THE STATE OF THE ART IN MODELLING
OF FOOD AND AGRICULTURE SYSTEMS

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PREFACE

People are becoming more and more conscious of the food problem and this fact is also reflected by the rapidly growing number of models dealing with food, agriculture and related issues.

The purpose of this study is to give an overview of modelling efforts in the food and agriculture area and to investigate some connected modelling problems. The choice of these problems reflects the interest of the Food and Agriculture Program at IIASA in middle and long-run agricultural macro-modelling.

Special attention is paid to models which consider the agricultural systems in their social, demographic, technological and environmental contexts on a national, international or world level.

ABSTRACT

The study is composed of two parts: at first we briefly discuss some questions of modelling the food and agriculture system over the long run, illustrating them with concrete model examples. The questions are:

o   population and economic development;
o   technological change and investments;
o   environment and agricultural production;
o   international relationships.

The second part contains short notes about the 43 models which have built the base of the study. The notes give information about the models' main characteristics, structure and applicability.

A bibliography is also enclosed listing references of papers and books which although not incorporated in this study may nevertheless be of interest to agricultural modellers.

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PART I

Some special issues of modelling in food and agriculture systems

Introduction

On the basis of the analysed models, we shall discuss some general modelling problems in the food and agriculture area. The choice of these issues is arbitrary and reflects our interest in long-run and universal aspects, rather than in short-run and particular problems. One could analyse other questions as well, but we have tried to focus on the basic ones, namely on modelling:
1) the interrelationships between general economic development and population growth;
2) the connection between technological change and investments;
3) relationships between agricultural production and environment;
4) the international economic relationships.

These are all critical points in our present modelling (and sometimes also theoretical) knowledge. None of these problems have been completely solved up to now. This has also been shown in the concrete examples of the models we analysed. In looking for shortcomings of different models, considering these topics, we tried only to clarify some difficulties without being critical, since we know that the non-complete handing of the issues is often not the modellers' mistake but a consequence of our present lack of knowledge.

1. Population and economic development

Looking at the food problem on a world level or in developing countries, population growth and its economic context is one of the basic questions.

Since the problem is well-known, and discussed often, we will not analyse it in detail. Rather we will focus only on the question of how economic development influences population growth by changing fertility and mortality rates, and how this was depicted in some concrete models.

In those models in which population is endogenously included, it is possible to describe the connection between malnutrition and mortality rates as well as changes in the fertility rates due to some economic impacts.

When modelling malnutrition, one must determine both food re-quirements and effective demand. To be precise, food requirements should be derived from a population model, which is detailed enough to give information about the age and sex structure of the population. Effective demand, on the other hand, should be deter-mined for different income classes, since not only the quantity, but also the quality of food intake is different. This means that the model should include income distribution as well.

Indeed looking at changes in the mortality rates, one should
also consider effects of health care systems. As we are interested
in the food problem,and as this has not been emphasized in the
models studied, we have dropped this question for the present,
and have concentrated on the description of malnutrition and
mortality rate relationships in the different models.

In the Mesarovic-Pestel model-set (26,27) the food require-
ments are calculated on the basis of the population model, but no
income classes are introduced on the consumption side. Thus no
differentiation could be made between the consumption by poor
or rich. An average food consumption was compared to the require-
ments, and this affects the mortality in the model. The degree
of malnutrition produced in this way is simpler and probably an
underestimate of the malnutrition in the real system.

In SARUM world model (49) income classes are generated assuming
log-normal income distribution. Food consumption is investigated
in total calories and for five food groups in the different income
classes. However, considering that the poor's consumer-behaviour
is such that it doesn't result in their voluntarily consuming
less food than necessary to survive, a lower physical threshold
was set, ensuring that if the poor's comsumption falls below the
minimum necessary level,they reorganize their consumption pattern
to restore their food intake, as far as possible, to the thres-
hold. Since it is not always possible in reality, the model
becomes incomplete in depicting hunger. Since the model does not
include a population model (though some possible growth paths
were simulated) no feedback effects can be described either.

The third world model, MOIRA (29) describes the food markets
and consumption patterns more precisely than the two models dis-
cussed above. Consumption is determined for rural and urban popu-
lation in six income classes, however this consumption is expressed
only in terms of consumable protein. The model treats population
exogenously, thus effects of malnutrition remain out of the
scope of the investigations.

Three of the national models are important from this point of
view. BACHUE - Philippines (42) includes a very elaborated demo-
graphic model, and determines nutritional requirements on this
basis. Consumption is determined for rural and urban population
in ten income classes and compared to the requirements. Effects
on the mortality rates are also described. However, all prices
are taken exogenously in the model, which means that connections
between general economic development and consumption cannot be
described satisfactorily.

It is interesting, that the Korean Agricultural Sector Model,
(17, 44, 45) determines nutritional requirements on the basis of
a very detailed demographic model and calculates food consumption
for rural and urban population, but doesn't compare them. Thus
neither malnutrition nor its effects were established.

The LTSM model (25) for Egypt also includes a population model,
thus it would be possible to describe this problem-complex if
consumption had been modelled in more detail. However, at present
consumption is determined as a fixed given proportion of national

income and no income classes are considered. At this point the model could be revised, enabling it also to be used according to its original purpose - to be a prototype for developing countries.

We should also mention the Indian consumer demand projections by D.N. Basu (4) who estimated the consumption basket under some realistic assumptions. This investigation is not a part of a socio-economic model, but it can be of methodological interest - the changes in the consumption basket were a result of shifting population distribution among the expenditure classes.

Turning to modelling effects on fertility rates, one can differentiate between purely economic reasons, which can be modelled endogenously, and non-economic or not purely economic reasons with direct or indirect effects. Examples of economic reasons may be outmigration from agriculture because of unequal rural-urban income distribution, or industrialization and increased female labour participation. To the not purely economic reasons belong birth control, rural/urban migration policies and educational programs. This means that from the modelling point of view, rural/urban migration, education and population policies should also be explicitly included in the model.

