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*Sectoral and Regional Analysis Objectives and Methods**

I. AGRICULTURAL DISEQUILIBRIA AND APPROACHES IN ECONOMIC ANALYSIS

THE topic that was assigned to me permits a variety of approaches, a comprehensive review of recent developments as well as a more eclectic, but broader, discussion of specific models or classes of models. I have chosen the second alternative referring for a recent review of alternative sectoral models to Thorbecke [14]. Specific emphasis will be given to modelling processes of change, to a sufficient degree of operationality and towards the usefulness of model analysis for policy evaluation and formation.

Physical, social and human processes that are perceived as change usually represent a complex system of causes and effects, of actions and reactions, of predictable and unforeseen events. Economically, changes can be viewed mostly as results of successive states of disequilibrium. The causes of disequilibria may result from properties of the system with an inherent tendency towards instability, some agricultural markets for example, from changes in technological and resource availabilities, or changes in the social and institutional environment.

Given a natural human tendency to develop stable states within the realm of variables under one's own control, the question arises to what extent situations of permanent disequilibria are preconditions for change, disequilibria that force individuals, groups and governments to react and adapt to new conditions in the environment. Analytical economics when concerned with the analysis of change should try to incorporate the essential elements of these processes, focusing on situations of disequilibrium and the forces initiated by them. We need to develop a state of mind that concentrates on causes, directions, and, very importantly, on rates of change. Stating the analytical task in this way emphasizes the need to understand the possibilities for controlling directions and rates of change over time in an economic system that is far from equilibrium and not likely to reach it. Success in this approach may improve the usefulness of economic analysis to decision-makers in various areas of responsibility.

To develop sectoral and regional models of agricultural change with a

* Critical comments and assistance by St. Tangerman are highly appreciated.

view towards their usefulness for policy purposes the process of goal formation on the part of individuals and governments needs more attention than it has received in the past. Stated public policy goals often conflict, which may lead us to assess the goal structure by analysing actual policy behaviour. If we assume a largely adaptive behaviour on the part of those exercising political control, we can investigate reaction to changes initiated outside the sphere of direct governmental influence by considering two major aspects: a continuing search for the amount of change that can be considered socially acceptable and control of rates of change in economic variables which have negative effects on specific groups. Obviously the concept of social acceptability of rates of economic changes leads us on to uncertain ground because acceptability depends on a variety of factors. The acceptable rate of decrease in agricultural employment, for example, certainly considered a hardship by many concerned, will depend on opportunities outside of agriculture, age structure of the farm population, political influence of farmers, regional population effects, etc.

The models discussed below are conceived as disequilibrium-oriented with emphasis on permissible rates of change at the sectoral and regional levels. They are designed to illustrate the approach advocated, but they are not exclusive in the sense that they alone would permit this focus nor would they answer all questions that arise.

II. ADAPTIVE APPROACHES TO MODEL BUILDING

To develop the model building approach satisfying the objectives stated above, several specific model requirements should be considered.

First, the dynamic disequilibrium character of models should enable the analyst to trace the development of a system over time with respect to

—directions of change explainable in terms of known principles of economic theory and traceable to the causal variables;

—rates of change that are subject to economic, technological, behavioural and political constraints. These constraints should allow explicit incorporation of the concept of individual and social acceptability of rates of change. Such constraints should be explicitly stated as testable hypotheses.

Secondly, models should be open to situations of limited information and uncertainty. Ideally they should include learning processes that enable decision-makers to evaluate results of past actions and to adapt or improve their information base. Uncertainty requires cautious optimizing behaviour assessing potential negative effects. Both aspects imply that the outcome of actions resulting from optimizing decisions under limited information and uncertainty may deviate from expected outcomes and that actual outcomes are available as a basis for further decisions. The sequential character of information, decision, action, outcome and new information must be recognized.

Thirdly, the partial character of all economic models should be recognized explicitly which results in the necessity to use environmental information and feedback. Changes in the real world may result from actions of decision-makers leading to endogenous feedback. Further, they may be affected by actions from these decision-makers without being the sole result of such actions. In these cases we may speak of model-environment interaction where the relevant transformation processes need close attention. Finally there are real world developments that do not follow from actions in the system under investigation but that are nevertheless important for state variables of the model.

A fourth requirement is the ability of models to incorporate multiple goals and possibilities of adaptation of goals. The area of finding goals, their modification in the light of additional experience and the ranking of goals is insufficiently investigated, but nevertheless marks an important area of real problems and thus should be accounted for at least in principle.

At least a partial fulfilment of these requirements appears to be necessary if we want to enhance our understanding of change and if models are to be used as a basis for decision-making in the public realm.

In the following sections two examples will demonstrate the approach. The first, sectoral, model is derived from a budgeting approach as known from individual firm analysis. In spite of its simple structure it demonstrates some of the most essential elements of the approach postulated here, although in practically all cases additional analysis is needed. The second class of models, applied mostly at the regional level, is generally referred to as recursive programming analysis. The level of analytical content is much higher than in the first type and more of the requirements outlined above are met. In particular the dynamic character is more explicit. But these models too must be supported by additional analysis of state variables.

III. DIRECTIONS AND RATES OF CHANGE AT THE SECTORAL LEVEL

The budgeting oriented model will be demonstrated by analysing the effects of economic growth and inflationary developments in the economy on the necessary adjustment rates of the agricultural sector. The basic principle is that economic policy-makers tend to think in terms of alternative ways of acting on a problem whenever new circumstances seem to make it necessary to deviate from past behaviour. Mostly a small number of endogenous variables, often not more than one, are involved, while careful attention is paid to the environment, that is to the state variables of the system. Skilful use of budgeting procedures depends upon a sophisticated analysis of state variables and the interaction between decision and state variables. As the environment changes, either because of interrelationships with decision variables or independently of these variables, new comparisons of differently phrased alternatives are called for. The process of approaching optimal or tolerable conditions extends over time and permits the incorporation of new information on technology and other state variables. In this sense the process of continuing comparisons of important alternatives over time can be described as a rudimentary dynamic disequilibrium model with endogenous and environmental feedback. Although deficient with respect to the small number of endogenous variables and an economical method of choosing the next step in a sequence of comparisons, the continued wide use of budgeting procedures indicates its adaptiveness in assessing the dynamics of change in a changing environment and reflects its low cost and the possibility of timely use. Such sequences may be considered an important antecedent for more comprehensive dynamic models.

The basic model structure is simple in that it proceeds from sectoral accounts, a production function constraint, and three policy constraints. Starting from the typical problems of agricultural policy in an industrialized society the broad policy goals are usually defined as providing a sufficient supply of food at low cost to the consumer while at the same time farm families can participate in the general growth of living standards either within agriculture or in a different occupation. Policies pursued under these broad goals have led to initial conditions that are characterized by a variety of support measures for agriculture.

Suppose the initial conditions are characterized by a situation prevailing in the member countries of the European Communities, an administered price support level maintained considerably above world market prices, additional net transfers to agriculture, yet a persistent situation of income disparity for agriculture. With a given policy system, the short-run optimizing problem can be formulated as choosing a policy mix that

(*a*) minimizes direct and indirect public support for agriculture;

(*b*) keeps the rate of decrease of the agricultural labour force within socially acceptable limits;

(*c*) provides a minimum rate of income growth for farm families comparable to that in other sectors of the economy;

(*d*) allows a rate of production growth that corresponds to the international trading position without sacrificing a minimum level of home production.

Problems of intrasectoral income distribution cannot be taken into account at the sectoral level of aggregation.

Which one of these four objectives is chosen as a target variable in the model and which ones are incorporated as constraints is not of primary importance. Since all are functionally related any analysis should pay attention to existing trade-offs by a parametrization of constraint parameters.

Here the first objective, minimization of public support for agriculture is chosen as the target variable while the other objectives are introduced as policy constraint.

Let $P_i(t)$ and $Q_i(t)$ represent product prices and quantities for commodities $i = 1, \ldots, m$, $R_j(t)$ and $X_j(t)$ prices and quantities for intermediate inputs with $j = 1, \ldots, n$, $D(t)$ depreciation on capital stock, $S(t)$ net amount of indirect taxes and subsidies and $N(t)$ the number of people employed in agriculture in terms of full-time equivalents, then net per capita domestic product in agriculture in period t, $ndp_A(t)$, can be defined as

$$ndp_A(t) = \frac{1}{N(t)} \{\sum_i P_i(t)\, Q_i(t) - \sum_j R_j(t)\, X_j(t) - D(t) + S(t)\}. \tag{1}$$

The variable $ndp\ (t)$ will be used as an indicator of agricultural income.

