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SOME METHODS USED IN AGRICULTURAL ECONOMICS RESEARCH

G. F. WARREN
CORNELL UNIVERSITY, ITHACA, NEW YORK

A PROPER presentation of this subject would involve a complete treatise on the theory and practice of statistics, but I shall confine myself to a few general statements and then give more detail on a single method of collecting data.

The major way in which new truth has been discovered is by exact observation or measurement and subsequent reasoning as to causes, that is, by the scientific method.

One of the most common methods of scientific research which has been highly developed in the past fifty years has been the experimental method. A test is set up in which all the forces, except one are identical. By varying this one force, its influence is measured. The miscroscope and the chemist's test tube have become the symbols of scientific method.

In some fields such as heredity and economics, neither observation nor experiment are easily applied. It was not easy to have two wheat plants that were pure in all characters, and alike in all but one. Therefore, little progress was made in the study of heredity until Mendel applied the statistical method. Mendel's law would have been discovered by other methods in time, but the statistical method must be credited with the first great advance in the knowledge of heredity.

Economic problems are not easily solved by observation or by the experimental method. The experimental method is used to some extent in economics but it is not easy to set up two businesses or two societies that differ in one respect only. Observation is very untrustworthy because the resultant is due to so many forces that it is practically impossible to tell how much is due to each. For example, before scientific farm management work began, the opinion was commonly held that farms in America were too large, and too highly specialized.

Direct measurement and the experimental method are used in economics, but the statistical method will always be the method most generally applicable. We are usually dealing with resultants of many forces combined algebraically. The problem of determining the direction and influence of each force is a statistical

problem. Economic theorists have often arrived at a correct conclusion as to the direction in which forces operate, but since theory cannot evaluate the strength of various forces, its conclusions as to resultants have been very incorrect. The resultant has often been due primarily to what was considered to be a trivial force.

For statistical work, large numbers are often necessary and are always desirable. The more common methods of assembling economic data are by mail questionnaires, wholesale enumeration as is done by a census, detailed surveys, and record keeping.

The mail questionnaire is very cheap and very useful for many problems. It is particularly valuable in extending the area included in a study, supplementing more intensive survey or accounting work.

It is limited to questions that can be answered by those who receive the blank and must not include too many questions. The most serious limitation is the fact that those who reply are more intelligent, more progressive, more successful than the average. This applies to all reports by mail. The farmers who report on crop yields to the United States Department of Agriculture have larger and more successful farms than the average. They take up new crops and new methods more rapidly than the average.

In Niagara County, New York, those who reported on apples, by mail, had 34 per cent of their trees under 14 years of age. But a survey showed only 25 per cent to be under 14 years. Those who reported had 11 per cent of the McIntosh variety, but a survey showed that only 8 per cent were McIntosh. This is a new variety. The more progressive farmers on the best soils planted more young trees and also answered the questionnaire.

The census method is so well known that I will not comment on it other than to say that it deserves much more scientific study in order to prepare the blanks in a scientific manner and also needs to have the results checked by skilled field enumerators in sample areas in order to learn what the errors are.

Everyone who does any economic work uses census data. Some of its inaccuracies are overlooked. One of the most amusing uses of it is to disprove the accuracy of the survey method, that is, to use records obtained by an unskilled enumerator as against the records obtained by a skilled enumerator who is paid many times as much, and who has spent much more time on a record.

Accounting is a good example of the method of daily record

keeping. It has been used very extensively in Europe, and to a less extent in America. It is a careful, but expensive method of obtaining data. It assembles a vast amount of data on many subjects. Its chief limitations are the expense and the fact that it does not include all classes of farms. Also the farms change as a result of the work so that they often cease to represent the farms of their own original class. The cost accounts in the United States usually cost $100 to $300 per farm to assemble and close the accounts without making any tabulation of results. This may be compared with perhaps 10 cents for a mail questionnaire, about 50 cents for a census schedule, $1 for a very brief survey record, and $8 for the most elaborate survey record.