In the investigated models we can find the following solutions:

Both SARUM and the Mesarovic-Pestel model-set consider this question by simulation runs assuming decreased fertility rates by effective birth controls, or as an effect of a higher standard of education, but don't include an education or migration sub-model.

The third world model we deal with, MOIRA, does include rural/ urban migration caused by income differences, but does not describe its effects on fertility rates.

The national models, BACHUE, KASM and LTSM are better from this point of view. BACHUE includes migration and education models, differentiating between rural, urban, skilled and un-skilled workers and investigates their effect on fertility, as well as effects of increased female labour employment and birth controls.

KASM's population model reflects effects of family planning programs, public health programs and the changes in fertility rate due to rural/urban migration. In the LTSM fertility rates are influenced by educational level, modern job opportunities for females of a child bearing age and population policy.

Though none of the above models has completely solved the problem of modelling the effects of economic development on population growth, they have produced some very good partial solutions.

Indeed, BACHUE-Philippines, for instance includes almost all relevant factors, its relative weakness stems from its relative simple economic model. Other models give perhaps better solution in the details, but are less comprehensive.

Finally, we should mention one difficulty in modelling this issue, namely the lack of data availability. Although this is

generally a burden in the modeller's job, it is particularly noticable here as income distribution statistics are seldom available.

2. Technological change and investments

Economic models, and therefore also agricultural models of the middle and long-run must face one unavoidable difficulty, namely, how to consider technological changes. The main problem is how to depict the behaviour of technological progress in its context of economic expectations and requirements. To achieve technical improvements one needs to invest in capital, in research, in new organizations, etc. The allocation of the investments depends mainly on the expected advantages, e.g. profitability.

Even in the short run it is difficult to handle the investment allocation, when the technology or possible technology-mixes are given. Models, like CHAC (12) are able to describe a great variety of technologies (CHAC includes 2000 cropping patterns!) but only investments can be considered that become effective in the same year. In the case of short-run disaggregated models there is some possibility of identifying profitability of investments with profitability of given technologies.

In the aggregate, however, this is impossible, since the technology-mix in a given industry is continually changing, and what we can measure, is only the sum or average profitability of this changing technology. In practice, what we can measure is the profitability of investments in given production sectors, or production units, but we cannot identify the profitability of an investment in a given technology.

Thus, looking at the long-run models, one can establish that the number of different technologies taken into account fall rapidly as the time horizon increases, and the aggregation level becomes higher. Very often only fertilizer use is considered, other effects of technological development (new machines, irrigation, land maintenance, new seeds, etc.) are determined implicitely or by a trend, which is to represent all these changes without differentiating between various concrete possibilities.

The Mesarovic-Pestel (26,27) model-set includes a technological change-module, but agricultural production is only affected by gross-capital. It is planned to improve the model at this point, a Clapham-Bose type model is being built in. This model describes the usage of land resources in crop production for five cropping types. The question of how this will be linked to other parts of the M-P Model (to investments, to livestock production, water, etc.) is open and a lot of reformulation of the original Mesarovic-Pestel agricultural model will be needed, since it deals at present only with aggregate agricultural production.

SARUM (49) considers technology changes by land maintenance investments, by additional investments in social infrastructure, by decreasing availability of water, by machinery investments and by fertilizer and pesticide usage, generally assuming diminishing

returns. Fertilizer response curves were estimated for different regions of the world, as well as costs of land and water development. For some crops maximum potential yields have been estimated, mainly according to agro-climatic constraints, but also productivity increase resulting from irrigation is considered. The allocation of investments is based on the expected profitability of the different sectors, so the identification of profitability of different technology-sets is not ensured. One problem is, that SARUM does not differentiate between governmental and private investments thus it does not differentiate between these different investment decision-patterns.

MOIRA (25) considers technological changes by specifying the production curve (which relates the level of production per hectare to the input mixture per hectare) in such a way, that any shift along the curve is only possible, if production techniques change. The maximum possible yield is taken as an asymptote, to which the actual yield approaches by enlarging the input per hectare. Fertilizer use was investigated explicitly, as well as substitution possiblities between labour and capital. The capital variable represents the "level of equipment", and so covers machinery, stocks of herbicides, drainage network, etc. Thus differences between the roles of these factors can not be established, their common development represents technical change and technical progress is seen as embodied in the capital and fertilizer inputs. Capital investment decisions and decisions about fertilizer use are explained by producer's income maximizing behaviour. No special attention was paid to governmental investments.

Two of the three national models, dealt with in the previous section, describe technological changes in a very simple way. BACHUE (42) pays less attention to the production side of the economy than to the consumption side, and takes investments as exogenous. Technical changes are taken into account only by some simulation runs, investigating effects of decreasing skilled and unskilled labour demand per unit of output.

In the Martos Wuu (25) model for Egypt gross investment is considered as the remainder of output after private and government consumption, and this is allocated by using exogenous policy variables. Yield increments are taken as a function of capital increments and additional material inputs (i.e. better seeds, fertilizer, veterinary services, etc.). As mentioned above, investments allocation is exogenous. Though the additional material inputs are endogenously determined from a short-term saving function, this is taken to be proportional to the net output increment of the last year. Thus there is a feedback between economic growth and technical progress, but this is not described in more detail than discussed above.

The KASM (1,7,44,45) model pays more attention to technology change than the models above, it contains a technical change component. "The production functions express crop yields as functions of (1) conventional variable factor inputs, supplied mainly by the private sector, and (2) structural change variables, including public investments in research, resource base improvement, credit and private investment, primarily in perennial crops. The structural change variables are considered to be

function shifters of production, as well as of factor demand[1]".
Government price policies and credit programs can be considered
as well as impacts of public investments in land and water
activities (irrigation, drainage, etc.). While the government's
role in technological change is stressed, the private sector
seems to be neglected from this point of view since private
agricultural investments are exogenous.

