I am using the convenient word aesthetic, in the sense of something which gives intellectual satisfaction.

On this view, statistics must always have a purpose, either to help in making policy and administrative decisions in economic and social affairs or in making inductive inferences in all the sciences, both natural and social. The statistical method now emerges as a technique for the collection of data and for extracting information from such data for a given purpose with maximum efficiency, that is, at minimum cost.

Let us look to the last three or four decades of statistics itself. Sir Ronald Fisher introduced the concept of design of experiments and

the analysis of variance in order to improve the efficiency and useful-
ness of agricultural field trials[7]. We see here the dual motivation, one
utilitarian and economic and the other aesthetic, for example, in the
beautiful concept of equi-partition of variance which is the basis of the
analysis of variance. The normal distribution of statistical variates had
supplied the basic concept of distribution of velocities of molecules in
the kinetic theory of gases which reached its highest generalization in
the principle of equal distribution of energy among the different modes
of motion or different degrees of freedom of the gas particles. I venture
to suggest that perhaps this theorem again, in its turn, supplied to sta-
tistics the basic principle of equi-partition of variance in the analysis of
variance.

It is about thirtyfive years ago or a little more, in the early 1920's,
that the concept of design of experiments was introduced. At about the
same time, Walter A. Shewhart developed the method of SQC or Sta-
tistical Quality Control, which he very accurately described in his classic
work as the *Economic Control of the Quality of Manufactured Products*[8].
It is a beautiful method with which we are all familiar; it has something
which satisfied scientific or aesthetic values, and yet it is basically
motivated by utilitarian or economic considerations.

All these methods involved the application and use of a good deal
of mathematics. It is very proper that we should use mathematics to
solve practical problems. We cannot have too much of mathematics for
statistics, but as a tool, not as a master. Statistics must have a purpose
and mathematics must serve this purpose.

I may now turn to the field of economics. It was unfortunate in
many ways that one part of statistics was included under pure econo-
mics, and got somewhat divorced from reality in a different way.

As time is short, I shall draw attention to only two points. Firstly,
among economists, there developed a somewhat naive faith in the infal-
libility of a so-called complete enumeration or census, with almost com-
plete lack of awareness of the fact that the collection of information
about economic and social coditions are as much, or I should say, even
more, subject to errors of ascertainment than observations in natural
sciences.

It is only during the last decade or two that there is increasing

recognition that censuses, even when they are called complete, are often incomplete and subject to errors. It is interesting to note that at the session of the International Statistical Institute which would be held in Tokyo next week there would be a special meeting to consider errors in censuses.

During the last twenty years, appreciable advances have also been made in the design of sample surveys based essentially on the fundamental principles of randomization, replication, and local control, first introduced in the Fisherian design of experiments. It has been shown that a properly conducted sample survey can supply information of sufficient accuracy for most practical purposes with greater speed and at a fraction of the cost of a so-called complete census. The accuracy of a sample survey is often greater with the added advantage that it is possible to calculate the margin of error on a logically valid basis. The method of interpenetrating net work of samples (IPNS), that is, two or more independent samples drawn with replacement, furnishes a very powerful tool for the study and comparison of both sampling and non-sampling errors[9].

In recent years there have been also great advances in operational research in which statistical methods have played an important role. In all these developments the motivation has been both utlitarian or economic and scientific or aesthetic. These two aspects, the economic and the scientific (or technological)aspects of statistics, like two sides of the same piece of paper, may perhaps be distinguished but cannot be separated.

There is continuing need of the use of mathematics in statistics; as I have already mentioned we cannot have too much of it. There is also continuing need of economic thinking in dealing with practical affairs. But I submit that statistics cannot any longer be dichotomized and included partly under pure mathematics and partly under pure economics, or wholly under one or the other.

The time has come to recognize statistics as an integrated discipline or technology in its own right. Teaching and research in statistics must therefore have an intimate relation to all the sciences, both natural and social. The teaching of statistics should be looked upon as something analogous to the teaching or training in engineering or medical sciences. I am glad to mention that, in India, in the Indian Statistical Institute, we hope to be able to introduce, very soon, full professional

courses leading to the degree of Bachelor of Statistics or Master of Statistics; the degree of Bachelor of Statistics being exactly comparable to a professional degree in engineering or medicine*.

I should now like to consider some of the problems of economic development in India where the statistical approach, or perhaps you may call it, the approach of operational research with the help of statistics, was extremely useful.