Another objection to accounting is that it usually seems to overwhelm the investigator in just keeping the work going so that the work often remains unpublished. The very wealth of detail becomes an objection if it prevents publication. Professor Larsen of Denmark seems to have been an exception to this rule as he has published many bulletins based on accounts and gets them out promptly. Minnesota has published a number of bulletins, but the cost per bulletin is certainly high. At Cornell, cost accounts have been kept for twenty-two years and three bulletins have been printed. Surveys of various kinds have been conducted for twenty-seven years and about sixty bulletins have been printed.

Another objection to cost accounting is that with the funds available, it usually does not give large enough numbers of records for statistical analysis. Suppose that it is desirable to sort farms by five factors such as soil type, type of farming, size of business, yield per acre, and yield per animal. If the farms are divided into two groups of size above and below the average size, and two groups for each other factor, there will be 32 groups, *i.e.* 2^5. If there are to be twenty farms in each group, this calls for 640 records. But since some of the factors are correlated, there will be less than 20 in some groups. Also, it is very desirable to see the results with very high or very low size, yields, and so forth. These extremes may not be run across in a smaller number of records. New mathematical methods such as coefficients of determination help, but large numbers are still needed.

The extent to which different methods of assembling data are used is shown by a classification of 548 bulletins, mostly for the United States (table 1).

Table 1. Methods Used in Collecting Data in 548 Bulletins on Agricultural Economics

Method	*Number of bulletins*	*Number of pages*	*Per cent of pages*
Survey	339	14,290	63
Accounting	81	3,419	15
Questionnaire	72	3,431	15
Census	33	1,204	5
Direct measurement and other methods	23	507	2
Total	548	22,851	100

The advantages of surveys are the wide range of adaptability, the economy, and the rapidity with which work can be done. Some of the problems studied by the survey method are cost of production, cost of operation of trucks and tractors, cost of hauling milk, cost of operating milk plants, cost of operation of apple-shipping stations, cost of operation of feed stores, factors affecting profits in farming, farm tenure, cost of living and standard of living, movements of farm population, part-time farming, rural health, readjustments to be made on farms to meet new conditions, such as readjustments in the timothy hay regions now that the market has been destroyed by the automobile, classifications of land as between forestry and agriculture, and the like.

The chief objection to the survey method is that it is not sufficiently accurate. Let us first consider the degree of accuracy necessary. When the data are themselves extremely variable, accurate conclusions are best obtained by reasonably accurate measurements of many cases. For example, one could never learn the sizes of Devon cows by the most accurate measurement of any one cow. Weighing many cows to the nearest 50 pounds might do very well. Much of the economic data is of this class as to variability. Pearson has shown that the coefficient of variability in the field of economics is far greater than it is in most fields of study. For example, the coefficient of variability for the length of the forearm of man is 3.9, the age of farmers 25.2, the yield of oats per acre 34.0, the size of farms 42.5, farm receipts 56.2, farm expenses 59.1, farm income 75.2, labor income 190.7, entrepreneural profits which represent the profits above interest on capital and wages for farmer's time 456.4.

The mathematical formula for probable error is:

$$0.6745\sqrt{\frac{\sum D^2}{n(n-1)}}$$

The size of the answer may be reduced by increasing the number of observations (n), or by decreasing the difference between observations (D). Which of these methods is best depends on what one is doing. It would be as foolish to weigh the cow with great accuracy as to do chemical laboratory work with pound weights.

Some interesting comparisons of probable errors are shown in table 2. In the biological field, small numbers were used with greater care in measurement. By asking a large number of farmers (135) the amount received from the sale of milk, the actual error was reduced below most of the probable errors in animal husbandry or agronomy work.

By referring to the table, it will be seen that students were able to estimate the length of a pin with a low probable and actual error, but that the probable error was very large and the actual error very much larger when they tried to estimate the weight of a pin. The weight of a pin is not a question with which persons have had any previous experience. There is a tendency to overestimate the weight and it is impossible to even approximate accuracy by estimation. It is, however, possible to get the weight by estimating the weight of a considerable number of pins and count the number in the package.

Non-compensating errors of this sort are the ones to be watched at all times.