Looking at modelling technological changes we have to discuss
some agricultural sector models too.

The most direct confrontation of this problem is to be found
in AGRIMOD (19,20,21). It contains a generalized Mitscherlich-
Baule production function, relating yields of different crops
in different land regions to machine utilization expressed in
gallons of fuel per acre and to a fertilizer response curve,
Labour is not included as a productive factor. Machine utili-
zation is used in the model instead of machinery available,
since it turned out, that the U.S. agriculture has reached a
steady state, and it is not the availability, but the cost of
operating the available machinery which is the limiting factor.
The fertilizer response curve is constructed in such a way that
it can represent changes resulting from the introduction of
higher yield varieties, effects of improved fertilizers and
changes in the soil productivity, when their specific parameters
are changed. These parameters can be made time functions.
Non-capital inputs are taken into account as costs. Three types
of agricultural investments are considered which are used to
improve the land quality (irrigation, drainage, etc.). This
land improvement will also affect production if it is a change
in the land category too (13 of them are considered in AGRIMOD)
since it results in a shift in the land-quality distribution
which in turn influences production.

In a more indirect way, technological change is considered
in the model for Denmark by F. Andersen and P.E. Stryg (2).
It is a recursive linear programming model, in which technical
development is assumed to continue according to past trends. This
assumption, and the recursive character of the model, results in
changing the technical coefficients. The model endogenously
generates shifts in the farm size structure, and this is also
reflected by the parameters of the next period's model. Thus
the parameter changes also reflect the changes in the "average
technology" caused by the shift from smaller farms to bigger ones.

Another recursive linear programming model, that for the
State Niedersachsen in the Federal Republic of Germany by
H. de Haen (9) deals with other aspects of technical progress.
It considers different farm sizes, and investigates how invest-
ment decisions (based on maximization of expected profits)

1/ T.W. Caroll and M.H. Abkin: A System Simulation Model for Agri-
cultural Development Planning and Policy Analysis: The Korean
Agricultural Sector Model. Paper prepared for presentation at
the International Conference on Cybernetics and Society,
Washington, 1976.

influence machinery availability in the farm groups. Technical
progress is looked at as embodied in machinery aggregates. At
any time the technology mixture of capital utilization and labour
is determined by the marginal productivity of the factors and
on their availability. Technical changes, other than those
represented by machinery are implicitly included.

The agricultural planning models of socialist countries
consider technical progress by trend extrapolation, and adjust
investment, resource requirements and allocation according to
this projection. This can be done in two different ways: either
requirements, norms, etc., can be established, whose fulfilment
has to be ensured during the planning period, or a recursive
programming model generates technology mixes on the basis of
the projection and optimizes them for single years as well as for
longer periods.

The great variety of different approaches to model technological
changes show the difficulties of solving this problem. At this
point not data availability but the lack of appropriate theoretical
and methodological knowledge hinders modellers' work.

3. Environment and Agricultural Production

Environment and agricultural production are strongly inter-
related. Environment is a limiting factor to the agricultural
production as far as the extent of arable land and different
soil types, water availabiltiy for irrigation and climate
are concerned. But on the other hand, excessive productive activities,
e.g. overgrazing, deforestation, etc., and different agricultural
techniques, e.g. fertilizer and pesticide usage, irrigation,
drainage, etc., influence the quality and/or quantity of environ-
mental factors.

In modelling this interrelationship, the limiting character
is generally emphasized while the effects of agricultural
technologies on the evironment are usually neglected. This fact
can be explained very easily if we consider, that while the
first relationship has been always well known, mankind is only
now becoming conscious of the full interrelationship. Accordingly,
we possess less theoretical knowledge, and data in this field.
This has been a great drawback for modellers and has resulted
in the fact that the environment has been mainly considered only as
a limiting factor when modelling agriculture. Or alternatively,
when concentrating on environmental problems agriculture has
been considered in a non-detailed crude way.

Looking at the models which are covered by the study, the
picture is as follows:

At present agricultural production is described in the
Mesarovic-Pestel model-set (26,27) by using a land-use model,
also taking account of fertilizer usage and water availability.
Though the loadings can be computed, the effects of agricultural
technology on the environment are not modelled.

Also MOIRA (26,29) takes account of environmental limits
when considering soil fertilities, irrigation possibilities
and climatic conditions. When production possibilities are
calculated, fertilizer usage is considered. By assuming

that management behaves intelligently enough to avoid land degradation, soil erosion, water pollution, etc., the effects of production on the environment remain out of the scope of the investigations.

This problem is very similarly treated in SARUM (49) - they also calculate the upper limit to production according to agro-climatic zones taking account of land availability, land depletion and effects of rainfall, etc., and assume that management techniques are adopted which ensure that the fertility of the soil does not deteriorate seriously and that necessary investments are met. Thus the connection between agriculture and environment remains one-sided.

Also the national agricultural sector models consider environmental limits. In the linear programming models, which optimize agricultural production according to different criteria, land availability and qualities as well as water resources are taken into account. As examples we can mention the CARD-models (14) and the Hungarian Planning Bureau models (16,28). Fertilizers and pesticide usage is considered only from the technical and cost point of view. The problem is similarly treated in AGRIMOD (19,20,21).

Models are available for two regions which focus on environmental issues. In character these regions are diametrically opposite regarding their economic development - the USA and the Sahel-zone. But their problem is common - how man deteriorates his environment. In both regions, the problem becomes more and more acute and we have to realize that countries developing in one or the other way, (as far as a worsening environmental situation can be called development!) do not seem to care much about it, at least not in their modelling efforts.

