PROCEEDINGS OF THE THIRTEENTH INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS

held at the University of Sydney
Sydney, New South Wales, Australia

21–30 AUGUST 1967

The Economist and Farm People in a Rapidly Changing World

LONDON
OXFORD UNIVERSITY PRESS
NEW YORK TORONTO
1969

GROUP D

Chairman: SOL SINCLAIR
University of Manitoba, Canada

Rapporteur: K. DEXTER
Ministry of Agriculture, U.K.

Integration of Technical and Economic Investigations

EARL O. HEADY
U.S.A.

BOTH the need and opportunity for integration of technical and economic research grow with economic development. There are, of course, some definite needs for relating the two fields of investigations in less-developed agricultures. However, the demand and possibilities for the application of interdisciplinary research come into sharpest focus when decisions and management become highly market oriented and choices are made against fairly sophisticated objective functions for the farm. Interdisciplinary research between economic and technical sciences has its most obvious applications within farms of a highly commercialized agriculture where managers attempt a fairly specific optimization. But, it also has possibilities of broad application for designing regional economic development plans, irrigation projects, and even national plans. It is difficult to imagine how the investment for an industrial sector such as chemical fertilizers can be well planned, either in total investment or in number and location of plants to produce various materials, when technical research on yield-response functions is completely absent. Similarly in the development and allocation of water resources, plans are nothing but crude guesses when knowledge is absent on the response of crops to different amounts of water for different soils and in interaction with other farm inputs. Economic models can be formulated to guide technical research, to provide coefficients for decisions and allocations at the regional, project, and national level as much as at the farm-unit level. We should not overlook these broad possibilities and needs in our discussions because they are important in national planning. However, because of the restraints of time and space, I will restrict my remarks largely to opportunities, problems, and models in integrating technical and economic research directed at farm-level decisions. If these are extended to cover a sufficient number of locations, inputs, commodities, and farm types, they provide the basic coefficients for regional and national models and plans.

Opportunity and need under development

The need and opportunity for interdisciplinary research increases with economic development and the high commercialization and market orientation of farms for several reasons. In fact, because of this advance in commercialization, an entirely new era is opening up for agricultural research. While the change from one environment to another is only gradual, obvious characteristics of the new era can be identified. Among others, three characteristics stand out. One is the greater capital now available to research because of larger investments in science and because of advancing research technology *per se*. This larger investment, placing an economic premium on scientists, provides equipment and facilities making possible research which is much more sophisticated, powerful, and appropriate relative to the basic phenomena which it attempts to predict and simulate. Examples in capital technology are modern laboratory equipment and computers which extend the scope and depth of research possibilities. A second characteristic is the knowledge, advance and accumulation, which provides intellectual tools and extended models for more productive and complicated research. The third important characteristic is growing commercialization of farming *per se* and the need for agricultural research in a form (*a*) better adapted for economic application in an increasingly sophisticated decision framework, and (*b*) more consistent with the biological and physical realms of agriculture.

That this period is already here is emphasized by the efforts of large industrial firms in advanced countries. They are beginning to emphasize recommendations to farmers from more sophisticated economic models, rather than purely brand names, as a means of distributing inputs or technologies such as chemicals. In doing so, they base recommendations on rather precise economic models of optimization. These optimization models suppose quite specific forms of agricultural research data (e.g. formal production functions) and suggest that much more research needs to be developed around systematic input–output models or production functions than in the past. Farmers of highly developed agricultures are now ready to use these sophisticated models and rapid advance should be made in integration and application of technical and economic research to allow this use.

In earlier days (or even now for many countries) when capital was extremely limited and costly, labour was the most important and dominating resource of farming and scientific knowledge was elementary. The simplicity and form of agricultural research data was less important. The farmer could make only small investments at one time and the application of refined decision principles was less important. As he obtained a few funds, he might buy a new seed variety this year and a small piece of equipment next year. Isolated and discrete research findings thus were not entirely inconsistent with this investment pattern. Too, his level of knowledge often kept him from comprehending the results of more than one practice at a time and he was frequently reluctant 'to change his ways' even then.