Many economic facts cannot be determined except by estimating. For example, agriculture has a very slow turnover, and the profits in a year's business are affected by the inventories at the beginning and end of the year. Any inventory is an estimate of values regardless of whether it comes from books or by what method it is taken. One who has not checked up the problem will be surprised at the large number of items which are obtained by exactly the same method whether cost accounts or survey methods are used. Values to be placed on farm-grown products used on the farm, values to be placed on unpaid labor, inventories, and so forth, must be matters of judgment.

During the last two years, interesting checks have been made at Cornell by wholly independent surveys, by two different col-

leges. A farm-management survey including farm receipts and expenses was made. This was followed by a home economics survey which accepted these figures and obtained all other items in

Table 2. Percentages of Probable Errors Calculated by Students in Agricultural Statistics from Bulletins and Other Data

	Percentage of probable error	*Per cent actual error*
Animal Husbandry:		
Feed per pound of gain, 4 Berkshire hogs	3.4	
Feed per pound of gain, 4 Tamworth hogs	6.0	
Feed per pound of gain, 10 hogs	1.5	
Feed per pound of gain, 4 steers	2.66	
Feed per pound of gain, 4 steers	7.1	
Cost of gain, 20 steers	3.0	
Feed per pound of gain, 8 calves	0.5	
Feed per pound of gain, 8 calves	2.0	
Cost of 1 pound gain, 7 calves	2.2	
Creaming ability of milk, 10 samples*	1.7	
Amount of water consumed daily per hen, 15 hens	5.9	
Agronomy:		
Average yield of corn in the United States, 20 years	1.6	
Average yield of wheat in New York, 10 years	2.7	
Protein content of wheat when treated with complete fertilizer, 12 plots	1.6	
Yield of selected potatoes, 5 plots	7.4	
Scab treatment of potatoes, 9 plots	11.0	
Length of growing season, Storrs, Connecticut, 28 years	1.1	
Soils:		
Extraction of soluble matter from soil, 6 tests	15.0	
Solids in drainage water, 3 tanks	6.1	
Nitrogen content of soil, 3 plots	49.0	
Per cent P_2O_5, 8 check plots, Ohio	0.2	
Yield, 8 check plots, Cornell University	2.0	
Yield, 8 check plots, Cornell University	5.6	
Yield, 8 check plots, Cornell University	4.5	
Yield, 12 check plots, Ohio	1.7	
Yield, 11 fertilizer plots	9.6	
Yield, 10 limed plots	1.8	
Per cent carbon in soil, 6 samples	0.8	
Other:		
Per cent that feed represents of total cost of milk production, 33 herds	1.9	
Labor income of 670 farms, Jefferson County, New York	2.5	
Guess on length of stick, 82 persons		2.0
Guess on length of stick, 37 students, 1915	0.2	2.5
Guess on length of same stick, 15 students, 1916	1.42	5.7
Guess on length of a piece of paper, 35 students, 1915	1.6	8.5
Guess on length of pin, 16 students, 1919	1.7	2.4
Guess on weight of pin, 15 students, 1919	20.8	942.0
Guess on weight of pin, 24 students, 1923	12.7	644.0
Guess on length of pin, 22 students, 1923	1.78	0.94
Estimated amount received from sale of milk, 135 farms, New Hampshire		0.7

* Depth of cream layer divided by per cent of fat.

the cost of living, other receipts, other expenses, savings, changes in bank balances, and so forth. Results for 193 farms showed combined total average receipts from all sources of $2,296, and combined average expenses and savings of $2,223, or an error of $73, or 3 per cent. Considerable error occurred on individual farms, but apparently the errors were mostly compensating errors.

In the following year, farm-management and home economics records were obtained from 297 farms, and total receipts from all sources were $4,301, and total expenses and savings, $4,467, or an error of $166, or 3.8 per cent. A considerable number of the records were seriously in error, but apparently errors were compensating.

In all survey work, the ability of the man in charge of the work, and the mental alertness of the enumerators are of first importance. For the complicated records, about ten out of every 100 university graduates are sufficiently alert and have sufficient ability with figures so that they make good enumerators.

There are many other tests of accuracy besides probable error. For example, if one determines the labor incomes for farmers with different crop yields, and if each group arranges itself in symmetrical order, that is, fits a reasonable mathematical curve, this in itself is some evidence.