The R.f.F model (41) for the U.S. deals with the environment as the source to meet resource requirements at different levels of population, national income and technology and investigates, if the nation could produce enough food, for exports as well, if fertilizer and pesticides usage were limited. They have found that this would be possible at somewhat higher agricultural prices. The model pays great attention also to the problems of solid animal wastes. These,like fertilizers and pesticides can enter surface or ground water, causing excessive algae which can be deadly for fish and unpalatable for man. The quantitites generated of these three pollutant factors are estimated as proportional to the agricultural output.

The model of the Sahel-zone by Picardi (35) describes the self-amplifying cycle of deterioration of rangelands, caused by permanent overgrazing, since the only chance for herdsmen to survive is to keep as many cattle as possible. The conclusion was that so far aid programs like veterinary services, and restocking programs have made the situation worse rather than better. The author has tried to find a solution to get out of this cycle.

As mentioned already, except for these two models, environmental consequences of agricultural production are in general not considered. It is worthwhile to mention that just the disaggregated models, which could describe this issue in more detail because

they describe agricultural technology in more detail fail to
do this. The possible reasons have been discussed at the
beginning of this section.

4. International relationships

International relationships are getting more and more important
in our social and economic situation and especially in the
food and agricultural area. Since countries have different
natural endowments, climatic conditions and resources (raw
materials, arable land, etc.) and since they are at different stages
of economic development, they are differently specialized in
their production and consumption structure as well. This fact,
among others, which we don't discuss here, increases the need
of international interactions. Thus not only more advantageous
production structures can be formed, but also consumer's
requirements can be met on a higher level. This latter fact is
extremely important in the food consumption. Some countries
are able to produce far over their own food requirements, some
others are not able to feed their population. In this situation
international trade, international food aid, building up of
international grain reserves, foreign investments and technical
aid etc.,have a crucial role.

Indeed, this fact is reflected in one or another way in all
international models included in this study.

Summarizing the situation in modelling international trade
relationships, one can very crudely establish that modellers
either strive after a precise description of international market
mechanisms, but assume that the markets are free competitive
ones, or if they relax on the free market assumptions, they
neglect the description of market-behaviors and simply accounts
for foreign trade in an ex-post way.

MOIRA belongs to the first group (29) as does the FAO World
Price Equilibrium Model (51) and the LINK model system (3). There
are however some important differences. MOIRA, dealing with only
one category of food, namely with consumable protein, solves
the world price for this single commodity, bringing into equili-
brium total food consumption and supply. The balancing role of
stock piling activities is also considered. World prices affect
producers' decisions via domestic price levels.

The FAO model generates equilibrium world prices for eighteen
agricultural commodities and twenty eight regions under similar
assumptions. This model is, however, very simplified in des-
cribing production and consumption decisions on the national level.
Since the model deals with more commodities, substitution effects
have also had to be taken into account. This was done, however,
with fewer commodities and regions.

The LINK-project uses a special tool in calculating world
equilibrium prices, namely the matrix of market shares. This
matrix describes for each country covered by the project, the
shares of total imports supplied by the other countries. The
economic assumptions are very similar to those of the models
discussed above but there are essential differences as well.
The FAO model and MOIRA deal with the foreign trade of special
commodities and pay great attention to effects of price and income
policies of governments. In the LINK project total trade flows
are dealt with and price policies are not investigated.

To this first group also belongs the Takayama-Hashimoto model (50), which like the FAO model determines world prices for several agricultural commodities. But the model is methodologically different, the FAO model is an econometric one, the Takayama Hashimoto model uses a quadratic programming, algorithm. This methodological difference has economic consequences - the monetary system of the Takayama Hasimoto model is not closed.

To the second group of models, which don't describe market mechanisms belong to the two global models: the Mesarovic-Pestel model system (26,27) and SARUM (49).

The Mesarovic-Pestel models represent world trade by a simple ex-post iterative allocation mechanism, which is able to introduce trade policy impacts, but is essentially a non-causal description. The method is basically the following: total export supplies and demands are generated region by region and the allocation occurs according to some rules but mainly according to purchasing powers. Prices are used only as a means of accounting and are not changed during the iteration.

SARUM represents world trade by a matrix of biases which reflects deviations from fixed proportions, set by observed trading patterns according to proportions of total outputs of the regions. The existence of these deviations is not explained in the model, however.

Turning to the next type of international relationship, to food aid, we can mention MOIRA, the only complex model, which investigated if hunger could be alleviated in the developing countries by food aid, financed by rich countries. It was shown that food aid in itself, can't solve the problem.

The main objective of international grain reserves is to ensure a stable grain supply. But besides that, grain reserves can play a stabilizing role with respect to the grain prices as well. The grain reserve models, included in this study [by Eaton et al (11), G. Johnson (15) and Reutlinger (140)] concentrate only on the first role of the grain reserves mentioned above, but neglect the second one.

They determine optimal grain reserve sizes, under alternative, (and sometimes rather abstract and simplified) assumptions about production and consumption, risks, etc., but don't consider how reserves affect production and consumption via prices. The other shortcoming of these models, is that they don't consider any international interactions of the stock-building process, reserves are always looked at as global or independent national ones. In such circumstances reserves have real contact neither with the real economies, nor with national policies.

The only model in our example, which explicitly deals with foreign investments even if in a very simple way, is the Kaya et al Two-Level Multination Model (17). It emphasizes the role of private overseas investments and official development assistance, which are very important for the countries (South East Asian countries, U.S.A., Australia, Japan and EEC countries) covered by the model. Private overseas investments as well as official development assistance are determined as functions of gross domestic product and exogenously fixed parameters. No attention was given to explaining these policies in more detail.