If $T(t)$ is the total level of support for agriculture the objective function can be written as

$$T(t) = P_{p_i{}^s(t),\, S^{\min}_{(t)},\, Q_{(t)}} \{\alpha_1 \sum_i P_i^s(t)\, Q_i(t) + \alpha_2\, S(t)\} \tag{2}$$

where

$$P_i^s(t) = P_i(t) - P_i^w(t) \geqslant 0,$$

the price support level represents the difference between administered prices $P_i(t)$ and world market prices $P_i^w(t)$.

The weights α_1 and α_2 allow for a differential assessment of policies chosen to support agriculture.

The policy constraints are:

$$\left|\frac{N(t) - N(t-1)}{N(t-1)}\right| \leqslant \lambda(t), \tag{3}$$

the socially acceptable rate of decrease in the agricultural labour force;

$$\frac{npd_A(t) - npd_A(t-1)}{npd_A(t-1)} \geqslant \omega(t), \tag{4}$$

the rate of growth of per capita income in the economy in nominal terms;

$$\frac{Q_i(t) - Q_i(t-1)}{Q_i(t-1)} = \mu(t) + \eta_i \omega(t),\ i = 1, \ldots, m, \tag{5}$$

the approximate rate of growth of demand* on the basis of population growth $\mu(t)$ and income elasticities η_i.

The migration constraint (3) states that the expected rate of decrease of the agricultural labour force may not exceed the acceptable rate $\lambda(t)$ which in turn may change over time depending on the time span in which outmigration has been going on, on the age structure of the farm population, on labour market conditions and on specific employment policies, in short on the opportunity costs of remaining in agriculture. As a first approximation we will define $\lambda(t)$ as being in the neighbourhood of

* For an exact formulation see [7].

realized past values.

Thus the current initial value will be assumed for the Federal Republic of Germany as $\lambda = 0{\cdot}05$.

The income constraint (4) assures that the expected rate of agricultural per capita income growth as indicated by per capita net domestic product should not be smaller than income growth in the total economy. This condition does not require income parity. It merely states that existing disparities should not increase in magnitude.

The output constraint (5) is formulated as an equality while ideally it should be separated into an upper and lower bound. The upper bound is derived from the trading position and prevents the degree of self-sufficiency from increasing while the lower bound may be derived from considerations of minimal home supplies. Under present conditions of aggregate supply in the EEC only the upper bound will be considered.

In addition to these policy constraints information on the technology of agricultural production and on the decision structure, in particular input demand of the sector, need to be introduced to complete the model. Therefore a production function was derived from an estimate by Schrader [13] as

$$Q = k\, N^{0{\cdot}351}\, S^{0{\cdot}620}\, e^{0{\cdot}025t} \tag{6}$$

where

Q = total volume of output
N = number of full-time equivalent labour
S = aggregate of capital, livestock and intermediate inputs
k = constant.

It serves to derive the rates of technical substitution between various classes of inputs for a given volume of production.

Factor input functions are not available in the form of quantitative estimates. Therefore a feedback procedure is introduced where the government assumes current input quantities to change according to past outcomes. In particular it is assumed that production growth corresponds to the growth of demand as evidenced by a fairly constant degree of self-sufficiency in Germany. Secondly, regarding the rate of decrease in the labour force the government assumes continuation of past trends.

If we were able to introduce one or more functions explicitly representing farm decision criteria, the problem might be formulated as a non-linear recursive programming model. In its present form it is suitable for simulations of likely outcomes subject to corrections on the basis of feedback from the real world.

The usefulness of the model can now be illustrated by assessing the effects of given rates of economic growth and inflation on the agricultural income position. We are then able to derive the marginal rate of support for agriculture that is consistent with the policy objectives stated above. The data approximately reflect the conditions in the Federal Republic of Germany in the early seventies. The rate of real economic growth per capita is assumed to be 3 per cent per annum, the rate of inflation 4 per cent. Table 1 in connection with the supporting calculations in the Appendix gives the actual calculations.

The result indicates that within the given economic environment, within the policy constraints assumed and with the nominal agricultural price level held constant agricultural per capita income would increase by 3·2 per cent less than for the population in general. The income growth constraint, equation (4), implies that the rate of decrease in agricultural labour at a rate of 5 per cent can be achieved with the existing income

TABLE 1. *Marginal rate of support for agriculture*

Variable	Percentage
I Rate of growth of non-agricultural per capita income:	
1. real	+3·0
2. inflationary	+4·0
3. total nominal increase	+7·0
II. Rate of growth of agricultural per capita income, $ndp_A(t)$*:	
1. demand increase from	
(a) population growth	+0·6
(b) income growth (η=0·2)	+0·6
2. decrease in the labour force	+5·0
3. cost changes from	
(a) price increase for intermediate products	−3·0
(b) increase of labour substituting inputs	−3·2
(c) productivity growth	+3·8
4. total	+3·8
III. Remaining difference in per capita income growth in the economy compared to agricultural income growth	+3·2

* For details of the calculation see Appendix.

distribution. Therefore, under a policy of not allowing further increases in income disparity the remaining 3·2 per cent of differential income growth would have to be compensated for by one or a combination of support policies. Which particular policy is chosen depends on the relative weights α_i attached to these policies for reasons other than sectoral income and on their effect on the policy constraints. For example, under the production structure observed in Germany an increase in product level of 1·3 per cent would compensate for the difference of 3·2 per cent. Alternative schemes of income transfers through direct payments, social policies a.o. are possible. A medium-run policy alternative is a stronger orientation towards increasing the acceptable rate of outmigration from agriculture.

An important feature of the model is the possibility of assessing the effect of exogenous variables, for example the rate of inflation which affects the outcome through its effect on nominal income growth in the economy and on non-agricultural input prices. Similarly, parametric variation of the policy constraints allows the assessment of policies affecting these constraints.

The dynamic character of the model is incorporated in the policy constraints which change over time as a result of the policies concerned or exogenous factors. Moreover, the production function may change over time and needs continuous reassessment.

This example illustrates the essential features of the model, ability to incorporate disequilibrium situations, concentration on and possibilities of control of rates of changes in major variables, possibilities of incorporating feedback on decision and state variables. The model is flexible in the assessment of various policy alternatives and allows the introduction of results from additional analysis, for example econometric analyses of labour market conditions and of price relationships in an inflationary environment or the agricultural production function.

If used in medium- or long-term policy analyses additional information on supply response in individual products, input developments and technological change is needed [11, 12]. The model presented here can serve as a starting point for more disaggregated analysis.

IV. DYNAMIC REGIONAL MODELS OF AGRICULTURAL PRODUCTION AND INVESTMENT

The second example is a class of recursive programming models of agricultural production. These models meet the requirements set forth above while their analytical stringency is much greater than in the budgeting approach [1].

The objective of these models is to explain regional or sectoral farm production and investment decisions with a view towards understanding these processes and to obtain a basis for policy evaluation in terms of comparative dynamics. Two behavioural assumptions are essential, that decision-makers act rationally in the sense of pursuing an objective and choosing between alternative actions so as to maximize pay-offs towards their objective. Secondly, faced with an uncertain future they tend to limit deviations from past actions thus limiting the risk of *ex-post* results of their actions. This principle of cautious optimizing can be introduced in a variety of ways; one possibility is to estimate permissible rates of change exogenously, for example the maximal possible rate of outmigration. Another possibility is to derive such rates from learning functions, for example with regard to the adoption of new technology. Frequently the operationally most feasible procedure is to estimate permissible rates of change from past behaviour in the region without identifying individual causes that limit the rate of adjustment to economic changes in any single period [1, 3, 4, 8]. Day has called the resulting constraints flexibility constraints.