It is often possible to check much of the information more carefully. For example, the receipts from milk are usually obtained from the buyer, or from statements which the farmer received from the buyer.

One soon learns the rate per bushel charged for threshing in the region. Crop yields and threshing expenses can thus be checked against each other. The number of animals on hand at the beginning of the year, plus births and purchases, less sales, deaths, and slaughter for home use, must equal the number on hand at the end of the year. Innumerable other checks as to reasonableness of answer can be made after one has become sufficiently familiar with the region and the work.

The method of asking questions has a great deal to do with the accuracy of the work. For example, if one wishes to obtain the number of bushels of wheat sold each month, he would first ask the total sales of wheat and then ask the months in which it was sold, rather than begin with the months.

The fatigue of the farmer has much to do with the accuracy of

the work. One should not ask more questions than are necessary. One should not ask, "Do you grow wheat?" and then ask the acreage. He should ask, "How many acres of wheat did you grow?"

So far as possible, the question should be asked so as to require no calculations by the farmer. It is ordinarily not desirable to ask the cost of the tires and gasoline for the truck, but ask them separately.

Since the confidence and interest of the farmer are important, one should begin with the questions which everybody can see and which are, therefore, in nowise confidential, such as crops, and should end with more delicate questions such as amount of indebtedness, interest paid, and the like.

The enumerator should know his blank so thoroughly that he can follow it with rapidity. He should be able to think fast enough to keep ahead of the farmer, so that the work may be done systematically.

It is important not to attempt too much, particularly if one has not had experience in the work.

Such data are of great importance as years go by. It is, therefore, important that maps be made of each region and that the location of each farm be indicated so that 50 or 1,000 years from now these same records may be checked up and found on the map. The present interest in the Doomsday book suggests how important more accurate data may become later on.

It is practically impossible to fill out a record satisfactorily while talking to the farmer. Records should, therefore, all be copied and checked immediately after they are taken. If records are taken in the daytime, they can be copied in the evening. With elaborate records, it is sometimes necessary to make an appointment with the farmer in the evening. Then, the records can be copied in the daytime.

In many pieces of research work, it is advantageous to combine various methods of obtaining information. For example, if one wishes to obtain economic facts on farm tractors, he would use all of the available census and other data on tractors made, sold, and the like, study all previous work on the subject, obtain data from cost accounts in so far as these are available, then follow with a survey for a large number of farms. After these are worked up, he would be ready to send out a mail questionnaire to expand the work on a much larger scale.

DISCUSSION OF DR. WARREN'S PAPER

Dr. Taylor—The most careful and accurate work in America is being done by the cost account method. The survey method introduced by Dr. Warren has spread all over the country, and to other countries too. In America he is looked upon as the father of scientific farm management. He put the quantitative method into farm analysis. Interpretation of the census statistics has been made possible, with much more detail, by this method initiated by Dr. Warren. The elements of the farm which can be got by the detailed cost account system all fit in together. Analysis makes one think and plan more accurately. The chief uses of the cost account system are for analysis of individual cases rather than for statistical purposes.

Sir Thomas Middleton—What number of investigators is most appropriate for a complete farm to farm investigation? What numbers are best for other special enterprises? How do you determine the number of investigators needed?

Dr. Warren—One person may work alone and often does, but where a considerable amount of work is to be done, and where the plan is already fairly well worked out, it is desirable to have a group of about 5 workers. The one who is in charge of the party checks all of the records and takes some records—at least enough to keep in touch with the work of enumeration. In some cases more than five work together to advantage.

Mr. Bridges—Dr. Warren has read us an excellent paper. There is much food for thought in what he has told us. It was interesting to hear of the variety of methods which are used by Dr. Warren in farm management research. Each method—surveys, financial accounting, cost accounting, expensive though it may be, questionnaires, and so on, evidently has its part to play, though the relative importance of each is different. The application of research funds into the channels in which it will exercise the greatest amount of good is a point we must keep continually before us.