Finally we have to mention briefly the modelling efforts to depict the connections between countries of the world by input-output models. In principle, these models within their strong methodological limitations could reflect different international economic relations, discussed above in detail. There are several such projects going on, our study includes A. Bottomley's model. This model covers the world country by country by national input-output models. Three variants of the model exist, i.e. the model has 10, 20 and 60 sectoral disaggregations. Although the model contains an enormously large data base, it still lacks some appropriate data so a lot of guesswork has to be done, which can cause the results to become rather untrustworthy. The essentially static construction of the model makes the results of any projection experiments doubtful.

PART II

Some special issues of modelling in food and agriculture systems

Introduction

The notes are composed of two parts: first, major characteristics of the model are listed and these are then followed by a short discussion of the model:

Some of the characteristics require short explanations:

o   Generalization level: outlines the highest level of generalization.

o   Aggregation: outlines the representative aggregates which the model operates.

o   Usage: outlines a list of possible uses and intended or real applications of the model.

o   Time: outlines some of the following characteristics: reference years, data base, time horizon and projection periods. All models included in the study are based on annual data.

o   Validation: outlines attempts to ensure the verification and validation of the model.

The structure of some models is also depicted graphically, to give a quick and clean overview about the main relationships of the variables. A "reference model structure" (see page 15) was used to allow an easy comparison of different models. As we tried to keep the figures simple, no time lags appear, the arrows means only, which variable is used to calculate another one. Arrows crossing the dotted box around the "market part" of the figure are places where government policies can be introduced. More information about the concrete policies and the contents of the individual boxes is given in the "short discussion" on each model.

The models have been grouped as follows:

1.   International and world models, and

2.   National models.

Both groups have several subgroups:

a.   Economic and socio-economic models.

b.   Economic and socio-economic models focussing on the F & A system.

c.   Agricultural sector models.

d.   Agricultural commodity models. Here we have to mention that no national single-commodity models are included since they are of partial interest to our present investigations.

A list of the models is given overleaf. The numbers in brackets are the reference numbers.

I.   INTERNATIONAL AND WORLD MODELS

    A.   Economic and Socio-economic Models:

        1.   System Analysis Research Unit Model (SARUM) (49)

        2.   Mesarovic-Pestel Model Set (26, 27)

        3.   Project LINK (3)

        4.   Kaya et al. Two-Level Multi-Nation Model for Development Planning (17)

    B.   Economic and Socio-economic Models Focussing on the Food and Agriculture System:

        1.   Model of International Relations in Agriculture (MOIRA) (29)

        2.   Picardi: A Model for the Sahel (35)

        3.   Bottomley: World Agricultural Input-Output Model (6)

    C.   Agricultural Sector Models:

        1.   FAO World Price Equilibrium Model (51)

        2.   Takayama-Hashimoto: World Food Economy Model (50)

    D.   Agricultural Commodity Models:

        1.   Rojko-Schwartz: GOL-model (43)

        2.   Schmitz-Bawden: A Spatial Price Analysis of the World Wheat Economy (47)

        3.   Reutlinger: A Simulation Model for Evaluating Worldwide Buffer Stocks of Wheat (40)

        4.   Eaton et al: A Method to Size World Grain Reserves. (11)

        5.   Johnson-Sumner: An Optimization Approach to Grain Reserves for Developing Countries (15)

II.   NATIONAL MODELS

    A.   Economic and Socio-Economic Models:

        1.   Rodgers et al: BACHUE - Philippines (42)

        2.   Martos-Wuu: LTSM - Egypt (25)

        3.   Ridker: R f F - Model for the U.S. (41)

        4.   Gupta-Bhakta: An Economic Model for Argentina (13)

        5.   del Rio-Klein: Macroeconomic Model for Mexico (10)

B. Economic and Socio-Economic Models Focussing on the
    Food and Agriculture System:

    1. Rossmiller et al: Korean Agricultural Sector Model
        (1, 7, 44, 45)

    2. Manetsch et al: Nigerian Agricultural Sector
        Analysis (23, 24)

    3. Goreux-Manne: CHAC Model for Mexico (12)

C. Agricultural Sector Models:

    1. Heady et al: CARD Linear Programming Models (14)

    2. Monypenny: APMAA '74, Model for Australia (22,23)

    3. Soviet Models for Optimization of National Plan
        of Public Purchases of Agricultural Commodities
        (36)

    4. Hungarian National Planning Bureau Models for
        Agriculture (16, 28)

    5. de Haen - Heidhues: Recursive Programming Models
        to Simulate Agricultural Development in West
        Germany (9)

    6. Andersen-Stryg: Interregional Recursive LP Model
        for Danish Agriculture (2)

    7. Singh, I: Recursive Programming Models for Indian
        Agriculture (48)

    8. Pandey-Takayama: Temperal Equilibrium Analysis of
        Some Commodities in India (32)

    9. Pant- Takayama: An Investigation of Agricultural
        Planning Models: A Case Study for India (33)

    10. Bertele-Brioschi: The Italian Food Sector: An
        Input-Output Model (5)

    11. Kulshreshtha-Holub: An Aggregate Econometric Model
        of Canadian Agriculture (18)

    12. Ruch et al: A Long-term Simulation Model for
        French Agriculture (46)

    13. Levis et al: AGRIMOD for the U.S. (19,20,21)

    14. Ray-Heady: Simulated Effects of Alternative Policy
        and Economic Environments on the U.S. Agriculture
        (39)

