1 INTRODUCTION

The use and application of quantitative models in the process of agricultural decision-making has always been controversial. In spite of methodological progress, models have been criticized as lacking an empirical foundation and excluding relevant facts which may not easily be pressed into the formal structure of mathematical models although they are offered up to policy makers as the complete basis for rational decisions. On the other hand, there is a growing demand by agricultural policy agencies in many countries to evaluate costs and benefits of alternative policy measures quantitatively.

In order to promote the discussion of this issue, four questions will be analysed in this paper: (1) Do we need quantitative models and what can they contribute to the decision-making process? (2) What are the theoretical requirements on which models should be based? (3) What is the state of the art of model building and application? (4) How can quantitative sector analysis be better integrated into the policy process?

2 QUANTITATIVE MODELS AND THE PROCESS OF AGRICULTURAL POLICY DECISION-MAKING

2.1 What are the determinants of agricultural policy?

Ideally policy conclusions derived from model calculations could be directly transformed into policy action. However, such a one-to-one relationship would not only require that economic models could predict future developments accurately. It would also assume a complete congruency between the domain of competence of economic theory and the range of responsibilities of practical policy. This congruency, however, does not exist: economic efficiency and growth are only a subset of the goals of agricultural policy. A deeper understanding of their respective impact and mutual interdependence is needed in order to improve the relevance and application of models as planning and policy analysis tools.
Several theories have attempted "to explain" policies within the political economy, as were dealt with in the 1976 IAAE Conference on "Decision-Making and Agriculture". Yet a lack of empirical knowledge and widely accepted theories about agricultural policy processes remains. There is, however, agreement that governments typically do not "articulate a single-valued long-run policy and immediately adopt it. Instead they formulate a broad general concept of long-run goals and move in their direction, away from structures existing at the moment, through a succession of short-run improvisations upon which agreement can be obtained".

Two conclusions for the economist and model builder follow from this. One is the notion that the policy process is a stepwise and iterative procedure in which information collection and analysis precede decisions and actions in which goals and instruments are frequently, in the course of time, revised.

The other conclusion is that economic analysis can only have a limited relevance for practical policy. The desire of a government to stay in office, the attempt to reach agreement between interest groups, preference for the avoidance of any kinds of short-run bottlenecks and institutional resistance to change are other policy determinants.

Those groups negatively affected by a policy will tend to prevent its full application by organized political action. Success of these groups is more likely when they are small with a comparatively high burden per head and when the groups positively affected are large and the benefits are relatively dispersed. This paradigm may explain why many developed countries, with low levels of food expenditures in consumer budgets and well organized farmers' unions, have maintained high levels of farm support and many developing countries, with high levels of food expenditures and few organized farm groups, have neglected farm support and emphasized more consumer oriented policies. The prevalence of national over international interests in the absence of external political or economic pressure is another aspect of this political process. The stabilization of agricultural prices within the EC at the cost of destabilizing prices on international markets may exemplify this tendency.

Although the significance of the elements in the preference function of different countries may vary, an increased material well-being, a more equitable distribution of income, a more ecologically sound pattern of growth, and an increased awareness of the impact of domestic policy on international relations are all goals which must enter as elements in the decision process. This alone would justify the development of new quantitative models which would incorporate these elements in the analysis and describe the impact of alternative policy instruments on them.

2.2 The potential role of quantitative models in the policy process
The stepwise and iterative process of policy decision making has been frequently described as a sequence of the following phases:

1. goal definition and problem perception,
The use of quantitative sector analysis

2 analysis and diagnosis of past development,
3 analysis and projection of policy effects,
4 discussion and evaluation of policy alternatives within and outside the decision making bodies,
5 decision,
6 execution and control.

Ideally, model development and implementation should occur in close co-ordination with the preparation of policy decisions. In phase 1, the problem – discrepancy between desired and observed states of the system – is defined based on an observation of the facts and a knowledge of stated goals. The co-ordination would ideally continue through the following three phases, to each of which corresponds a distinct model type (consistency and explanatory modes to phase 2, simulation models to phase 3, and policy decision models to phase 4).