The general model structure is illustrated in Figure 1. As a first approximation to the firm–household interdependence decisions will be decomposed into two separate but interrelated steps. Firm decisions are *ex ante* optimizing on the basis of available information on the production

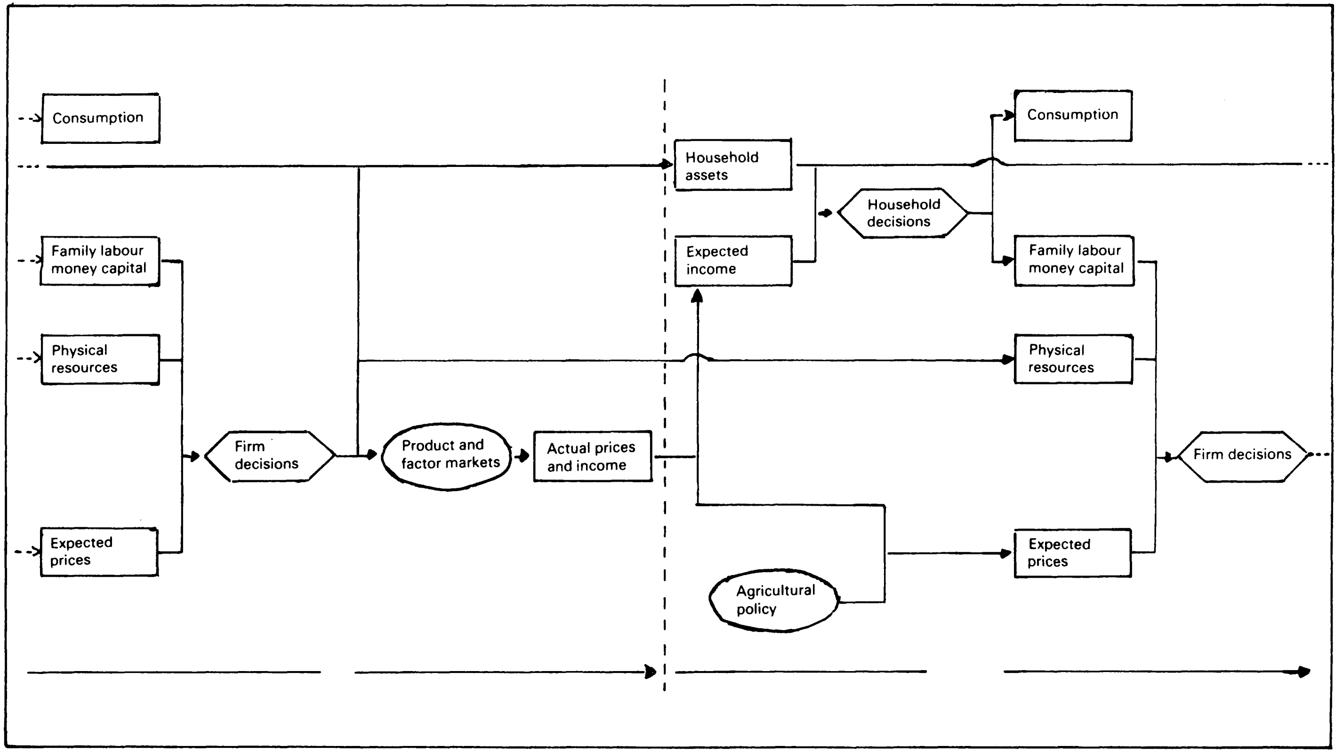

FIG. 1. Schematic representation of regional RLP models.

technology, the supply of inputs, and specified behaviour towards risk and uncertainty.

$$\pi^*(t) = \max_{x(t)} < \hat{\mathbf{z}}(t), \mathbf{x}(t) > \quad (9)$$
$$\text{S.T.}$$
$$A(t)\boldsymbol{x}(t) \leqslant \boldsymbol{b}(t) \text{ and } \boldsymbol{x}(t) \geqslant 0.$$

Where $\hat{\mathbf{z}}(t)$ is a vector of expected pay-offs, $\mathbf{x}(t)$ a vector of decision variables, $A(t)$ a technology matrix and $\mathbf{b}(t)$ a vector of constraint capacities. Decisions lead to action and production results in terms of accumulated product supplies and input purchases. These in turn form the input variables for the market transformation where it is assumed that product demand and input supply functions are known to the investigator. Short-run equilibrium prices at the markets are established which enables us to determine actual as opposed to expected income. Short-run equilibrium prices in connection with government price policies form the basis for price expectations in the following year, the most simple case being

$$\hat{p}_i(t) = p_i(t-1). \quad (10)$$

Investment and disinvestment decisions affect the capacity of physical resources of farms and the asset position of households. Asset position and expected income which is derived from actual income in the current period provide the major inputs for household decisions in addition to family size and the rate of growth of per capita income in the economy as an indicator of rising expectations. Econometrically estimated farm household consumption functions can be used to simulate household decisions, specifically to estimate consumption in period $t+1$. Savings are assumed to be available as a money capital resource for the firm in period $t+1$. The determination of the availability of labour requires additional analysis with regard to the choice between farm allocation and employment outside of agriculture. An interesting alternative in treating firm–household relationships has been proposed by Day and Singh [3]. They introduce a hierarchy of goals, subsistence consumption, current cash consumption versus future forecasted income streams, cautious optimizing and profit maximization. These objectives require sequential attention.

Now the stage is set for determining the initial conditions for production and investment decisions in period $t+1$, specifically the capacities of various constraints, coefficients of the activity matrix, and expectations about pay-offs of activities. The general functional form for determining the constraint capacity i can be given as

$$b_i(t) = b_i\{\boldsymbol{x}^*(t-1), \ldots, X^*(t-s_i), v_i(t)\} \quad (11)$$

where $\mathbf{x}$ $(t-j)$ is the solution vector of the program solved for $t-j$ and s_i the number of preceding periods relevant for a particular constraint. Thus s_i may be the usual life of a capital good. The term $v_i(t)$ indicates that exogenous information may be relevant for the determination of a constraint capacity. Expectations of costs and returns are derived from realized product and factor prices and thus may depend on production decisions of previous periods, and from exogenous market information $u_i(t)$.

$$\hat{\mathbf{z}}_i(t) = \mathbf{z}_i \{x^*(t-1), \ldots x^*(t-s_i), u_i(t)\}. \tag{12}$$

If the model is applied to small regions with an insignificant effect on market prices $\hat{\mathbf{z}}_i\ (t)$ may completely depend on exogenous information.

Expectations concerning input-output coefficients are derived from realized past technology which may be changing over time. Thus

$$\hat{a}_{ij}(t) = a_{ij}(t-1) \tag{13a}$$

or from engineering information

$$\hat{a}_{ij}(t) = \bar{a}_{ij}(t). \tag{13b}$$

Alternatively exogenously provided new technology may increase the number of alternatives open to farmers by expanding the number of activities from which to choose. Thus new activities are added over time. To this expansion of the number of choices corresponds a decrease in available activities if certain technologies are generally abandoned and the supply industries cease to produce the inputs needed for such activities.

The general recursive structure of the model can be viewed as a sequence of one period models, each of which consists of different parts. The core component is the mathematical programme with state variables of any given programme partially a function of decision variables of preceding programmes. The structure is flexible as to the institutional organization of the industry, the level of aggregation and the decomposition into submodels. Thus, in order to reduce the aggregation bias, to explain the differential impact of changing technology on different systems of farming and different farm size classes and to identify the specific problems of growth and decline de Haen [4] has decomposed a large region into such subregions and subgroups. Theoretical properties of such systems were analysed by Day and Kennedy [1, 2].

Applications of models that belong to the general class discussed here are numerous. They include analyses of regions or the whole agricultural sector in industrialized countries [1, 4, 6, 8, 10] as well as regions in India, Brazil, Korea [3, 5, 9]. In reviewing the literature several points emerge. Cautious optimizing is introduced in an operational manner. The explanatory power, especially the description of the introduction and the adoption processes of new technologies is promising. Development paths for a great number of variables, the causes of development and the consequences of behavioural constraints have been derived and validated under a variety of conditions.