    15. Ray-Moriak: POLYSIM for the U.S. (37,38)

    16. Nelson-Cochrane: Economic Consequences of Federal
        Farm Commodity Program (31)

    17. Parikh: India in 2001 (34)

    18. Basu: Consumption Pattern and Life Style in 2000
        in India (4)

    19. Clapham-Bose: Land Resources and Food Production
        Model for the Indian Subcontinent (8)
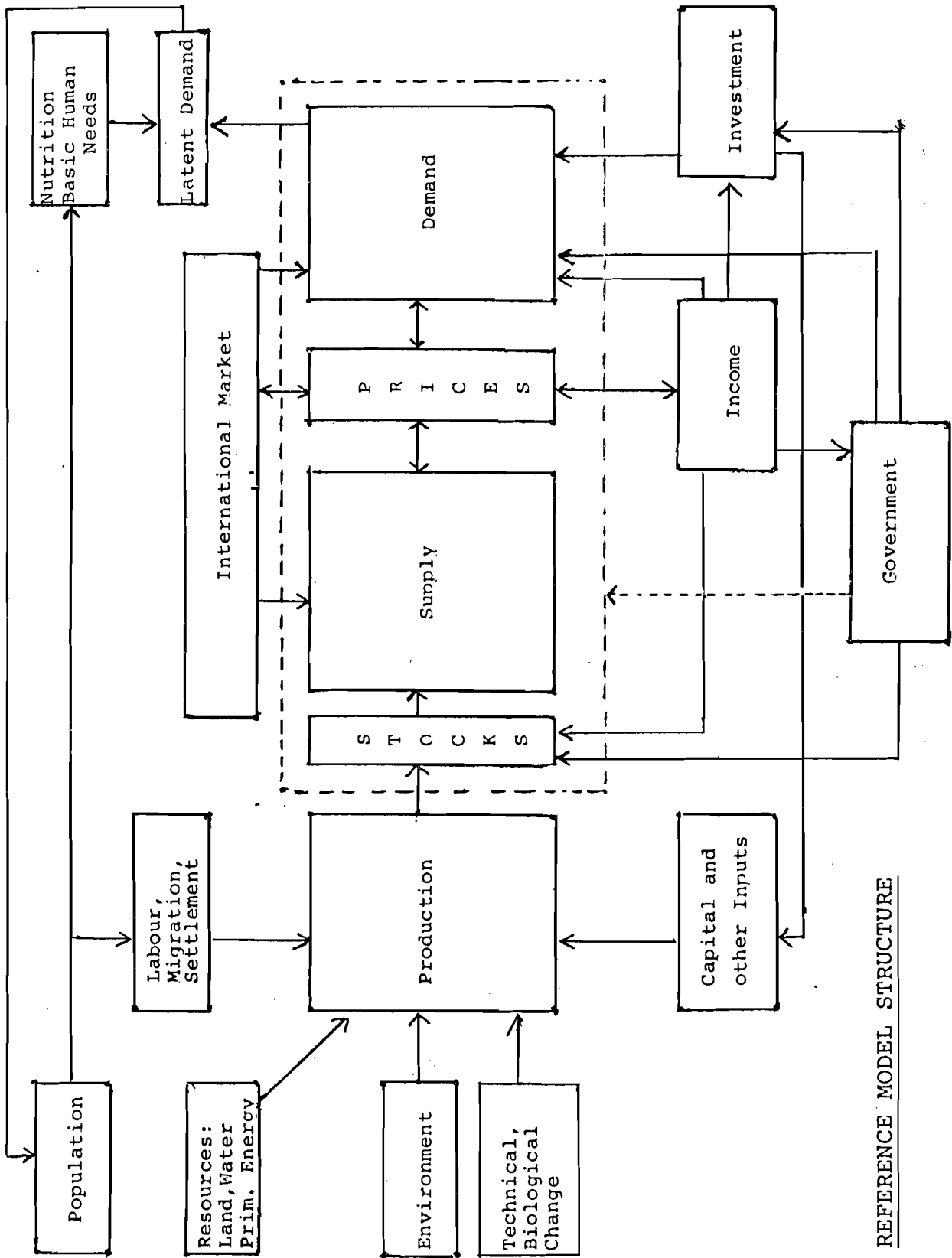
REFERENCE MODEL STRUCTURE

I. INTERNATIONAL AND WORLD MODELS

I.A. Economic and Socio-economic Models

Model:	System Analysis Research Unit Model (SARUM) (49)
Coverage:	World by three regions (USA; OECD plus the block of socialist countries excepting the USA, countries of the third world including mainland China).
Generalization level:	Regional and global socio-economic development.
Aggregation:	Three regions, ten sectors, a number of commodities, income classes (The income classes can be generated for different purposes, for different regions).
Method:	System simulation, input-output, econometric.
Type of system:	Dynamic, deterministic/stochastic.
Usage:	Projection of food situation and mineral resources with slackening population growth for all regions and with continuously expanding population for the third region (predictions under other assumptions have been carried out too).
Time:	Base year 1968, projections for 90 years.
Validation:	Calibration, sensitivity analysis.
Short discussion:	The modelling effort attempts to introduce neo-classical economic theory into the system dynamic approach. The method has been refined; SARUM is more disaggregated than the first system dynamics models: the three regions', commodity groups have been taken into account and the demand is determined for different income classes. Also an allocation mechanism was used for determining investments using the expected marginal profitability of the different sectors.

Markets are represented by changes in stocks. If stocks (defined as differences between supply and demand) are above the desired level, prices fall and if stocks are below, prices rise. World trade is represented by a matrix of biases which reflects the trading patterns between the regions, based on the proportions of their production levels and also the deviations from the proportions, thus this matrix attempts to indicate strategic, political and economic barriers of trade.

Ten sectors of the economy are included. The agricultural sector is more disaggregated than the others. The model deals with population, minerals and energy-depletion; pollution and the energy sector. The model can describe agricultural production in two alternative ways: either by grain

equivalents or by different commodity groups (un-processed cereals and starchy roots, unprocessed livestock products and fish, processed livestock products and fish, unprocessed fruits and vege-tables, processed fruits and vegetables). , The production function is of the Cobb-Douglas type with constant returns to scale. Capital, arable land, labour, irrigation, fertilizer and dis-embodied technical progress are viewed as produc-tion determining factors.