What is the potential role of quantitative models in the policy process? Simply speaking, their role is to take into account complex interactions between real world events and policy measures and reduce these interactions to a limited number of performance indicators which clarify the effects to alternative policy instruments. Models can thus help to detect conflicts, i.e. undesired side-effects, inconsistencies between instruments and goals etc., which are potentially foreseeable on the basis of given data and assumptions but which of themselves are too complex to be envisaged and quantified without models. One example is the annual decision on intervention prices made by the European Council of Ministers, when the long run allocation effects are usually neglected in favour of short run income effects. Another example is the domain of rural development policies in many developing countries. Many of the investments, such as rural infrastructure, small farmers’ programmes etc. in this area, may not be effective or even be made ineffective by counteracting macro policies, i.e. policies of reduced interest/wage ratios, low food prices etc. Quantitative models are clearly needed which can be used to evaluate the mutual interactions of policies at the micro and macro level.

3 PROBLEMS OF FORMALIZING GOAL–INSTRUMENTS–SYSTEMS IN ECONOMIC POLICY

The following aspects of quantitative modelling for economic policy deserve more consideration in empirical research. They represent pre-conditions for a closer interaction between quantitative modelling and policy making. Such aspects include: (1) analysis of goals and problems; and (b) analysis of the relationship between explanation, forecasting and controllability of a system’s development.

(a) Goal and problem analysis
Two issues need to be discussed in the context of goals and problem analysis: the delineation of model boundaries and model structure and
the specification of performance indicators. A positive relationship between the number of goals incorporated and the richness of structure given to a quantitative model clearly exists. In order to broaden the range of policy goals in an analysis one needs to endogenize more real world phenomena, e.g. to explain policy effects on income distribution, market stability, employment, inflation etc. While some attempts have been successful within the boundaries of sector models, others have had to incorporate the explicit consideration of national or even international markets. The larger the share of the agricultural sector in total resources, consumption or production of a country and the less realistic the assumption of zero or infinite elasticities of intersectoral supply and demand, the more important is the construction of a full national model. The analysis of intersectoral resource flows and foreign trade in developing countries, for example, is hardly possible with an isolated agricultural sector model.

Similar considerations apply to the boundaries between national models and the rest of the world. Usually, the “small country hypothesis” of infinitely elastic world supply and demand is made. For countries with large world market shares this is unrealistic and their trade policies have then to be analysed under explicit consideration of the demand and supply behaviour of the rest of the world. Increasing research effort is indeed moving in this direction of linking national and global models. Yet, the delineation of necessary boundaries and of optimal complexity of models remains an unresolved issue.

A second aspect of goal analysis, the specification of performance indicators, will only be briefly discussed here. Two fundamentally different approaches are conceivable. One approach is to define a set of unweighted performance indicators, to simulate their development through time under alternative assumptions, and to present the decision-makers with the full range of policy alternatives. General System Simulation Models fall into this category. The other much more ambitious approach is to specify a policy preference function and to generate through the model an “optimal” policy. Most optimizing policy models are still restricted to a single hypothetical objective, such as maximum growth or least cost resource allocation, possibly expanded by some lexicographic ordering of constraints.6

Empirical estimates of governments’ (multi-valued) “revealed preferences”7 and their use in practical planning are still problematic if not impossible. Governments frequently update even their most vaguely defined goals which has the effect that the use of an objective function derived from past trends could lead to the neglect of some or all of the determinants discussed earlier.