A feature that has been commented on extensively is the way the principle of cautious optimizing is introduced through flexibility and investment constraints. In particular, it has been criticized that such an approach tends to produce results that are desired in some sense. Although these behavioural constraints are in no way the central part of the model and different theoretically more satisfying behavioural assumptions could replace them, it has to be pointed out that this approach offers two major advantages: it is operational in that the only currently available source of estimating behavioural patterns, past information, is utilized. Moreover these constraints represent hypotheses about behaviour that are made explicit and testable. The class of models presented here permits economic choice within limits. As such it introduced an element of testability which otherwise is frequently lacking in incompletely specified activity analysis models.

An assessment of the predictive power of such models depends primarily on the ability of introducing future technological alternatives explicitly which are currently at least partly unknown. A major advantage is to be seen in the fact that such models, based on cautious optimizing, can describe likely effects of new policies that fall outside the range of past actions. It is here, in addition to the possibility of testing hypotheses about change processes, where the greatest potential must be seen. However, the need for detailed specification of technological alternatives at the same time introduced an element of uncertainty and limits model projections to a time span for which these alternatives are known. The advantage over macro-production functions that lies in their technological detail may prove to be a disadvantage when projections into the future are wanted.

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APPENDIX

The calculations in Table 1 include the effects on agricultural per capita income of a percentage output growth which is equivalent to the percentage growth of demand, the decrease in agricultural labour, inflationary price increases for non-agricultural intermediate inputs, and changes in the use of inputs other than labour due to labour substitution, output growth and productivity increases. Total net domestic product at market prices (ndp_A) is considered as an indicator of farm income at the sectoral level.

The relative effects of these variables on ndp_A depend on input–output relationships which for Germany are approximately as follows.

	Value	ndp_A Multiplier	
Total production	100	2·50	
Intermediate inputs			
Non-agricultural	30	0·75	1·50
Agricultural	20	0·50	
Depreciation	10	0·25	
ndp_A	40	—	

The entries in Table 1 are calculated as follows: *

II.1 An increase in output due to population and income growth leads to an equivalent increase in intermediate inputs and depreciation and consequently in *ndp* (1·2 per cent).

II.2 Decrease in total agricultural labour increases per capita product (5·0 per cent).

II.3.a A price increase of 4 per cent (rate of inflation) for non-agricultural intermediate inputs reduces ndp_A by –3 per cent (4×0·75).

II.3.b Labour leaving agriculture is partially substituted by other inputs. With output increasing by 1·2 per cent and productivity by 2·5 per cent, a 1·3 decrease in agricultural labour is allowed for under assumptions II.1. Actual decline in labour use is 5 per cent. Thus the

* Cross terms may be neglected for small changes.

difference of 3·7 per cent is to be substituted by other inputs. With a substitution rate between labour and other inputs of 0·567 calculated from the agricultural production function, an increase in intermediate consumption and capital goods (and thus depreciation) of $3{\cdot}7 \times 0{\cdot}567 = 2{\cdot}1$ per cent is required. The effect on ndp_A is $-3{\cdot}2$ per cent $(2{\cdot}1 \times 1{\cdot}5)$.

II.3.c Productivity growth allows a decrease of non-labour inputs by 2·5 per cent. The effect of ndp_A is 3·8 per cent $(2{\cdot}5 \times 1{\cdot}5)$.

The following production function for German agriculture was estimated by Schrader [13]:

$$Q = 3{\cdot}218 e^{0{\cdot}025t} \{0{\cdot}995 N^{0{\cdot}208} + 0{\cdot}005 C^{0{\cdot}208}\}^{0{\cdot}354/0{\cdot}208} L^{0{\cdot}123} I^{0{\cdot}494} B^{0{\cdot}093} G^{-0{\cdot}124} V^{0{\cdot}067} \tag{9}$$

where

Q = output volume (mill. DM)
N = labour (thousands of full-time equivalent)
C = capital (mill. DM)
L = livestock (thousands of animal units)
I = intermediate inputs (mill. DM)
B = land (thousands of ha)
G = grassland in percent of total acreage
V = index of land quality.

Assuming B, G and V constant, assuming further fixed proportions between C, L and I in the short run and denoting their aggregate as S we obtain for 1969/70 data

$$\partial Q/\partial N \cdot \frac{N}{Q} = 0{\cdot}351 \tag{10}$$

$$\partial Q/\partial S \cdot \frac{S}{Q} = 0{\cdot}620. \tag{11}$$

Thus for a small neighbourhood of the current input–output structure the production function can be reduced to

$$Q = k N^{0{\cdot}351} S^{0{\cdot}620} e^{0{\cdot}025t}$$

and the rate of substituting non-labour inputs S for labour is $^{0{\cdot}351}/_{0{\cdot}620} = 0{\cdot}567$.

M. De Benedictis, *Italy*

Before discussing Professor Throsby's paper, I would like to make two general comments on some aspects of the programme of this conference. It is certainly useful to allocate some time to a review of the major areas of the literature: Professor Throsby's paper is a convincing proof of the goodness of this criterion. However, I find two major weaknesses in the way in which the criterion has been applied. First, it is rather optimistic, if not naive, to assume that one paper alone can adequately survey recent development on production and marketing, as it was intended by the programme organizers. Professor Throsby has wisely decided to restrict his review to the sole area of production economics. However, the direct consequence is that the marketing area has been unduly neglected. The second consideration concerns the fact that papers aimed at a survey of methodological developments, like the one we are discussing now, considering the still limited reciprocal knowledge existing today between Eastern and Western agricultural economists, should be articulated in a double presentation covering the developments in the two groups of countries. In fact, Professor Throsby has been able to give us a thorough assessment of developments in production economics but unavoidably restricted to the Western literature. It would have been certainly interesting to hear a parallel discussion illustrating the directions along which the analytical tools in the decision making areas in the socialist countries are moving.

Coming now to the paper, it is my opinion that we should all be grateful for his significant contribution to this Conference. Referring to his analogy in the introductory comments to his paper, one can say that he has succeeded well in setting up and solving this exercise in constrained maximization. My utility function, if not maximized, has increased considerably (of course, it remains to be seen to what extent it is representative of those present here) and one also has to agree with his selection of the appropriate constraints. Putting forward an overall evaluation, I consider his review, wisely restricted to the contributions which have appeared during the last three years, complete and well balanced. The bibliography, in spite of his disclaimer to have covered adequately only the writings that have appeared in English, shows a commendable effort to survey the literature in other Western languages.

As pointed out by the author, the methodological events that have occurred during the last three years in the production economics area may be considered as the logical continuation of the efforts that economists have been increasingly directing to a complete revision of the traditional model of the theory of the firm. These efforts may appear as separate attempts to relax the assumptions of perfect knowledge and of a static decision-making environment. However, they can more appropriately be interpreted as indicators of a general striving to construct theoretical and analytical models appropriate for taking decisions in an uncertain and dynamic world. Professor Throsby has carefully surveyed the field, giving us a clear picture of the directions along which things are moving. One objection which could be raised against his presentation is its too neutral tone: one would have liked to hear from him, more often and more clearly, which tools and contributions stand out from the mass, both from the point of view of professional quality and promise of future application.

Moving now to more specific comments, I find some source of disagreement with Professor Throsby in the classification adopted by him in the presentation and discussion of the different models.

Certainly, as the author suggests, there is no watertight criterion for classifying models, and any attempt to find completely satisfactory pigeon-holes for all models is going to show some deficiencies. However, what I do not find entirely convincing is his definition and grouping of the non-programming models. He has included in this class both the models characterized by a smooth-curved production function and 'those which broaden the interpretation of the decision problems of the firm to include utility and other subjective considerations'. His decision to group these two classes under the common heading of 'Decision theory models' may be somewhat misleading. Firstly, to employ the term decision theory—which is generally used to indicate the set of tools derived from Bernoullian and Bayesian statistics—to cover also the static deterministic models, may indeed generate some confusion.

Secondly, one of the most significant developments in the literature in the recent past are the numerous and interesting attempts to incorporate features of the decision theory framework into the programming format. The boundaries between non-programming and programming models—using Throsby's definition—are therefore becoming increasingly thin and hard to defend.