In the highly commercialized farming now emerging, however, capital becomes the dominating input. It is purchased mainly from off-farm industrial sources in the form of machinery, chemicals, insecticides, feed additives, etc. Farms are extremely competitive and have low profit margins per unit produced. Consequently, it is necessary to apply more sophisticated decision models and to have the data to do so. Rather than simple isolated bits of information, the highly commercial manager needs systematic research data which not only allow him to relate the various technologies or investments to each other, he also needs the relationships or responses estimated in the form of continuous functions which also incorporate the interaction effects of different classes of inputs.

Research and education performed on behalf of, and communicated to, agriculture over the last century somewhat paralleled the traditional decision-making framework outlined above. Experimental designs and statistical analyses seldom treated agricultural phenomena in the functional sense, that is in terms of response surfaces and production relationships adapted to marginal analysis, economic interpretations, and systematic incorporation into decision models. Classically, agricultural data were provided as point estimates or discrete phenomena. Often only a small number of treatments were included in experiments, with statistical decision and prediction based accordingly. These approaches and their recommendations contained some very explicit assumptions about the production function and the price coefficients which enter the farmer's profit model. They assumed that practices could be evaluated separately and that yield effects were linear and additive. They also assumed the marginal product of inputs representing the treatment to be constant and greater than the ratio of the product/treatment price ratio. While weak in economic base and content, this approach did not depart greatly from the 'discrete investment approach' implied in the crude-decision processes used by less-advanced farmers.

Now, however, our knowledge is greater. We know that the agricultural production process does not generally follow this discrete data form. Managers are becoming knowledgeable and sophisticated. They can, or can be led to, apply precise decision models. With this change, we need much more agricultural research performed within a framework of formal production functions or response surfaces. In the absence of data formulated to conform with economic principles and without the use of economic principles, recommendations to farmers can be no more than by rule-of-thumb guides and quite frequently in a manner inconsistent with income maximization. Alterations in experimental designs and statistical designs need to be made accordingly. Hence, in a sense, as agricultural decision making progresses from a simple to a more complex framework, experimental designs and statistical analysis also need to follow a progression under economic development. Quite a different set of designs and quantitative analysis is needed when we substitute the concept of continuous functions for that of discrete phenomena and simple decisions.

Beyond the decision framework of agriculture, the new approaches in technical research also are needed simply because they are more consistent with the phenomena being predicted, than are conventional designs and methods. Agricultural scientists have been too little trained in mathematics (and also in economics) to formulate the most relevant models for the biological world which they attempt to predict. The technical sciences have employed models which relate to optimization against specific objective functions. Examples are fertilization schemes to maximize yields, rations to provide the greatest output from a dairy cow or hen, feeding programmes to minimize ingredient inputs per unit of gain, rotations to optimize the condition of the soil or yields in crop series, etc. However, to this time, the models of optimization employed by the physical and biological sciences have been more of a rule-of-thumb nature and less sophisticated and systematic than those of economics. There is no reason why this should be so; it just is. In the future the concepts or models of optimization employed by technical scientists in agriculture should be equally or more sophisticated and logical than those of economists. In fact, many of the concepts in the optimization models of economists are derived from relationships of physical and biological phenomena. Technical scientists, rather than economists, should have taken the lead in developing or refining them. In any case, the hope is that these models and concepts will be both more widely used and more highly refined by technical scientists in the future. They are relevant as guides in experimental designs, both for predicting the biological world as it is and in providing data in appropriate form for farmer decisions; more so than models and concepts now widely used in much of biological research.