Some simulation results are available but not dis-cussed in detail.

The model contains many simplified assumptions, especially about market mechanisms. No attention is paid to distinction between private and government activities.

SARUM: DIAGRAM DESCRIBES ONE

REGION'S MODEL

POPULATION

RESOURCES:
land, Water Prim.
Energy, minerals

LABOUR
MIGRATION

ENVIRONMENT
CLIMATE

TECHNICAL
BIOLOGICAL
CHANGE

PRODUCTION
10 prod. sectors
CD & CES functions
food production
determined in grain
equivalents
resource and flow
limits, and also
I/O coefficients
act as limits.

CAPITAL AND
OTHER INPUTS
(irrig.,fertilizer)

INTERNATIONAL MARKET

SUPPLY
Stock variable
determine
how much will be
released from stocks
Initial prices are
calculated by pro-
duction costs.

P
R
I
C
E
S

DEMAND
Food demand
determined for
five food cate-
gories and
different income
classes.

INCOME
distribution
incl.

INVESTMENT

Endogenous

Exogenous

Model: Mesarovic-Pestel Model Set.   (26) (27)

Coverage: World by regions.

Generaliza-   Regional and global socio-economic development.
tion level:

Aggregation: Heterogenous: appropriate to time horizon, region
                  or country and to issue under investigation.
                  (see "usage" and "time")

Method: Multi-level, hierarchical systems approach.

Type of   Dynamic, deterministic.
system:

Usage: Policy - and problem - oriented projection; in-
                  puts necessary for the model are specified
                  through scenario design: for global system simul-
                  taneously or for separate regions (nation).

Time: Data base used begins with 1964 or earlier.
                  Horizon issue-dependent (15 to 50 years).

Validation: Ex-post prediction and sensitivity analysis, attempt
                  to increase plausibility of alternative future
                  scenarios through consultation with experts.

Short   The so-called second generation model of the
discussion: Mesarovic-pestel project resulted partly from sub-
                  regionalization of the original world model and
                  partly from specialization on problem-bundles.
                  Initially the model operated on ten regions; now
                  it includes up to 25 regional models some of which
                  are national models (e.g., USA, Canada, West-Germany,
                  France, England, Mexico, Venezuela, Iran,
                  Saudi-Arabia and Egypt). This subregionalization
                  makes more reasonable policy investigations possible
                  insofar as political units and regional units are
                  more closely connected in the second generation
                  models than in the earlier ones. One can also dif-
                  ferentiate between several modules: energy, food,
                  economy, technology, investment goods, population
                  and some resources. Efforts to link modules on
                  different levels of aggregation for the purpose
                  of focusing on special issues within the world
                  system analysis are continuing.

                  The Mesarovic-Pestel group's efforts in the area
                  of food and agriculture (F & A) have two goals:
                  (1) to include F & A as an objective and as a
                  constraint in global development analysis and
                  (2) to develop national food policy models, begin-
                  ing with the USA.

The following discussion roughly describes the representation of F & A in the world model. At present food production is aggregated into total food production as a fraction of total agricultural production; food requirements are deduced from the population model and energy requirements for food production are taken into account in the energy model, etc. Feedback effects are introduced (e.g., protein and caloric deficiency affects age-specific mortality rates in the population model). For the purposes of analyzing worldwide F & A interactions it will be necessary for the modellers to introduce additional detail.

Until August 1976, two topics have been investigated: (1) land resources and production and (2) the food trade problem. The land resources and crop-production will be depicted in more detail. Much effort has been invested to develop adequate production functions. To date four different types can be used in the global model. The land resources and production model will be linked with the economic model, population model, food use model, livestock production model, climate and water model, consistent with the approach outlined above.

Since at present world trade is represented by a simple iterative allocation mechanism (year-by-year) with some possibility of introducing policy impacts, this will be described in a more realistic way.

In spite of the enormous amount of data collected by the group (e.g., over 50 agricultural trade commodities bilaterally nation-by-nation and annually from 1964 on and practically all relevant FAO material) the wellknown data gaps force certain compromises.

It is necessary to emphasize that the F & A efforts of the Mesarovic-Pestel group are still being developed, improved and comprehensive publications are rare. Therefore it is difficult to get (and give) a closed picture about the project.

Model: Project-LINK. (3).

Coverage: Thirteen developed countries, (socialist coun-
                 tries in one group), twelve developing countries,
                 four developing regions, not including countries
                 from the previous group.

Generaliza-   Economies and trade relations of countries and
tion level: regions.

Aggregation: Various in different models (all models are multi-
                 sectoral macro-models).

Method: Econometric

Type of   Dynamic, deterministic.
systems:

Usage: Prediction of international trade relationships
                 assuming a) higher import absorption by Middle East
                 oil exporting countries; b) inventory recession in
                 the U.S., U.K. and Italy; c) higher commodity export
                 prices for developing countries and d) constancy
                 of world oil prices at 1973 level.

Validation: All models are estimated, ex-post predictions
                 were carried out.

Time: Different reference years at estimation of the
                 different models. Forecasting for the years
                 1967-70-71.

Short   The problem of linking national models was solved
 discussion: by the world trade matrix, which represents the
                 market shares, having the general element
                 $a_{ij} = x_{ij}/\Sigma_i\ x_{ij}$, where x_{ij} is the total merchandise
                 exports from region i to region j. In order to
                 allow a_{ij} to change over time it was made depen-
                 dent on the import price index of the country j,
                 (i.e. on the weighted average of the export prices
                 of all countries supplying the j-th market) and on
                 the prices of exports from country i to country j.
                 It was assumed, that the elasticity of the real
                 market share with respect to relative export prices
                 is the same for all suppliers in the j-th market.
                 It was further assumed that the traded goods are
                 homogeneous (i.e. in the absence of transportation
                 cost and other trade barriers there is only one
                 price in the world market).