I may start by saying that sophisticated economic theories, which may be appropriate for advanced countries, had acted for a long time as a formidable thought barrier to economic progress in India. India had started making steel in 1908. But in 1950, India was still making less than one million ton of steel per year, although India had a population of about 380 million, and had more iron ore of better quality than any other country of the world, more than USA plus USSR.

In 1950, Government had decided and announced that a plant to produce a second million ton of steel (a second and only a second million ton of steel) would be installed but this was immediately followed by a survey of current demand by economists and expert committees who pointed out that India was making one million ton of steel and was importing about 300,000 tons while the additional demand could be for only 200,000 or 300,000 tons. That is, the total current demand was only 1 1/2 million tons; and the question was raised would it not be foolish to produce two million tons of steel? This was the subject of a beautiful exercise in economic theory which led to the proposal for a new factory for a second million ton steel being dropped from the First Five Year Plan of India. We were assured that this decision was in accordance with the most refined economic theory, and that we should not produce two million tons of steel but purchase steel from abroad. This has cost India hundreds of million rupees subsequently for the import of steel.

Looking up the statistics of UK, USA, and USSR, I found that they were producing a great deal more steel than India, although the population in all these countries was much less, even the population of the three countries put together was only somewhat greater than that

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* These courses were inaugurated in Calcutta on 16 August 1960.

of India. They were not only producing a great deal more but they were going on increasing the production of steel. Japan also was doing the same thing; and I thought then all of them must be either bigger fools than my countrymen or there was something wrong in our own outlook.

Economic theory was originally developed for advanced countries; and is appropriate for such countries, because short range decisions can be effective in highly developed countries. If the demand goes up but there is a shortage of supply, the production process would get into operation very quickly. In an advanced country, if there is an export subsidy, motor cars would roll out of the factory in large numbers. But in a country which has no factories, even if you! give a billion dollars not a single motor car can physically come out until the tools of production and the technical personnel become available.

The heart of the problem of an underdeveloped country is this factor of time. It takes time to acquire the ability to manufacture goods. It is necessary to establish factories. It is necesssary to have the scientific and technical personnel, and this takes time. Therefore, the problem of economic development has to be viewed over a long span of time. One must see where we want to go and how we should go there. And, in trying to do this, it is essential, continually, to use quantitative information, that is, statistics.

I may perhaps give an example to illustrate this point. In India, population may be increasing, we are not very sure, but it is quite possible that population is now increasing at the rate of seven million persons per year. Now, roughly, we need one ton of foodgrains for seven persons. On this basis, the additional foodgrainsl required for seven million persons would be one million ton per year, in five years this would come to 15 million tons. If we have to import this, at the world price of about 90 dollars per ton, we would have to spend about 1300 or 1400 million dollars in foreign currency in five years.

Instead of foodgrains, we can import fertilizers in the form of, say, ammonium sulphate. In India we have found that one ton of ammonium sulphate would usually give two or a little more than two tons of foodgrains; to grow 15 million tons of foodgrains we would require roughly half or say 7.5 million tons of ammonium sulphate. At a price of 50 dollars per ton, the totol cost would be less than 400 million dollars in

five years. This would call for long range planning because orders have to be placed in advance for the fertilizers and arrangements for distribution have also to be made in advance. But, if we can look ahead and plan for the future, then the savings in foreign currency would come to one thousand million dollars in five years.

We can look further ahead. Instead of importing fertilizers, we can manufacture fertilizers in India. The cost of installing a factory to produce a million ton of fertilizer per year, we find from our own experience, would be about 150 million dollars; and if we install five such factories in five years, the cost would come to 750 million dollars in five years. But a good part of this amount would be wages of domestic labour, and cost of domestic material ; the foreign exchange required would be about 50 or 60 million dollars for each factory, or say 300 million dollars in all in five years which would be much lese than cost of imported fertilizers. Also, once these factories are established, they would continue to produce for a very long time beyond the five year plan. But we must now plan eight or ten years ahead, because the first factory would take three or four years to start production, and so on for each of the factories which are to be erected in successive years.

We can go a step further and establish a factory to make the machinery to install new fertilizer factories, and the cost of foreign exchange may be only fifty or sixty millon dollars, once for all. If we do this then the machine building factory would go on producing machinery to install a new fertilizer factory every year. In this way, only fifty or sixty million dollars of foreign currency can serve exactly the same purpose as 300 or 400 million or even 1400 million dollars in five years. This would, however, depend entirely on our ability to plan fifteen years ahead. I have given a simple example of the kind of thinking which is needed in India. In Japan, you are already familiar with this.