We may ask why the economists have thus taken the lead in developing and urging models and concepts which relate to physical relationships and which may better portray the technical world than some formulations used in biological research. Probably they did so not only because they employed decision or optimizing models but also because they related their concepts and quantitative relationships to econometrics while the technical scientists related his to biometrics. Although the concepts, designs, and quantitative analyses posed by econometrics and biometrics are now converging, a considerable difference prevailed in the past. Econometrics supposed that most relationships of economic and related technical phenomena were of continuous nature, best predicted as regression equations and best applied in the form of continuous derivations. Biometric precedures more nearly supposed technical phenomena in discrete forms requiring classical parameters such as means and variance around means. Technical scientists traditionally were led onto a set of concepts, not the most appropriate either for the biological world, or the optimizing models for recommendations to which they related their effects. Fortunately, however, recent trends in biometrics, particularly these related to design and prediction of response surfaces, is helping to release agricultural technical scientists from that mental mould of a natural world made up of discontinuous and discrete phenomena. On the other hand, econometrics also is now much better tooled with models which admit the presence of discrete and integer-type phenomena.

These tendencies in biometrics and econometrics will bring the two general sets of concepts much closer together, and will improve data prediction or generation and application for real world conditions and decisions. A verification of this proposition is the rapid strides in operations research, a set of methodologies which encompasses and integrates appropriate predictorial and optimizational models from biometrics, econometrics, mathematics, and statistics and poses their more fruitful application for recommendations and decisions. Subsequent developments in agriculture, patterned after operations-research procedures, will certainly draw specialists from biological, physical, and economic fields much closer together and help erode away those time-imposed, artificial mental barriers and scientific traditions which drew sharp lines among the disciplines and methodologies.

The agricultural economist greatly needs the aid of the natural scientist in obtaining and applying data within the modern framework of decision principles and the growing commercialization of farming. Also, the technical scientist needs the aid of the economist in the application of models for generating data and in making recommendations which have greater economic applicability. Both major branches of science are now at a stage of maturity where this interdisciplinary activity is not only desirable but is highly possible, since (*a*) modern scientific concepts and theories transcend the lines of classical delineation in applied fields, (*b*) modern trends are away from the barriers that scientists historically were prone to erect around their particular fields, and (*c*) computers and empirical techniques have removed much of the data-processing restraint, and a much larger and wider range of quantitative models can be estimated and applied and thus become practical.

Problems to be overcome

Given these possibilities, there are still two major problems to be overcome in extending interdisciplinary research and the application of relevant models to provide improved technical data for decisions. One of these relates to enlisting the sincere interest of more technical scientists. The second relates to development, refinement, and practical application of research designs, and regression models relevant for predicting systematic production functions or response surfaces.

With advancement of knowledge and quantitative procedures in agricultural technical sciences, the time will come when concepts encompass systematic production functions and models which relate them to economic decisions. One task is to speed this process and, for the present, the burden of doing so falls largely on the agricultural economist. I have found that this task is not difficult. In my experience it mainly requires that I spend several informal seminars with the technical scientists involved. The seminars are best held away from the interruptions of busy offices and should not include persons on the fringe of interest or who have completely 'closed minds'. Ordinarily, one must explain the economic concepts of production functions and decisions models as the counterpart and equivalent of the concepts now being used by the technical scientist. Usually, one needs to start with the arithmetic equivalence of the two. One can then progress to the algebraic basis of the relationships, and then to the design, estimation, and application of the relevant technical–economic models. I have yet to find a modern technical scientist who could not understand, accept, and implement these concepts and approaches. He is not likely to be highly enthused over them, however, unless he fully understands their nature and application. Once this understanding is accomplished, he ordinarily then sees a greater significance and challenge in his realm of research.

Vigorous co-operative effort rests particularly on the individuals doing the research. They need to be genuinely interested in the investigation and its purpose. A statement by administrators of the need for the research may facilitate co-operative effort, but will not assure highly productive co-operative research. The real stimulus for scientific integration must come from the individual research workers. Hence, success and attainment of co-operative and interdisciplinary research depends partly on the type of staff hired by institutes and universities. For institutions and administrators attempting to encourage interdisciplinary research but not able to get it started, perhaps the answer is to provide short on-campus sabbaticals at full pay, with the individuals freed of all other duties to delve intensively into concepts and their application. There is no logical reason why improved research is best encouraged by one-year sabbaticals taken off the campus at part pay at intervals of several years.