(b) **Explanation, forecasting and control**

A review of the models which have been applied to agricultural sector analysis and planning reveals three issues which require further discussion: (i) explanatory power of models; (ii) time horizon and dynamic behaviour; and (iii) controllability of model development.
(i) The "explanation" of relevant world phenomena is a precondition for useful forecasting because it provides the positive basis for any normative policy decision. This precondition, however, is often neglected. In the place of an empirically validated theory one often finds *a priori* fixations of parameters and/or output variables which, although fixed by assumption only, are "buried" in the computer programmes and have not been properly documented so that they may be understood and manipulated by the user. Models of this type produce only limited "surprises" and represent hardly more than a book keeping device. In order to evaluate the level of goal attainment of alternative policies, however, the output variables have to be widely endogenized, i.e. causally related to level and time path of exogenous variables. While pure econometric models mostly fulfil the requirement of endogeneity, many General Systems Simulation and Programming Models, both of which often contain a more or less overseeable number of switching rules and restrictions, do not. Misled interpretations and premature or false policy conclusions may be the result. In addition to ex-post validation tests, the effects of such restrictions on the model output and the model's remaining structural degrees of freedom have to be carefully documented by sensitivity runs and earmarking of pre-specified variables. As models have become more complex and various kinds of parameter (guess) estimation are frequently used – e.g. where so called General Systems Simulation is involved – a comprehensive documentation has become more difficult. However, this should not lead model builders into the temptation to be dishonest and suppress essential information about *a priori* fixations of model behaviour. It is not unlikely that competition for public reputation and funding further support such dishonesty.

(ii) The time horizon of projections, limited by the decreasing confidence in parameter forecasts, has to be consistent with the expected duration of policy effects. Although no definite rules can be given here, an important characteristic of a model should be its ability to detect conflicts between short-run and long-run goal achievements. To give an example, farm support policies via price and investment subsidies in the EC are justified because of their income raising effect in the short run. A useful quantitative model should not only project the income effects but also indicate the related economic costs of resource malallocation in the long-run.

Both comparative-static and dynamic models are used to compute the changes of allocation patterns through time. What is usually of interest to policy makers is not a hypothetical final state or equilibrium growth path but the structure of disequilibria and the direction of time paths of development. Dynamic systems' simulations do potentially fulfil such requirements.

(iii) Finally, the usefulness of such dynamic forecasts is very much determined by the controllability of the system's performance. Many models contain no, or an insufficiently specified, policy component linking the state of the system's model to instrument variables. To give an
example, there exists an increasing number of regional simulation models which may yield a good ex-post time-series tracking. Yet, such models are often useless for regional planning because instruments such as investment subsidies or labour market policies etc. are not explicitly included. This increases the surplus of officially declared goals compared to the number of instruments which is typical for agricultural policy in many countries. A broadening of the set of goals (e.g. improved personal income distribution or better ecological balance) is often not accompanied by the introduction of appropriate new instruments. It is a mostly neglected task of the analyst and model builder to detect such inconsistencies and propose alternative goal-instrument systems. Not only do such systems have to have as many goals as instruments, but the structure of the models developed has to ensure that the output variables are indeed controllable.9

So far, the theoretical potential of quantitative sector models has been discussed. The following part of the paper will be devoted to a discussion of the state of the art and limitations of available models.

4 THE STATE OF APPLICABILITY OF MODELS IN PRACTICAL POLICY DECISIONS

In spite of a growing number of quantitative sector models reflecting some of the theoretical issues discussed above there is more and more concern about the credibility of such models among decision-makers.10 Unfortunately, policy makers seldom clarify the reasons for their hesitation to make more use of the models. Presumably, these reasons have to be seen in the following three domains: (1) lack of clarity concerning structure, empirical basis and policy relevance of existing models; (2) uncertainty with respect to the empirical performance of available models; and (3) inappropriate implementation of model building and model use in the policy process.

A comprehensive survey and evaluation of models is impossible here.11 Instead, the following section will exemplify how the discussion of the state of modelling could be systematized.

4.1 Classification of models according to structure, methodology, and decision-making problems

With the exception of some recent empirical applications of optimal control which have limited policy relevance,12 none of the known sector models can be classified as policy decision models in the sense that they yield an optimal policy set on the basis of empirically validated relationships between policies and system development. Theoretically, optimal control models do have such properties. Yet, further structural richness and empirical foundation will be needed before a direct policy use can be recommended.