I should like quickly to sum up. In India we are now looking on the problem of economic development as having a five fold structure, with five aspects or five phases. It is easy to establish consumer goods in four or five years. We can import the machinery, work the factory with a diesel engine, and produce the goods. This does not take very long. The second phase or aspect consists of the large scale production

of elecricity, development of modern communications, mining, and light engineering. This would take eight or ten years to make an impact. The third aspect is of a more long term nature with the large scale production of steel, metals, and heavy machinery which would take, at least, fifteen years. The fourth aspect is the training of scientific and technical personnel in adequate numbers ; this would require planning twenty years ahead. And the most basic and fundamental is the organization of scientific research which would take one whole generation or more.

Rapid progress would be possible only if we start, as soon as possible, laying the foundations of scientific and technological research; the training of scientific and technical personnel; economy building up of the steel and heavy machines industries; and proceeding with electricity, communications, and consumers goods etc., as much as possible out of domestic resources. This is the only way to make the economy self sustaining in the course of a single generation.

The problem of planning then, as we see it in India, is to have a time horizon of ten, fifteen, or twenty five years. The basic principle is that the right quantity of goods must be made available at the right moment, either for consumption or for investment, and the right number of sceintific and technical personnel must also be made available to produce and utilize the same at the right moment.

Whatever targets we set up, there must be internal consistency, or balance, between requirements and supply of all important commodities and of labour and scientific manpower ; and such balances must be achieved not only over short periods but also over a time horizon of five, ten, fifteen or twenty five years.

This has given a new challenge to statistics, or, if you like, to operational research with the help of statistics, firstly, for the continuing collection of essential information required to prepare the plans for economic development, not in a rigid way, but retaining a good deal of flexibility, and with a time-horizon, as I have mentioned, of five, ten, or twenty years or more ; secondly, of assessing the progress of the plan; and thirdly, of arranging a feed back of the information on the assessment of plan implementation so that rolling adjustments can be made or drastic changes can be introduced in the plan in the light of experience[10]. This is what I mean by "statistics for economic development",

at a national level.

But I should like to refer briefly, to something even deeper or more comprehensive. A big country like USA, USSR or China can bring about economic develoment almost on the basis of the resources available within the country itself, without much concern about foreign trade, although for every country, however big, foreign trade can be of great help in economic progress. For a smaller country like India, it is necessary to give greater attention to the development of foreign trade. The importance of foreign trade would be still greater for countries which are smaller than India.

The long range planning of international trade cannot, however, be done by any country, however big, by itself. There is an urgent need of long range planning at the international level. I am convinced that this is a problem of supreme importance for the future of the world.

One of the important factors in international tensions is the very existence of under-developed countries. It is my conviction that a rapid transformation of the under-developed countries is an essential condition for an enduring and world-wide peace[11].

Statistics and operational research are important tools for this purpose. The work has scarcely started. It would require a long educative process to prepare our mind for the shape of the one world which we must achieve if human civilization or the human species is to survive.

With the progress of science and technology, ancient barriers of space and time are rapidly vanishing. Whether we welcome it or resist it, the world is coming closer and becoming more integrated. International cooperation in economic development of the world, *as a whole*, is inescapable to save the human species from annihilation. I am convinced, therefore, that there would be a continuing and increasing demand for statistics and also for operational research to bring in the new age of peace, prosperity, and progress of the world, *as a whole*. International cooperation at a scientific and technical level is the first step in this direction.

I, therefore, thank you for having given me the opportunity to give this lecture.

BIBLIOGRAPHICAL REFERENCES

Note (1)

Harald Westergaard noted : "Etymologists may find the root of the word 'statistics' in the Italian word *stato*, and a statista would thus be a man who had to do with the affairs of the State. "Statistics" would consequently mean a collection of facts which might be of interest to a statesman, whether they were given in the form of numerical observations or not." (Contributions to the History of Statistics, London, 1932, p. 2).

Note (2)

The Arthasatra of Kautilya[1] claims to date from the period 321-296 B. C., that is, the Maurya period which reached its peak in the time of the great Asoka. The detailed description of contemporary industrial and commercial practice points to a highly developed statistical system. In Chapter xxxv (p. 158), instructions are given about the classification of villages. Specific directions are also given for a detailed census of land and field (p. 158).

"It is the duty of Gopa, village accountant, to attend to the accounts of five or ten villages, as ordered by the Collector-General.

"By setting up boundaries to villages, by numbering plots of grounds as cultivated, uncultivated, plains, wet lands, gardens, vegetable gardens, fences (vata), forests, altars, temples of gods, irrigation works, cremation grounds, feeding houses (sattra), places where water is freely supplied to travellers (prapa), places of pilgrimage, pasture grounds and roads, and thereby fixing the boundaries of various villages, of fields, of forests and of roads, he shall register gifts, sales, charities, and remission of taxes regarding fields.