There is a second point, perhaps more substantial than a mere divergence of opinions on models taxonomy, which I would like to stress. In evaluating new analytical tools, and their impact on our professional activity, I believe that it might be useful to think in terms of the three classic stages: (*a*) invention, (*b*) innovation and (*c*) diffusion. Restricting the discourse to the field of agricultural production economics, we can leave aside the first phase. The experience of the past shows clearly that the 'invention' of theories and tools takes place within other branches of economics. The 'new' theoretical and analytical products are then adopted—with minor or major modifications—by production economists interested in trying out the usefulness of the new instruments in describing and solving decision problems at the farm firm level. My argument is, first, that our professional interests and behaviour are strongly biased in favour of the innovation phase—which is certainly richer of professional and academic rewards—and secondly, that our knowledge is quite unsatisfactory on how things proceed inside the diffusion stage. We should remember that what shows in the literature are mostly the results of the innovative efforts.

As a consequence, a survey of contributions in any given area—like the one carried out by Professor Throsby—directs the spotlight on the tools that have successfully reached the innovation stage, but can tell us very little about their behaviour within the diffusion phase. I am quite convinced that a better degree of knowledge on how things proceed in this phase, and on the reasons why certain tools have achieved the point of widespread use by agricultural economists and others have never succeeded in coming out of the innovative stage, should help us in trying out new methods of refining those that, after a promising appearance, have then deceived our expectations. There is even perhaps a certain amount of disagreement among us in judging the way in which given tools have performed when submitted to the harder test of solving adequately and efficiently the variety of problems that we face in our professional activity. I have the feeling that we would benefit by devoting some time to considering this kind of question.

With the hope of contributing in stimulating the discussion, let me make a few comments on the performance of two tools that by now have been on the scene for quite a time: (*a*) the traditional smooth-curve production function and (*b*) the linear programming model. I will also take the opportunity to cite a few references which, with respect to these two areas, supplement the rich bibliography assembled by Professor Throsby.

With regard to the traditional production function approach, it is my contention that this tool particularly in the domain of the so-called experimental production functions, has reaped rather meagre results, if we think in terms of the objective of a generalized adoption of this conceptual framework in setting up and analysing experiments. In spite of the fact that contributions continue to appear in the literature of various countries, reproducing more or less the, by now, classic formulation, it is my impression that the great majority of experiments—even in countries that have pioneered this stream of research—are actually conducted according to the framework traditionally used in the areas of agronomy and animal husbandry and not followed up by an economic appraisal of the results. The failure of a widespread adoption of the static deterministic framework in analysing experimental data may be due, to some extent, to the not very successful propaganda conducted by agricultural economists versus the researchers in the technical fields. This, however, is not the only and the major reason. In my opinion the partial failure of this class of models is also attributable to the weaknesses inherent in the static formulation.

Referring to a recent article by de Janvry,[4] I find very convincing his argument that those modifications of the model aimed at including the treatment of risk and the possibility of extrapolating the experimental results to other climatic and production conditions should receive high priority in our methodological research.

Another limitation of the traditional formulation of production functions may be associated with excessive partiality of the model: the limited number of independent variables which could be treated as endogenous may reduce considerably the operational significance of the results from the point of view of the farmer. Dean *et. al*[3] in recent work have indicated the possibility and the operational advantages associated with combining the production function and the linear programming approaches for increasing the efficiency and profitability of dairy production through improved feed formulation and feeding programme. They have ascertained, through production functions analysis that: (*a*) the technical rate of substitution between concentrates and hay is essentially constant over the relevant range (linear and parallel isoquants and equal to the ratios of estimated net energy of the two feed components; (*b*) the feed/milk response is curvilinear and individual feed inputs could be combined into a single estimated net energy variable with little loss of accuracy; (*c*) the maximum voluntary intake line is only slightly curvilinear over the relevant range; (*d*) cow ability, cow weight, and stage of lactation (time) are significant variables influencing the position of the feed/milk response function and maximum voluntary intake line.

These findings suggest that milk production relationships can be closely approximated by linear or linearly-segmented functions.

Thus, the economic feeding programme can be cast in a linear programming framework with little loss of accuracy in expressing the basic production relationships while providing the possibility of including many alternative feeds and incorporating great computational advantages.

The Janvry and Dean contributions, both remarkable, by removing or beginning to remove some of the limitations that have so far reduced the usefulness of the traditional production function approach, may have a significant impact in opening up, for this class of models, the doors for a more rapid diffusion in the future than that experienced in the past.

Turning now to linear programming, this is undoubtedly the tool which has shown the best performance against the diffusion test: the generality and the flexibility of this instrument, even its deterministic formulation, have made possible its wide use in a large variety of problems and situations. What is somewhat surprising is the increasing methodological fertility of this class of models: a variety of modifications continue to appear, reinforcing the analytical power of this class of tools. Professor Throsby has given us a clear picture of the recent contributions aiming at introducing or improving dynamic and statistic features into the programming formulation. Some of these contributions, in my opinion, are not exempt from the old malaise of greater preoccupation with methodological novelty *per se* than a serious concern with solution of real world problems. In other cases significant contributions have been made either through innovation of new tools or by combining into a model methodological features which have been available for some time.

As an example of this kind of research, I would like to mention the collaborative work of Day, Mudahar, Singh and others,[1,2,5,6,7] which is discussed at some length in the paper by Professor Heidhues, but should also find a place in the bibliography at the end of Professor Throsby's paper.

The two most important features of this model—which has found relevant applications in sectoral and regional analysis—are the form of the preference function of the farmer as a decision-maker and the way in which the model is made dynamic. The objective function of the farmer is postulated in a lexicographic way. In the application made to Punjab agriculture, four major objectives are specified at the micro level, ranked in terms of absolute priority; (*a*) satisfying subsistence consumption needs; (*b*) utility function comparing cash consumption and future income; (*c*) a safety-first objective and (*d*) maximization of net returns. Thus, the model is solved through maximizing a lexicographic utility function subject to stringent constraints. The dynamic elements are introduced through recursive programming. Thus, for example, the farmer's decision in year *t* are influenced by past output prices, past realized sales and savings, and, in general, depend exclusively on the previous period's solutions.

More recent applications of this kind of model, like the one analysing evolution of employment and capital labour substitution in the agriculture of Southern Brazil, confirm the analytical power of this tool.

A final consideration, which is suggested by the type of models that I have just recalled and by the abundant work done in the area of utility analysis, is that the traditional barriers dividing normative and positive analysis are, if not crumbling, certainly less high and rigid than they once were. Our greater ability to include in the models farmers' motivations and behaviour patterns, augmenting their analytical strength, should increase their usefulness and, through this, accelerate their rate of diffusion.

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A. Sebastien Gonçalves, *Portugal*

The first of a number of important points which Professor Heidhues' paper puts before us is the agricultural disequilibrium facing the national agricultural industry as a part of the national economy. He says that 'the causes of disequilibria may result from properties of the system, with an inherent tendency towards instability from change in the social and institutional environment' (p. 170). In most countries I think such a situation arises mainly from the fact that agricultural economics takes a lower than second place in the national productive system and, secondly, from the fact that most large farms are not productive because the owner lives in a big town far away from his farm and is not personally engaged in its management. A few farms are made productive by tenant farmers even though they have no rights in the land and must work almost without 'technological' tools.

Of course, as is stated by Professor Heidhues, to develop sectoral and regional models of agricultural change necessitates the statement of economic and social goals. I think this statement should come from those exercising political control of the national policy.

Whenever one speaks about national or regional economic planning, the normal is to think about industry, which indicates that agriculture holds the lowest place in the economy as a whole, even in the social view. However, the economic problem can only be solved through a very close connection with the social objective. Furthermore, agricultural development is also greatly influenced by the growth of population.

The evolution of agricultural activity must deal with more complex and larger numbers of uncertain variables than industrial activity. Consequently every agricultural model is more difficult to use owing to (i) climatic variations; (ii) the influence of industry on the workers, and (iii) farmers not directing national policy as they did in feudal times. Today the policy of the country is under the industrialists' control.

As you have heard, Professor Heidues is very clear about the adaptive approaches satisfying the policy problems of agricultural activity. But I submit (i) very quick changes occur in economic variables; (ii) models must be open to situations of limited information and uncertainty; so a very careful optimization is obligatory; (iii) it is necessary to think of the partial character of all models; (iv) the capacity of models be large enough to reach the goals.

The paper also shows a very realistic view in saying: 'At least a partial fulfilment of these requirements appears to be necessary if we want to increase understanding of change and if models are to be used as a basis for decision-making in the public realm.'