Most sectoral optimization models, i.e. linear single or multi-period
programming models, lack an empirical component. Although frequently interpreted as policy instruments to “optimize” the projected future development, they assume an unrealistic identity between expected individual behaviour and optimal sectoral performance. Rather than providing policy recommendations directly, the equation system of sectoral programming models can be seen to be useful in the following four areas of application: (a) as an input-output system to check data consistency; (b) as a test for sensitivity with respect to short-term yield or price fluctuations; (c) as a comparative analysis of equilibria under alternative exogenous conditions to determine new policy goals and targets; and (d) as a computation of shadow price systems for given or hypothetical allocation patterns through space and over time.

An increasing number of models can be classified as non-optimizing forecasting models. Given assumptions about exogenous variables, they project time paths of future sectoral development without necessarily yielding an “optimal” path. Many of these system models follow a building-bloc structure, i.e. they are bloc-recursive with dynamically linked components. Typically, for instance, resource capacities and supply are assumed to depend on past prices and incomes, and market clearing is achieved through domestic consumption, foreign trade and, if short-run projections are intended, by stock manipulation. The building-bloc approach has several advantages for policy application, namely: flexibility in the choice of data bases, equation structure, and estimation techniques; possibility to use individual components separately; and lower level of complexity which facilitates communication with policy-makers.

The general systems simulation approach has increased modelling potential. Many relevant aspects of policy, however, remain poorly represented in the structure of most sector models, although separate analyses are often available. They include, for instance, components representing: (a) endogenous resource (land, intermediate inputs, labour) transfers between farm size groups and/or regions; (b) marketing and processing; (c) determinants of price or income instability; (d) ecological effects of intensive agricultural production.

Referring to the broader problem domain of agricultural policy more deficiencies of current quantitative analysis become evident. One is the dominance of aspects of allocation and growth over those of distribution. There are hardly any models which describe endogenously the impact of various policies on functional and personal income distribution in agriculture. The other is the neglect of interdisciplinary linkages. This criticism applies, for instance, to the hypotheses on farmers’ investment and production behaviour under risk and uncertainty or to assumptions with respect to cooperation and participation in regional development projects. In both cases, there are important contributions of psychology and sociology which need more consideration in quantitative models. A third aspect is the almost complete neglect of costs of policy implementation in quantitative models. Policy instruments, such as EC-market orders,
investment subsidies or promotion of rural development require considerable inputs of personnel and material. To neglect their opportunity costs would mean to overestimate the competitive position of the respective policy. Yet, the incorporation in formal models is an extremely difficult task.

In this final section, a discussion of the state of the explanatory and predictive capacity of models in the agricultural sector seems most appropriate.

4.2 State of empirical performance of agricultural sector models
The crucial questions model users ask are: which parts of the "real world" can be realistically modelled? How accurate are the forecasts? Which areas need more attention?

Given the great number of empirical models, these questions can only be tentatively answered here. A difficulty common to many empirical studies is the lack of an ex-post validation test for a sufficiently long period beyond the sample period. This is a serious deficiency which may cause a credibility gap to develop especially for general system models, whose behaviour is partially constrained by flexibility constraints or switching rules.

Explanatory and forecasting models of consumer demand have a fairly long tradition in the form of individual agricultural commodity models. Especially when the commodity under study has little interdependence to other consumer goods they have yielded high levels of accuracy. If larger sets of interrelated commodities are included, the specification of complete demand systems, however, becomes necessary. Good empirical applications including forecasts and policy evaluations have been presented in recent years. Complete demand systems have the advantage of a sound theoretical basis and consistency with respect to total income expenditure. In spite of remaining methodological and empirical difficulties, such as insufficient degrees of freedom in estimation, inappropriate choice of functional form, problems with separability requirements, and lack of household surveys, this research area is in a good state of applicability. Of course, when long-run, rather than short- or medium-run, forecasts are intended, problems of constancy of preference structures and parameters etc., also arise.