"Also having numbered the houses as tax-paying or non-taxpaying, he shall not only register the total number of the inhabitants of all the four castes in each village, but also keep an account of the exact number of cultivators, cowherds, merchants, artisans, labourers, slaves, and biped and quadruped animals, fixing at the same time the amount of gold, free labour, toll, and fines that can be collected from it (each house)."

In Chapter xxxvi (p. 160) similar instructions are given about the statistics of the Capital City (p. 160) :

"A Gopa shall keep the accounts of ten households, twenty households, or forty households. He shall not only know the caste, gotra, the name, and occupation of both men and women in those households, but also ascertain their

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1. Translated by Dr. R. Shamasastry, 3 rd edition, Wesleyan Mission Press, Mysore, 1929.

income and expenditure."

One striking feature in the Arthasastra is the emphasis on the need of checking and verification by independent agents working in secret without the knowledge of the original enumerators (Chapter xxxv, p. 159) :

"Spies, under the disguise of householders (grhapatika, cultivators), who shall be deputed by the collector-general for espionage, shall ascertain the validity of the accounts (of the village and district officers) regarding the fields, houses and families of each village—the area and output of produce regarding fields, right of ownership and remission of taxes with regard to houses, and the caste and profession regarding families."

"They shall also ascertain the total number of men and beasts (janghagra) as well as the amount of income and expenditure of each family".

Detailed instructions are given in other places about the standards of weights and measures, measurement of space and time; national accounts; and the duties of Government Superintendent in charge of multifarious deparments such as the treasury ; mining operations and manufacture; commerce; forest produce; tolls; weaving; agriculture; livestock ; armoury ; infantry ; chariots ; etc. etc. Specific duties are in fact described for no less than 25 different Superintendents by designation.

Note (3)

The *Ain-i-Akbari*[2] gives a detailed administrative and statstical account of India as it was about 1590 A. D. under the great Emperor Akbar. In Ain xi (pp. 62-63), for example, is given a detailed account of the classification of land based on the yield of crops. A distinction is made between yields in the two seasons 'spring harvest', and 'autumn harvest'. Furthermore, 'yields are given for three different grades of soil, "best, middling, and worst," and the average of the three grades is caculated as "the medium product of a bigha". For the spring harvest, figures are given for from 10 to 20 crops ; and for the autumn harvest, for 20 or 30 crops.

Ain-i-Akbari gives the area, revenue valuation, strength of army, and other details for about 15 subahs (provinces) comprising over 120 sarkars (districts) and over 3000 mahals (townships and sub-divisions) extending from Assam and Arakan to Afganistan; the average yield of 31 crops for 3 different classes of land; annual records of rates based on the yield and price of 50 crops in 7 subahs (provinces) extending over 19 years (1560—51 to 1578—79 A. D.) ; daily wages of men employed in the army and the navy; labourers of all kinds ; workers in stables, etc.; average prices of 44 kinds of grains and cereals ; 38 vegetables,

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2. English translation by H. Blockmann (Vol. I, 1873) and H. S. Jarrett (Vol. II, Vol. III, 1894) published by the Asiatic Society of Bengal.

21 meats and games, 8 milk psoduces, oils, and sugars, 16 spices, '34 pickles, 92 fruits, 34 perfumes, 24 brocades, 39 silk, 30 cotton cloths, 26 woollen stuffs, 77 weapons and accessories, 12 falcons, elephants, horses, camels, bulls and cows, deer, precious stones, 30 building materials; weights of 72 kinds of wood, etc.

Note (4)

In the first decade of the 19 th century, when the Britfsh regime in India was rapidly expanding and growing in stregth, a comprehensive survey of Eastern India was undertaken by Dr. Francis Buchanan under orders of the Board of Directors of the Hon'ble East India Company dated 7 th January 1807. The Survey was pursued by Dr. Francis Buchanan for 7 years when only a portion of the territories under the Government of Bengal Presidency was investigated. The material was sent to London in 1816, and Montgomery Martin published in 1838 a selection in three volumes comprising over 2400 closely printed pages.

The book still makes fascinating reading. Information is given, for example, about the number and proportion of families in different consumptjon levels such as, families that use milk daily; that use milk in the chief season; that use milk on holidays; that use milk seldom. In the same way, information is given by categories of families according to the use of different kinds of dress, bedsheets, blankets; the consumption of meat, fish, milk vegetables, oil, salt, rice, wheat, sweetmeats etc; different kinds of fuel and oil; different types of conveyance; state of education; etc.