Production functions can be estimated in rather simple frameworks which parallel those technical scientists have conventionally used in conducting research. Gain in knowledge and refinement can result accordingly. However, the most appropriate models which are relevant to biological phenomena quite typically are more complicated than those implied in the relatively simple procedures of conventional agricultural research based on a few discrete treatments for a single crop, at a given location under fixed time, weather, fertility, and other conditions, or in the initial production functions analyzed co-operatively by economists and technical scientists. But one of the advantages of seminars between these scientists is the opportunity to develop more complicated models of the production process and design experimental and statistical models accordingly. Numerous questions are yet to be resolved in (1) algebraic appropriateness of various models, (2) acceptable experimental designs within the purposes of efficient estimation and practical application restrained by limited budgets, and (3) optimal regression models for the complex phenomena which may be concerned.

As an example, take the milk-production function with two or more categories of feeds as inputs. The function may be estimated simply as milk output from (say) two feed inputs over a specified period of the lactation for cows of given milk-producing ability. Yet knowledge can be enhanced over the long run if other variables of the environment are recognized and incorporated in the design. The coefficients will differ depending on the stage of the lactation, temperature, humidity, and other environmental variables. They will differ with the genetic characteristic of cows. Further, the feed bundle will have effect on the composition of the milk, gain or losses in body-weight of cows, or even the performance of the cow in a subsequent lactation. While these variables and conditions are equally present in conventional research approaches, modern models of production functions lead us to more clearly recognize them and incorporate them into the design and analysis—thus leading to greater knowledge. An important function for a work group of international economists can be the outlining and development of these more-complete models.

Another useful activity of such work groups is the examination of designs which are appropriate for the estimates and livestock functions based on feed inputs. It is possible to design experiments in which each output observation is independent of others; this procedure requires a large number of animals. In experiments to date, research resources have been lessened by using the same animals for successive observations over feed space. Yet this procedure gives rise to problems of autocorrelation in estimates. While mean estimates are not biased, we have difficulty in specifying the number of degrees of freedom and the confidence intervals that are relevant. How much weight should be given to statistical refinements and research costs as we consider design of experiments to allow farm applications? Further, in most applications to date, measurements of outputs and inputs have been made at specified time intervals. What specification errors result if inputs as well as outputs incorporate stochastic characteristics? Is the gain in precision economic as we elaborate the experiment and cause inputs, rather than time, to be measured without error? In animal experiments, feeding is frequently or typically on an *ad libitum* basis. Hence, as feed input becomes a random variable, do we need to turn to statistical models other than least-squares regression? *A priori*, what algebraic forms and characteristics can be specified in meat production per animal, milk or egg output per cow and hen, or crop yield per acre? What are the implications of these algebraic specifications in statistical models and experimental designs? What are the interrelations among these conditions and steps and how should research be designed accordingly.

Exploitation of the upcoming opportunities in interdisciplinary research and resolution of the unanswered questions in its design and execution are opportunities for this generation of agricultural economists. It is the hope that the work group of the International Association of Agricultural Economists can contribute importantly to this goal.

GROUP D. REPORT

In concluding his introductory remarks, Professor Heady stressed the need for a joint approach by economists and technical scientists in the development of programming data for the integration of crop and livestock production. He also pointed out the value of economic criteria in determining the priorities of technical research programmes. For instance, in the more-developed economies, relative demand elasticities for different foods might be used as indicators in the allocation of research funds, whereas, in the lesser-developed economies the scarcity of capital relative to the labour supply, or the heavy dietary dependence on crop products rather than animal products, indicated the areas where research funds might be most productively invested.