Explanation and forecasting of supply involves many more unresolved problems. In analogy to the demand side, the substitutability of commodities in production and supply is at the core of the modelling problems. To compare available models it is necessary to analyse their data base and to evaluate how the approaches account for: (a) consistency of common factor use; (b) aggregation errors; (c) irreversibility of supply due to asset fixity; and (d) technical progress.

The major disadvantage of commodity-specific direct supply models is certainly the neglect of competition among enterprises for fixed resources. Moreover, there is hardly any a priori information to be used on the parameters so that several of them are statistically insignificant.
Simultaneous estimates of equation systems, on the other hand, require rather restrictive parameter constraints and functional forms.

Other models are based explicitly on the determinants of resource allocation and production. On the one end is the diverse group of pragmatic models, mostly disaggregated into yield functions and resource allocation components, where the allocation of resources (land more often than capital or labour) is either achieved by simple rules (e.g. productivity ranking) or by proportional scaling of output levels, or the consistency of demand and supply of resources is not considered at all. While models of this type lack a sound theoretical basis, they provide full flexibility with respect to estimation procedures and model structure discussed earlier.

Another type of model explicitly assumes behavioural rules (e.g. constrained profit maximization on farms) to simulate the allocation, production, and supply process. One type are linear production models (e.g. linear programming), eventually recursively linked through dynamic feed-back functions. These recursive decision models have a better theoretical basis than the first type described immediately above. Unfortunately, in the past the parameters in these models have not often been econometrically estimated, which has made confirmation of their results difficult. Moreover, because they need to assume linearity, unrealistic discontinuities in enterprise substitution have frequently arisen. Another type are supply functions derived from duality theory, which have some nice theoretical properties (e.g. linear estimation procedures) but which do not allow definition of the underlying technological specifications.

More recently, we have proposed a general nonlinear production model which combines the econometric parameter estimation and the behavioural hypothesis of an ex-ante optimizing resource allocation on the farms in one iterative approach. The structural form involves a standard nonlinear maximum likelihood parameter estimation in which the numerical evaluation of the function itself is performed through a nonlinear optimization routine. Initial results, received from a 14-commodity model for EC-member countries indicates quite a good explanatory and forecasting capability.

In spite of recent improvements, the state of applicability of agricultural resource allocation and supply models for policy purposes is less favourable than that for the demand models. The lack of data, the complexities of intertemporal, interregional, and intercommodity relationships, and the theoretical deficiencies of models which attempt to explain farmers' goals and behaviour have kept a series of questions unanswered.

Finally, a few comments about the simulation of agricultural prices (ratios and levels) will be made. So far, most quantitative sector studies have avoided endogenous price generation. This is justified in so far as prices are mainly policy determined by foreign trade and market intervention measures or, in the absence of national policies, by international markets. If national markets are separated from world markets by quotas,
if international trade does not exist due to differences in preference, high transportation costs, etc. or if world prices are to be explained themselves, an endogenous determination of prices becomes necessary. The unpredicted price boom of the early 1970s and the increasing number of efforts to link national and global models have considerably raised an interest in this area. However, more ex-ante validation tests of available algorithms are required.

It seems justified at this point to suggest that the rapid increase in the number of quantitative sector models in recent years has to a large extent served academic interest and has only brought slow progress with respect to policy relevance and empirical performance.

An important reason for the remaining credibility gap may be the fact that most modelling projects are initiated by academic institutions alone and not in direct co-ordination with policy-making bodies. Policy alternatives analysed with the help of these models are often highly hypothetical. Co-operation with policy-makers often starts only when the model development is completed and when published results happen to raise the interest of decision-makers.

5 THE IMPLEMENTATION PROBLEM: HOW CAN CO-OPERATION BETWEEN DECISION-MAKERS AND RESEARCHERS BE IMPROVED?

The following aspects are considered as requirements for model implementation, necessary to co-ordinate quantitative agricultural sector modelling and the preparation of policy decisions more effectively.