The paper shows two classes of models, both demanding additional analysis: the first is a sectoral model and the second applies mainly to the regional level.

As we can see from the example presented by Professor Heidhues, the basic model is simple because not many variables are necessary.

However, I believe it will always be difficult, for example, to use the inflationary developments in this budgeting oriented model: world market prices $PiW(t)$, the $RJ(t)$ as the prices of intermediate 'inputs', and some not well-expressed situations.

Professor Heidhues—assuming the European Community where the price level is higher—makes this important statement: 'With a given policy system, the short-run optimizing problem can be formulated as choosing a policy mix that minimizes the total level of support for agriculture subject to prevailing technological relationships, *tolerable* market conditions, *acceptable* rates of income growth assumed to be equivalent to developments in the economy, while maintaining a *high rate* of decrease in the agricultural labour force.'

What is the exact meaning of: *tolerable* market conditions, *acceptable* rates of income growth, *high rate* of decrease in the agricultural labour force? What is a *'tolerable'*, an *'acceptable'* and a *'high rate'*? See that the important Table 1 of 'rate of growth of agricultural per capita income

ndp_A (t)—(p. 176) is an exact expression but not easy to make concrete. So I am very glad to read in Professor Heidhues' paper that 'the variable to be optimized is government support and protection to agriculture' (p. 173). We are facing here the most important starting point: what is the effective will of governments in expressing the desire to increase the agricultural output level as an important item of economic and social life?

Mathematics is a very important tool but is not enough to solve these problems in the face of the fluidity of government political acts.

They cannot be solved with easy words but only by positive actions. For instance (p. 174), the 'socially acceptable rate of decrease in the agricultural labour force'—(t)—is a basic problem, as a result of uncontrolled situations more than of straight governmental policies.

This is a position which we must recognize as very important, particularly when the author says that 5 per cent per annum is an acceptable rate of decrease in the labour force in agricultural activity. But I think everything depends on the method of this decrease. If the people leave agriculture for other activities it will be very different from the situation if they leave to emigrate, or if they go to the suburbs of great industrial towns, like São Paulo, where their families will live in slums. Then, the economist cannot be indifferent to the outcome.

In fact, the example given by Professor Heidhues shows the most important characteristics of the model which are—as Professor Heidhues says (p. 177): 'ability to incorporate disequilibrium situations, concentration on and possibilities of control of rates of changes in major variables, possibilities of incorporating feedback on decision and state variables. The model is flexible in assessment of various policy alternatives and allows the introduction of results from additional analysis, for example econometric analysis of labour market conditions and of price relationships in an inflationary environment'.

Professor Heidhues makes this important remark (p. 177): 'if the model is used in a medium- or long-term policy analysis additional information on supply response in individual products, input developments and technological change is needed'.

As we can see, many conditions are necessary for a complete use of the model. Where are these statistical elements in a normal country? How is it possible to apply everything to a specific country, perhaps even a developed one?

Of course, it is true that this model is *flexible* but flexibility can imply uncertainty.

Here is the central point in the application of econometric models in the regional or sectoral agriculture economy, and not only in the agricultural field but in the planning and programming in general.

It was said by Steiner from California University[1] that most small farms do not use long-term planning, which is so necessary to the small as well as to large farms.

Reading that, I doubt whether planning models are possible—even linear programming—in countries where statistically 60 per cent of farms have less than two hectares, and more than 80 per cent have less than five.[2]

Statistic problems are decisive. Waardenburg says that 'we can see that even the simplest model implies a lot of variables'.[3] He also calls our attention to the difficulty of national or regional planning. It is not mainly a problem of mathematical evolution, but a problem of higher level of farmers' culture which has not been improved so quickly as theoretical tools have been.

The same difficulty was clearly shown in the UEC Congress in Vienna. At that meeting it was also said that programming depends on the objectives of economic policy which can only be presented by co-ordination at high level.

The second example given by Professor Heidhues has much greater analytical rigorousness than the budgeting approach. This model is shown in Figure 1 where the first approximation to decision is decomposed into two steps, as you see under number 9. Here the decisions are directed to the results of production actions in terms of accumulated product supplies and input purchases in order to obtain the input variables for the market transformation.

Here a very important aim is needed: short-run equilibrium prices at the markets in connection with government price policies as a basis for price expectations in the following year, for which Professor Heidhues gives us a very easy equation (p. 179).

Where can we find such price policy, controlling the free market? Professor Heidhues himself asks for and gives careful attention to this uncertainty, whenever we face problems of optimization and maximization of household profit.

Professor Heidhues points out two essential behavioural assumptions for the use of these models by sectoral and regional farms, but in my opinion both are impossible for normal farmers to apply. Firstly, the decision-makers have to act rationally, choosing actions to maximize their objectives. Secondly they have to limit deviations from past actions, for example to estimate the maximal possible rate of out-migration, or to adopt new technology. But I wonder, looking at the normal peasants who are more or less illiterate who know nothing about new techniques, whether Professor Heidhues has seen these things in India, Brazil and Korea as a rule or only as particular cases?

Professor Heidhues cautiously ends his paper saying that 'a major advantage is to be seen in the fact that such models, based on cautious optimizing, can describe likely effects of new policies that fall outside the range of past actions. It is here in addition to the possibility of testing hypotheses about change processes where the greatest potential must be seen'.

With these words Professor Heidhues gives the exact sense of what would be the best . . . inside the real possibilities of today's agricultural structure as a part of the economic world, where high level of mathematical models is like a dream. And this dream is connected to the first words of Professor Heidhues: 'the causes of disequilibria may result from properties of the system with an inherent tendency towards instability, some agricultural markets for example, from change in technological and resource availabilities, or changes in the social and institutional environment'.

Finally, in my own opinion, the basic problem is the changes in social and institutional environment. All other aspects—including mathematical planning and programming models—are just a consequence.

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Mohinder S. Mudahar, *U.S.A.*

First of all, I would like to congratulate both Professor Throsby and Professor Heidhues for their excellent papers outlining alternative approaches to build sectoral and regional models. I would limit my comments to Professor Heidhues' paper. However, some of the comments are more general and might apply to Professor Throsby's paper as well.

Specifically, I shall make five brief comments. However, I would like to point out at the outset that in the spirit of professional progress I would consider these comments as an elaboration and extension rather than criticism of the papers.

(*a*) Disaggregation of the model by farm size. Most of the empirical research done in India on farm size indicates that small farms are more efficient as compared to large farms. They differ not only with respect to their production behaviour but also with respect to their consumption behaviour, physical resource base, access to financial resources, their ability to bear risk, etc. Disaggregation of the regional agricultural development model by farm size will not only allow to incorporate the contrasting behaviour of different sized farms but will also help to trace out their response to alternative policy programmes and technological change. Furthermore, it will minimize the aggregation error in estimating and projecting aggregate supply of farm products and aggregate demand for farm inputs.

(*b*) Use of flexibility constraints. The use of flexibility constraints as an alternative to incorporate uncertainty in farm decision models has received much criticism. The basis of the criticism has been that the solution is always determined by the upper or lower limits of the flexibility constraints. I would like to point out that this is not always true. Theoretically, these constraints represent the farmer's cautious optimizing behaviour in an uncertain decision environment. From an empirical point of view, I have used such constraints in building and estimating recursive programming models for the agricultural sector in Punjab, India, and found that 80 to 90 per cent of the time these constraints were not effective.[1]

However, for comparative purposes we need to estimate the same model under alternative theories of choice criteria to incorporate uncertainty. This includes approaches such as: (i) use of behavioural constraints; (ii) focus-loss principle; (iii) safety-first principle; (iv) chance-constrained programming; (v) portfolio selection approach; (vi) game theory, etc. This has been attempted by J. Boussard and M. Petit in the standard linear programming framework. However, we need to extend it further for recursive linear and recursive nonlinear programming frameworks.

(*c*) Induced technological change. The question of induced technological change in agriculture and its relevance to economic development has been researched in great detail by Dr Vernon Ruttan by using the standard neoclassical framework.[2] However, it is possible to incorporate induced technological change in the recursive programming framework through the input-output matrix and the constraint vector. The input-output coefficients can be determined endogenously as a function of product prices, input prices, past levels of these coefficients, levels of other physical resources, etc. The same is true for various constraints. Furthermore, the recursive programming approach allows for a choice among alternative production technologies and the incorporation of simultaneous existence of both traditional and modern technologies, which is extremely important for low-income countries in which the agricultural sector is going through a process of rapid transition.