There was a general view expressed that co-operation between economists and technical scientists was more important in the less-developed economies than in the more-advanced countries because of the overriding importance of allocating the very limited capital resources to the most productive uses. Economic analysis at national and regional planning levels was, at times, limited by a lack of knowledge of technical relationships in agriculture. In some cases the technical relationships had not been established; consequently, micro-economic projections and decisions were being based on inadequate economic and technical analysis. The importance at policy-making levels of economic analysis based on technical data was repeatedly stressed. More integration was needed at several levels. In the planning of technical research there was a need for prior appraisal of the economic implications of the research programmes. There was a tendency to concentrate technical experimentation on the maximization of yields per unit area under conditions where labour and capital were much scarcer factors of production than land. Furthermore, low-income farmers had little capacity to absorb ill-directed technical advice, and, since the cultivator was frequently inarticulate in explaining his views to extension workers, the economist had a function in acting as the spokesman of the cultivator in establishing a feed-back of his views to the technical scientist. It was urged that one aspect of technical and economic co-ordination should take the form of extension workers being involved in transmitting experimental results to farmers and cultivators of national and regional administrators might be responsible both for the development of national agricultural policies and the over-all direction of investment in agricultural research. Sociologists and anthropologists could also contribute to the solution of agricultural problems, particularly in the less-developed countries.

Some Peruvian experience was quoted demonstrating the high economic results from technical experimentation. It had been found; for instance, that potato yields responded economically to fertilizers at rates of application far above the levels currently accepted by technologists, and further experiments were being designed to determine economic optimum rates of fertilizer applications. At the regional planning level, useful teaching and budgetary material had been obtained by the use of dynamic linear programming techniques.

Doubts were raised, however, whether it was possible to isolate biological variables by experimentation designed to establish production relationships for the infinite variety of soils and natural conditions. Similarly all the relevant variables in the preparation of response surfaces, e.g. the effect of dry seasons on crop yields, needed to be taken into account. On the other hand, more complex models were being developed which should improve the predictability of results under more diverse conditions and circumstances.

A further issue was raised about the wide divergences from the mean in crop experiments under tropical conditions. The wide variations in results, under apparently identical conditions, complicated the interpretation of experimental results. Similar findings had been recorded in parts of the U.S.A. One explanation of fluctuations in experimental results was the variation in the nitrogen level under apparently similar conditions and, unlike phosphate and potash, there was no fully satisfactory method of determining soil nitrogen levels.

It was pointed out that the design of agricultural experiments was largely determined by statisticians interested in measuring means, differences, and variances around means. Many agricultural experiments, however, needed to be assessed in economic terms, measuring the gain and losses resulting from the adoption of alternative strategies. Closer co-operation was needed, not only with natural scientists, but also with the statisticians responsible for much of the design and analysis of field experiments in agriculture.

More realism was needed on the part of economists in their dealings with research workers in other disciplines. Some successful economic/technical experiments had grown from a series of meetings between economists and natural scientists, first at formal meetings where concepts and methodology were discussed and then at informal discussions where the design of particular technical experiments could be analysed in detail. The result was the development of work aimed at systems–synthesis whereby the results of a series of experimental findings were synthesized to establish the over-all impact of new farming systems. Possibly that, relatively too much effort might be devoted to the further refinement and sophistication of economic models at the expense of detailed and painstaking co-operation with natural scientists in the design of specific experiments to quantify some of the available economic models.

On the general issue as to whether there was the same necessity for co-operation in subsistence and semi-commercialized agriculture as in highly commercialized systems, it was concluded that there was considerable scope for the joint development of sophisticated techniques in the more-advanced countries, but in the lesser-developed economies the primary need was to establish technical relationships. The degree of sophistication required in highly developed agricultural systems required elaborate experimental design hence, in these countries there was a need for a high level of co-operation in the design and analysis of experimental data.

Contributors to the discussion in addition to the opening speaker included: A. Valdes *Chile*, F. Lom *Czechoslovakia*, C. C. Malone *U.S.A. and India*, R. L. Anderson *U.S.A.*, R. C. Manning *Australia*, D. Paarlberg *U.S.A.*, M. E. Andal *Canada*, Ching-Yu-Lee *Taiwan.*