At the beginning of this lecture Dr. Warren gave us a practical demonstration of the value of an average based on a fairly large number of estimates. He then applied this science of large numbers to show the value of averages based on information collected by economic surveys. Now I can believe that where you get great homogeneity in both physical and economic conditions, such averages will present a picture which will not only be accurate, but which will also be in such form that farmers will be able to make the most use of the material and draw proper conclusions from it.

Where however, the same degree of uniformity of conditions does not exist, as in this country, I think we have to be very careful in using or at any rate confining ourselves entirely to the use of averages. You may have substantial similarity on many points in a group of farms, but here and there, or even on a number of farms within these groups, you may find variations in methods which, if averaged in the group, would give you a conglomerate picture of conditions. Now this might indicate that

a refinement in selection was necessary before grouping farms for averaging was undertaken. This would always be done if the number of farms was large enough. On the other hand it might involve a departure from the principle of the science of large numbers where only a small number of farms was concerned. It seems to me important to study the effect of these variations wherever they occur no matter whether they apply to large or small groups of farms or even to individual farms.

There is one question which I should like to ask Dr. Warren in connection with survey work. What kind of training is it usual to give a field man before he starts his work? Are the field men selected from graduates entirely? Do they have any opportunities of talking to and questioning farmers under supervision before starting work by themselves?

Dr. Warren—The field men are usually chosen from the upper 5 or 10 per cent of the graduates of various colleges of agriculture.

They are given some office training in methods of work before going into the field. In the field, a new man first watches the experienced enumerator take one or more records. He then takes one or more records while the experienced man observes his work. Always the man in charge of the party checks all the records daily so that the enumerator may have to go back and correct the information or get additional information.

Dr. King—The methods Dr. Warren has dealt with are questionnaires, the census method, surveys, and cost accounting. Has he a place for financial accounting in his list? Cost accounts cannot be universally used since we have not facilities for dealing with a large number of farms. In using the survey method much difficulty arises in a small country which is divided up, by differences in physical conditions, into numerous small agricultural areas in which the farming changes rapidly. We have only to travel in most of our areas in Scotland for a comparatively short distance to find a change in type of farm corresponding to a change in physical environment. Surveys find but few contiguous farms which are similar in organization and on which a system suitable to one, could be adopted without modification by all. Under the circumstances it seems we must approach our problems in another way. In Scotland we attempt first by analysis of farm statistics to classify and to find the distribution of farming types, and then, after a suitable process of sampling, collect a sufficient number of financial accounts from representative farms. Statistical work of this kind reveals that classification by size is not satisfactory where conditions are changing. We have found in some areas that where the rent per acre is high the farms are small, and *vice versa.* From some of the data analyzed it seems that size and quality of land may have to be brought together in defining a unit of land. Financial accounts collected from a proper sample of farms offer a method by which we hope to get a fairly precise measure of the farming position all over the country.

The survey schedule usually includes much more information than is covered by financial accounts. Where financial accounts are kept, they are of value in that they may give more accurate results. Usually they are not kept by all farmers so that if the farmers that are not keeping them are omitted in a survey you have a selected group.

Mr. Thomas—I should like to ask Dr. Warren one question on the use of schedules. There can be no doubt that a carefully prepared schedule is necessary for efficient survey work. But, is there not a real danger that dependence on a schedule may dull the alertness of the surveyor as an economic investigator? At the moment our department at Reading is investigating the economics of farm cheese-making in North Dorset. A farm to farm survey is one aspect of the investigation, and for this we have prepared a schedule. But there is much material which is very important for the study of the main problem which will not fit into the schedule at all. In other words, in this investigation, as in the majority of economic investigations, very much important data is required which cannot be treated statistically. The investigator, whose chief concern is to get as many schedules completed as possible, may very well miss all this non-statistical information. Again, in investigating farming practices, it is the exception which very often teaches one most. Now a survey conducted on a strictly statistical basis may very well fail to bring out the lessons of these important exceptions. I should like to know how you in America overcome this difficulty.

Dr. Warren—There should be a place on the survey blank for notes and comments. These call attention to things that should be studied. This is the chief purpose of such notes. A little information on innumerable topics is not of great value in advancing scientific knowledge except as it indicates topics to be studied by exact measurement.