(*d*) Financial activities and constraints. I was a bit surprised that Professor Heidhues did not mention the importance of financial activities and constraints faced by a farmer—an area in which he has done much analytical work. I consider this to be one of the most important components of regional or sectoral agricultural development models. It not only determines the production and investment activity levels on a particular farm or in a particular region but also is instrumental in determining various adoption, adjustment and investment possibilities. Consequently, the model must allow for borrowing and repayment activities and constraints for short-, medium- and long-term credit. This is extremely important for those regions which are going through a rapid transition from traditional to modern agriculture.

(*e*) Testing, validation and choice of a model. Neither of the two authors addressed themselves to the question of a choice among alternative models and validation of empirical results obtained from them. However, from a policy point of view the usefulness of any model lies in its ability to track the past history and make 'reasonable' projections with respect to various endogenous variables. Unlike statistical and econometric models, the empirical results obtained from programming models are not accompanied by various statistics such as R^2, F-ratio, t-value, etc., which could be used to draw some inferences as to the validity of these models. However, some unconventional statistical tests and model evaluation criteria have been suggested to evaluate the performance of these models. These include (i) prediction–realization diagrams; (ii) prediction of turning points; (iii) Theil's information–inaccuracy statistics; and (iv) Theil's U-statistics. These criteria have been successfully used to evaluate the performance of recursive programming models.[3] These tests help not only to evaluate the performance of a particular model but also to discriminate among alternative agricultural development models.

Finally, I would like to make a general comment which might be of interest to both model-builders and policy-makers. The results obtained from the majority of the econometric-type supply response models developed for various regions in many low-income countries unanimously agree that farmers are not tradition bound; rather, they are economic men and fully respond to the economic incentives made available to them. They make rational decisions within their existing economic and institutional framework. As a result, these models have served a very useful purpose in setting a stage to develop more complex programming and simulation models of agricultural development in the low-income countries. However, there are instances in which these supply response models have come up with contrasting magnitudes of acreage or production elasticities with respect to price for the same crop and in the same region. These contradictions with respect to the instability of the elasticity magnitudes (sometimes even the signs are different) throw serious doubts on the usefulness of the results obtained from these models for planning and policy purposes.

Consequently, there is a need to develop more elaborate and detailed microeconomic dynamic models for the agricultural sector rather than depending exclusively on the econometric-type supply response models. These models should be (i) adaptive in nature; (ii) incorporate the interdependence and feedbacks among production, consumption, investment, and financial components of a production response model; (iii) must incorporate technological change, alternative technological possibilities, and an uncertain decision environment; and (iv) focus on the complex decision making process at the micro level. The approaches outlined in Professor Throsby's and Professor Heidhues's papers do satisfy most of these criteria and hence can be used to build realistic agricultural development models for both high and low-income countries.

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3. Mudahar, *op. cit.*

José R. Alcaide, *Spain*

I would like to make some comments to the paper submitted by Professor Heidhues. On page 177 one can read: 'The objective of the models is to explain regional and sectoral farm production and investment decisions with a view towards understanding these processes and to obtain a basis for policy evaluation in terms of comparative dynamics.'

It seems to me that on regional and sectoral basis it is not useful to deal with the farm sector only, because of its dependence upon the industrial and service activities. I think Heidhues' model is useful at the farm level but it does not work to evaluate policy-makers' decisions on regional and sectoral schemes. When aggregating data and activities we must have in mind that the selected activities depend upon householder behaviour and market prices. But they are also strongly influenced by the backward multiplier effects of industrial and public works policy.

Therefore, to call regional and sectoral analyses the second one submitted by Heidhues could be confusing and misleading.

When working on dynamic programming within a regional and sectoral approach we must keep in mind, because of the level of data aggregation:

(*a*) The problems on products and technology homogenity.
(*b*) The sectorial instability of technical coefficient which is different for each economic branch.
(*c*) The discontinuity of investment growth for technological, risk and financial reasons in other sectors than agricultural ones, but influencing the future production patterns of farmers.
(*d*) The endogenous character of capital as a variable that we should introduce into the model.

It seems to me that to avoid all these problems we should use models that enable us to do so. In my knowledge an input-output model integrated with a LP analysis in one of the best ways to approach this situation.

John Dillon, *Australia*

Dr Throsby has presented us with a most comprehensive paper which I enjoyed—in part because his scheme of classification agitates me somewhat. In terms of fruitfulness, I think the classificatory suggestion of Dr de Benedictis is probably better. My criticism of Dr Throsby's division of advances into the two classes of Decision Theory and Programming is that at base I see the essence of production economics as being to give producers and others guidelines in their decision-making. In this sense, programming approaches are merely algorithms which should be seen as being subsumed within the more general context of Decision Theory. Another criticism I would make of Dr Throsby's paper is that it is just not critical enough. I think he should have taken the opportunity of severely criticizing many production economists:

(*a*) for their failure to distinguish between theories and models;
(*b*) for being subservient to their models rather than the reverse; and
(*c*) for seeking algebraic tricks which, when applied to some basic programming model, lead to some particular type of decision rule which they then suggest some farmers might like to use—rather, they should be working in the reverse direction of seeing what the producer wants and then proceeding to solve his problem.

J. A. Groenewald, *South Africa*

At the outset, I wish to state that it should be the aim in agricultural economics to arrive at solutions which are useful for decision-making at the individual, regional or national level. For this, two things are needed: good analysis and good data. Notwithstanding certain valid points of criticism which may be advanced in this sphere, it can yet be said that much progress has lately been made in analytical methods and analytical models. Much less progress has, however, been made in improvement in data collection. It is not uncommon to see refined or sophisticated analytical models being used on insufficient data. Improvements in data collection should now receive much more attention.

Another point is involved with assumptions, as already pointed out by Dr Gonçalves. In more formal mathematical models, assumptions not explicitly mentioned may very often be seen in constraint matrices. This is not, however, as easy in simulation models. This gives rise to the danger that the researcher's own subjective preferences enter into the conclusions arrived at.

Y. Maruyama, *Japan*

My question is concerned with Professor Heidhues' paper. There are three features in the model represented by Figure 1 on page 178 which are very vexing to me.

(1) The household assets in period $t+1$ are determined by those in t and by the firm's decisions. Why is it that the product and factor markets have no effects on the household assets?
(2) Only household assets and expected income come into the household decisions. Why are the actual prices and income not considered in the household decisions?
(3) Agricultural policy affects only the expected prices but not the actual prices and income. Why is it? Are they the errors made in the process of printing or are they in the way you wanted to specify them?

A. A. McFarquhar, *U.K.*

I think John Dillon touched, but did not develop, a very important aspect of general work in the field of agricultural economics, which was referred to in these papers. I am therefore going to make a critical point on those two papers together.

The basic problem, it always seems to me, in this kind of work is the lack of a test of scientific endeavour. If you build a bridge and the bridge falls down, you know the model is not good. If you make a model of a space craft, intended to land on the moon, and the spacecraft lands on the moon, you know it is good; if it misses it, then you have to do a lot of technical improvement. But in agricultural economics, you can build a model, and write papers on it and nobody cares whether it is good or bad. The main reason is that there are no means of testing the efficiency of the model.

Consequently, if we are going to make progress with this work, we have to think of some kind of test of the efficiency of models.

Basically, as we heard this afternoon, models can be divided into positive and normative types. If you have a positive model, intended to reflect gross behaviour, it is clear that unless the model actually does project or predict accurately what people, sectors or regions actually do, it is not a very good model. So in every projection model, you have a potential for testing efficiency. If linear programming models are to be used for projection—and sometimes they are—they must be tested by their ability over past periods to project what really has happened. But the normative model is much more difficult to test, or if you like, the normative elements of a model. Now, at the farm business level, or at the management decision-making level, it is a little easier to test a model. The main purpose is, presumably, to raise the income, subject to constraints of the individual entrepreneur. If, over a period of time, when the farmer is dealing with models, or dealing with advisers dealing with models, he increases his income, it might be regarded as having something to do with that model. But this may not be, so even that test is difficult. But this is a relatively easy test to apply, and yet it is never applied by agricultural economists. There has never been an attempt, at least to my knowledge, to see whether individual decision-makers have benefited from the use of normative models.