The utilization of land is shown by giving the areas separately for a large number of categories such as houses, trees, kitchen gardens, vegetables, etc. As regards agriculture, separate acreage figures are given for the area under 200 different combination of crops, single and mixed. A general table is given for the value of the produce in the case of commercial crops; and both quantity and value in the case of cereals and food crops together with estimates of the marketable surplus; and number of livestock under different categories together with the annual production of milk with prices.

There are tables showing the proportion of rent paid by different sections of the population; the economic position of farmers with proportion of indebted families; and the number of artisans classified into 108 different categories. The manufacture of cotton cloth receives special attention; and detailed estimates are given of the number of weavers; looms; monthly production; earnings and profit for different kinds of cloth. Finally, there are tables of exports and imports (for the region surrounding Patna city) in which separate estimates are given for 140 different categories of commodities.

Note (5)

The practice of descriptive statistics gradually developed, with ups and

downs, in all countries of the world. Aristotle's work contained references to information about no less than 158 states. Besides public administration, statistics was in much use in commerce. Certain forms of commercial insurance existed in Babylonia, Greece and Rome, and in the middle ages in Italy. By the end of the 18th century, life insurance was becoming prevalent in Western Europe. All this led to important statistical studies. In 1662, for example, John Graunt used the register of deaths (Bills of Mortality) in London to investigate population trends. Since then, in Europe, the study of statistics has been closely associated with acturial science. On the break-up of the feudal system, the expanding national economies required increasing use of factual information for the formulation of financial, military and political policies. This process has continued down to the present times.

Note (6)

In 1877 when Sir Francis Galton measured the size of sweet peas in his studies of heredity, he found a "regression" of the size of the daughter seed, compared to the size of the mother seed, towards the general mean. He found the same thing again in connexion with his observations on the height of fathers and sons. These studies led to the development of the theory of regression and correlation by Karl Pearson and others. It is worth nothing that Gauss himself had used the product term in his investigations on the theory of errors, but had failed to reach the concept of correlation. The French astronomer Bravais (1811—63) worked on what is in essence the mathematics of correlation, as early as 1848. The concept of regression and correlation, however, did not emerge until 40 years later; and this also, only under the stimulus of the study of biological variations. This is a corroboration of the view that statistics is essentially an applied science and not a branch of mathematics.

Note (7)

R. A. Fisher's work on the design of experiments had its origin in his studies on agricultural crops at the Rothamsted Agricultural Station, Harpenden, Herts, from about 1920. He published two papers on "Studies in Crop Variation" in the Journal of Agricultural Science, xi, 107—135 (1921) and xiii, 311—320 (1923), followed by a paper on "the Arrangement of Field Experiments" in the Journal of the Ministry of Agriculture, xxxiii, 503—573 (1926). A full account was given later in the book on "Design of Experiments" (Oliver and Boyd Ltd., London, 1935).

Note (8)

Walter A. Shewhart started his work on Statistical Quality Control in the early twenties in the Bell Laboratories, U. S. A; submitted his report on the subject to admistration in 1924; and later published two books on the subject,

namely, "Economic Control of the Quality of Manufactured Products" (McMillan & Co, New York and London, 1931), and "Statistical Methods from the View Point of Quality Control" (Graduate School, Department of Agriculture, Washington, D. C., 1939).

Note (9)

Examples of the use of interpenetrating network of samples is given in P. C. Mahalanobis's paper on "Recent Experiments in Statistical Sampling in the Indian Statistical Institute" published in the Journal of the Royal Statistical Society, Vol. 109, Part 4, 1946; and some further account is given by D. B. Lahiri in the National Sample Survey Report No. 5 "On Some Aspects of the Development of the Sample Design" (Government of India, Ministry of Finance, March 1954).

Note (10)

Some information on planning in India can be found in P. C. Mahalanobis's papers on "The Approach of Operational Research to Planning in India" (*Sankhya*, the Indian Journal of Statistics, Vol. 16, pp 3—90, 1955); and "Science and National Planning" and "Next Steps in Planning" (the two Anniversary Addresses to the National Institute of Sciences of India in 1958 and 1959).

Note (11)

This point has been considered in greater detail by P. C. Mahalanobis in an article on "Industrialization of Underdeveloped Countries—a Means to Peace" in the Bulletin of the Atomic Scientists, Vol. XV, January 1959, pp. 12—17 and 46.