(a) **Short time intervals between problem perception and availability of results.**

A period of five to seven years, which is needed to build up comprehensive information systems and sector models, would certainly be too long to be of any use for the preparation of most decisions. Hence, a quantitative system of models has to be permanently available.

(b) **Need for flexible modelling systems adjustable to real world problems**

The nature and complexity of policy problems change frequently. A unique, homogeneous model, e.g. a large scale sectoral linear programming model, lacks the flexibility necessary to accommodate such change. More flexible are separable building-bloc systems in which variable sets of components with consistent data bases and hypotheses can be assembled according to policy needs. Congruence between the phases of the policy process (information and diagnosis, projection, decision) and the respective model types is an important characteristic of a system, if it is to be of practical use.
The use of quantitative sector analysis

(c) Competence and objectivity in defining policy alternatives
In order to insure that policy alternatives are discussed before decisions are made, two points need to be considered. First, model builders and users should be competent technicians and knowledgeable in the area of agricultural policy formation, understanding both the quantitative and qualitative external effects involved. Second, researchers should be institutionally situated such that they are in close contact with policymakers, such as working attached to a branch of the Ministry of Agriculture, and sufficiently yet independent of the policy-maker that even "unpopular policies" (i.e. trade liberalization, agrarian reforms, reduced farm support, etc.) will at least be considered in the analytical phase and brought to the attention of administrative bodies.

(d) Open indication of potential for social conflicts
Any execution of policies causes conflicts of interest between groups within a society (producers and consumers, tax payers and farmers, those emphasizing environmental goals and those who pursue mainly income goals etc.) or between societies (e.g. EC-member countries’ conflicting interests in certain joint decisions on agricultural prices). Insofar as performance indicators for conflicting goals can be endogenized in models, their levels of attainment should be clearly documented. Provided the models have a sound empirical and theoretical basis and confidence intervals are indicated for the forecasts, this documentation removes potential conflicts into the pre-decision phases of the policy process. Yet, if they are not carefully specified and if unqualified predictions are published, such documentation could increase, rather than decrease, the potential for conflict.

(e) Availability of frequently updated data banks
Realistic policy analysis requires a data base which is up to date and adjusted to the needs of quantitative models. While the actuality and availability of data systems depends on sample intervals and the efficiency of data processing systems, the completeness and appropriateness of data banks is more often the institutional problem of feedback between data suppliers and users.

6 SUMMARY AND CONCLUSION

Considering the number and diversity of quantitative agricultural models, this review could not possibly provide a complete critique. The growing need for these models had not been fully matched by growth in our potential to meet the need. More work is needed.

Certainly, the benefits of quantitative models, which require considerable resources, cannot be measured only in terms of their direct use in the policy process – on this scale they still score poorly – they must also be seen as an educational tool for researchers and administrators, and as a
medium for public argument of policy alternatives. Yet, the ultimate purpose of building models remains to develop usable policy aids able to predict future developments as accurately as possible.

Progress in this respect requires improvements of the empirical foundation and the implementation of models. The progress of computer science in recent years has brought about an increasing potential to construct complex models, in many cases clearly ahead of the empirical basis. In order to reduce the credibility gap of models, the concepts of explanation, parameter estimation and validation have to receive more attention, especially when general systems simulation models are used. Moreover, since policy domains change frequently and since model development is a costly and time consuming process which requires frequent revisions and updating, there is a clear need for closer coordination between quantitative sector analysis and practical policy-making.

NOTES


4 This hypothesis has been formulated by B. Frey, Moderne Politische Ökonomie, München 1977, p. 16.


9 The concept of controllability of systems models is discussed in Manetsch, T. and Park, G. System Analysis and Simulation with Applications to Economic and Social Systems, East Lansing 1974, ch. 9.

10 See, e.g., Johnson, G.L. op. cit.


12 Recent applications can be found in Rausser, G.C. and Hochmann, E. Dynamic
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Moreover, interpreted as a hypothesis about farmers’ real allocation behaviour, programming models can be components within explanatory models of economic development (e.g. recursive linear programming). Such models, however, cannot be interpreted as policy optimization models.