At the regional level, or the national level, the problem is much more difficult. It is extremely difficult, in my view, to test the efficiency of a normative model, and I think we are making a mistake, when we tend to the solution that we build models ever more efficient in reflecting what a region will do, because if you build a perfect model of what a region will do, you picture what happened yesterday.

What we really need is a genuine attempt to adjust a region to the direction that policy-makers and the politicians wish it to go, therefore I would suggest that one of the ways of testing this kind of regional model, would be the attempt to measure how far adjustment actually proceeds, along the lines which the models have suggested. Even this is very difficult to achieve because just as for the individual unit, improvement in income, or adjustment, may take place because of processes which are not at all connected with operational models.

I am not really proposing any solutions therefore, I would merely say that if agricultural economists are going to deserve some real scientific interest in their work, they must find some way of testing the efficacy of these models. Of course, it may be true, that like anybody else, agricultural economists are just in the business of selling soap, and we all know that how the soap washes is not as important as how it sells, and how much profit is made from it.

Joaquim Severino, *Brazil*

Besides the natural difficulties of quantifying both technical coefficients and constraint coefficients, nowadays we are faced with a very serious problem, especially when we are working with linear programming models, which by their very nature are very difficult to test. Let me give you an example. We made a study for a given region using a linear programming model, we saw that the optimum solution that would maximize the results of the enterprise had characteristics completely different from reality itself. We were lucky to have found another region, where the solution could be adopted, but the other region was quite different. In the one region, the normative model was almost adapted to the situation, or, in other words, we could say that the farmers were adequately allocating their resources. In the other region the situation was entirely different. They could increase their incomes, but changes would have to be made, specially by changing their mental outlook and the system of production. We cannot control this natural tendency of the farmer himself. Although he could obtain much more income with the resources available, he would have to change his system and this could not definitely be controlled by the model.

My contribution, in other words, is to say that although we sometimes can test the efficiency of the model, most of the time the questions remain in the subjective and theoretical field. Our model was compatible with what existed, but I do not know if it would help the decision-makers if the kind of exploitation would have to be entirely changed.

Professor Heidhues (in reply)

Following Dr Gonçalves' remarks I would like to give a somewhat clearer exposition of how one could analyse problems of growth and inflation that is not given very explicitly in the paper. I was trying to present just a framework for analysing some effects that might be connected with both these phenomena—that is a methodological approach. This, of course, is not a clear-cut answer for any country, independent of the conditions existing in the country, it was intended to be a framework for assessing some of the effects.

That also refers to the second point he made, what are tolerable market conditions, and acceptable rates of decrease? In terms of tolerable market conditions, we assume a policy that would be necessary, or could be conceived as necessary, for the EEC, that is one which lets other countries participate in growth of demand. As far as the acceptable rate of migration is concerned, this is certainly a very difficult problem, and we do not have much to go on, except past experience. The post-war experience, in practically all developed countries, is that the rate of decrease has been increasing, but there are constraints even in economies with full employment. If someone is more than 45 years old, he will have problems and there are regions that offer little opportunity. In short, there is a considerable number of people in agriculture, even in the full employment economies, that have a low-opportunities cost of labour, and therefore have difficulties migrating into other occupations.

So, this might require a very close analysis of the existing situation. I would presume that the rate of out-migration will change with the processes of change going on. The longer that this process has been in progress, the more the younger group can adapt to new circumstances, can get better education, and can thereby increase their range of opportunities. And secondly, there are the explicit policies, directed at changing this coefficient, and this policy is addressed to various groups, for example, education for the young, regional employment for the middle aged, and social security for the elderly. So there is no fixed and clear-cut decision on what this is to be, it may change in different societies, and it depends on a number of variables.

The third point he made in his comments was, do ordinary peasants act rationally? They might not act rationally in the sense of accepting without question the results of a linear programming study. Neither would farmers in developed countries act rationally if you use that criterion, but then, maybe they are smart. But I would assume, and in my limited experience and by what I have seen in literature, this applies to developing countries in the same way, that farmers do have objectives, and they do try to maximize pay-offs towards their objectives. But these objectives are more complicated than profit maximization alone. Risk avoidance has a very important role to play. But basically, I assume that farmers exhibit some kind of behaviour which tries to maximize objectives. If this is not true, we might as well give up much of what we are doing in economics.

The points that Mr Mudahar made are really expansions on the subject I presented, and I think that I need not comment on them.

The problem mentioned by Mr Alcaide regarding the technological coefficients and their estimation over time is really one of the most difficult in using any type of explicit activity analysis model for projections. I think we should recognize that there are different types of technological changes. First, there are continuous changes, and here we are really able to estimate the rates of change, for example, rates of growth in plant yields, or in milk yields. But there are also discreet changes, some of them are revolutionizing, and it is very difficult to adjust to those changes, and that would take a long period of time. European farmers today, have not adjusted to the major transport revolutions of the 19th century, and that is part of a structural problem. Similarly if we assume that the best forms of present technology will be the common technology in ten years, this is an assumption that may or may not come true. We do not know what kind of discreet changes will come during the next decade, and a decade is a very long time. I think that this is a problem which activity analysis models cannot by their very nature solve.

On the comment by John Dillon, that adaptive systems might be the simultaneous equations of the Seventies, I thought that cost-benefit analysis was a closer competitor, but that might have been for the late Sixties.

Considering specifically the problem of evaluating models, in spite of your comments, I will use the word 'testability' of models, I think one of the more important points is clearly to formulate hypotheses, explain what you want to do, and what these models are designed for, state the objectives, and then, given these, you have a basis for comparison between what you achieve and what you are doing.

In relation to Dr McFarquhar's comment, it is really no test of scientific endeavour, first as a general comment, I would say that though you can see it better in mathematical models, it applies to others in the same way.

Certainly normative models are difficult to test, but I would not agree with the comment that the pictures of what happened yesterday are of little use to what might be coming tomorrow. I think that understanding 'why' and 'how' people reacted to pushes from the outside or to changes in their system, is a very important condition for assessing what will happen tomorrow, and from this we might be able to derive conclusions about behaviour.

In relation to a point made by Dr Ruttan several days ago about precision in prediction, I think that understanding why and how processes of change go on will take us a long way to understanding what the possible effects of innovations may be.

Dr Throsby (in reply, written contribution)

I should like to make three brief points:

(*a*) Of the many classification systems which might be devised for methodologies in agricultural production economics, the one presented in my paper is, I think, reasonably workable. But in distinguishing between programming and non-programming models, I should have chosen a better name for the latter group. I agree with Professor Dillon's remarks about the inappropriateness of the 'Decision Theory Models' terminology. Perhaps he and Dr de Benedictis would find my taxonomy more acceptable if a label such as 'Non-programming Models Other Than Simulation', were substituted, a bit of a mouthful but a more accurate indication of the contents of this subject.

(*b*) In regard to the question of model validation touched on by several speakers, I see the problem of testing normative decision models of the farm firm as being closely related to problems of testing positive ones, yet it is true that many builders of normative models evade questions of validation. Every normative model contains a descriptive component which should in principle be capable of being tested; that is, the accuracy with which a model portrays the technical relationships of farm production should eventually be capable of empirical assessment, and we should be more willing to discard models which perform poorly in this respect. As to normative assumptions in a model, it is not usually practicable to 'validate' them in a methodological study on other than *a priori* grounds. But doing at least this would be some progress towards achieving greater relevance in model building. Dr McFarquhar suggests that the worth of normative models should be evaluated by their performance when applied to the real world. I think there is also scope for more critical scrutiny of models before they leave the workshop.

(*c*) Finally, in considering methodology on its own, it is important to keep its role in perspective. The building and study of models is only the means to a rigorous evaluation of theories; ultimately it is the theories themselves that are interesting. Model building 'for its own sake' can only be productive if the methodological researcher understands the part he plays in this overall process. Whether the model building is stimulated in response to real problems (as Professor Dillon would like it to be) or whether it results simply from a remote intellectual exercise, the eventual worth of a model is determined in terms of its contribution to the testing of worthwhile theories.