                 No account was taken of market influencing factors
                 other than prices and capacity utilization.
                 (Tariffs, transportation, etc. are excluded from
                 the investigation).

Three so-called LINK-exercises have been carried
out (forecasting for the years 1969-70-71). In the
first exercise, (mini-LINK) world trade was set
equal to the sum of imports but the import total
did not equal the export total. The question to be
solved was at which level of world trade the models
generate equality of imports and exports. In this
exercise no price effects were examined. Price
effects were introduced in the midi-LINK exercise
where it was assumed that the import price index
for country i moves proportionally to the index
of world export prices. Thus for different levels
of world trade, different world and import price
indexes were used, and in this way the equality of
the sum of imports to world trade was found. In the
maxi-LINK exercises the matrix of trade flows was
introduced, and equality of the import sum and the
export sum was ensured by an iterative procedure.
(In practice, the world trade matrix does not auto-
matically quarantee this fact.)

Of course the methodology described refers to the
maxi-LINK exercise.

Model: Y. Kaya, A. Onishi, and H. Ishitani: A Two-Level
                  Multi-Nation Model for Development Planning. (17)

Coverage: Sixteen industrially advanced nations and fourteen
                  developing countries. The industrialized countries
                  are Japan, Australia, U.S., Canada and West-European
                  countries, the developing countries are Asian ones.
                  China is not included.

Generaliza-   Developed and developing market economies.
tion level:

Aggregation: Macro-models on GDP balances, three production-
                  sectors.

Method: Econometric.

Type of   Dynamic, deterministic.
system

Usage: Projection of economic relations between indus-
                  trially advanced countries and the developing
                  countries.

Time: Data base: 1960-71, prediction for 1985.

Validation: Parameters estimated by econometric methods.

Short   The first level of the model is composed of six
discussion: sub-sectors: production; expenditures on real
                  gross domestic product; profits and wages; prices;
                  expenditures on nominal gross domestic product;
                  official development assistance and private over-
                  seas investment.

                  The model is specified differently for the indus-
                  trialized and for the developing countries (and
                  some distinctions are made for OPEC-countries
                  as well). For developing countries the model is
                  pushed by production, for industrialized coun-
                  tries it is pulled by demand.

                  International interdependencies are represented
                  not only by the foreign trade, but also by private
                  overseas investments. The official development
                  assistance (a function of gross domestic product)
                  from the industrially advanced countries is dis-
                  tributed among the developing countries according
                  to temporary fixed ratios and exogenous policy-
                  parameters. The distribution and flow of private
                  overseas investment is also a function of GDP
                  (Gross Domestic Product) and different exogenous
                  controllable policy parameters.

                  The second level of the multi-nation model is a
                  series of three-sector production models.   The

sectors are: agricultural production, manufacturing production and other sector productions. The two levels are connected by the GDP and by exports. (During the preparatory process of these sectoral models the agricultural situation and the interdependencies between agriculture and industry have been studied for selected developing countries in Asia.)

The second level represents simply the three-sectoral distribution of the GDP production and exports, from which the sum in the first level is included.

A forecast run was carried out, taking 1970 as base year and 1985 as target year. The oil-shock in 1973 -74 has been simulated, and after this period 1974 oil prices have been fixed. These results are discussed.

I.B. Economic and Socio-economic Models
Focussing on the Food and Agriculture System

Model:	MOIRA: A Model of International Relations in Agriculture. (29)
Coverage:	World by 106 geographical units.
Generalization level:	Market and non-market economies.
Aggregation:	Agricultural and non-agricultural sectors; consumable protein per hectare per region; per capita consumption per income class in the sectors.
Method:	Econometric.
Type of system:	Dynamic, deterministic.
Usage:	Analysis and prediction of food-economy at different policy assumptions.
Time:	Data base: 1965, predictions: 2010.
Validation:	Cross-section estimates.
Short discussion:	The model depicts food production, demand, the channels between food supply and demand as well as buffer stocks.

The equations of the model are directly linearizable with respect to the unknown parameters (DLUP) which ensure not only the possibility of adequate estimates but a reasonable interpretation too. Production functions are given for production of food from land. Fish production is estimated exogenously.

Production of protein is expressed in terms of a land production function and of the intensity of land use functions. The consumption function is specified in a form which takes into account different income classes. The model is able to generate equilibrium world prices from year to year under free market assumptions. The countries are linked by the common world market for food imports and exports.

Two policy alternatives were examined to find possibilities for eliminating or reducing the extent of hunger in the period 1975-2010. These policies are: [1] redistribution of the available food in the world; [2] stimulation of the food production in the developing countries. It was found that though food aid will remain an important factor in the future, the growth of food production in the developing countries at a stable, somewhat higher world market price level would bring us closer to the alleviation of hunger if a more equal income distribution could be realized.

Short
discussion:
cont.

The main limitation of the model is that it deals
with only one kind of food: consumable protein.
All different food types are converted to this
measure. This simplifies the economic treatment
of the production and markets, but has the draw-
back that all operations of the model are abstract
in the sense that consumable protein is produced
and traded in the model, rather than specific
crops and livestock products. Because of this
limitation price movements of different commodities
and diet structure problems cannot be described.

NUTRITIONAL NEEDS

LATENT DEMAND

DEMAND

INVESTMENT

INTERNATIONAL MARKET AND STOCKS

P R I C E S

INCOME
6 Income Classes

SUPPLY

GOVERNMENT

POPULATION

LABOUR MIGRATION

PRODUCTION of consumable protein

RESOURCES:
land, water

CAPITAL AND OTHER INPUTS

MOIRA

┌─ ─ ┐ Endogenous variable
└─ ─ ┘
┌───┐ Exogenous variable
└───┘
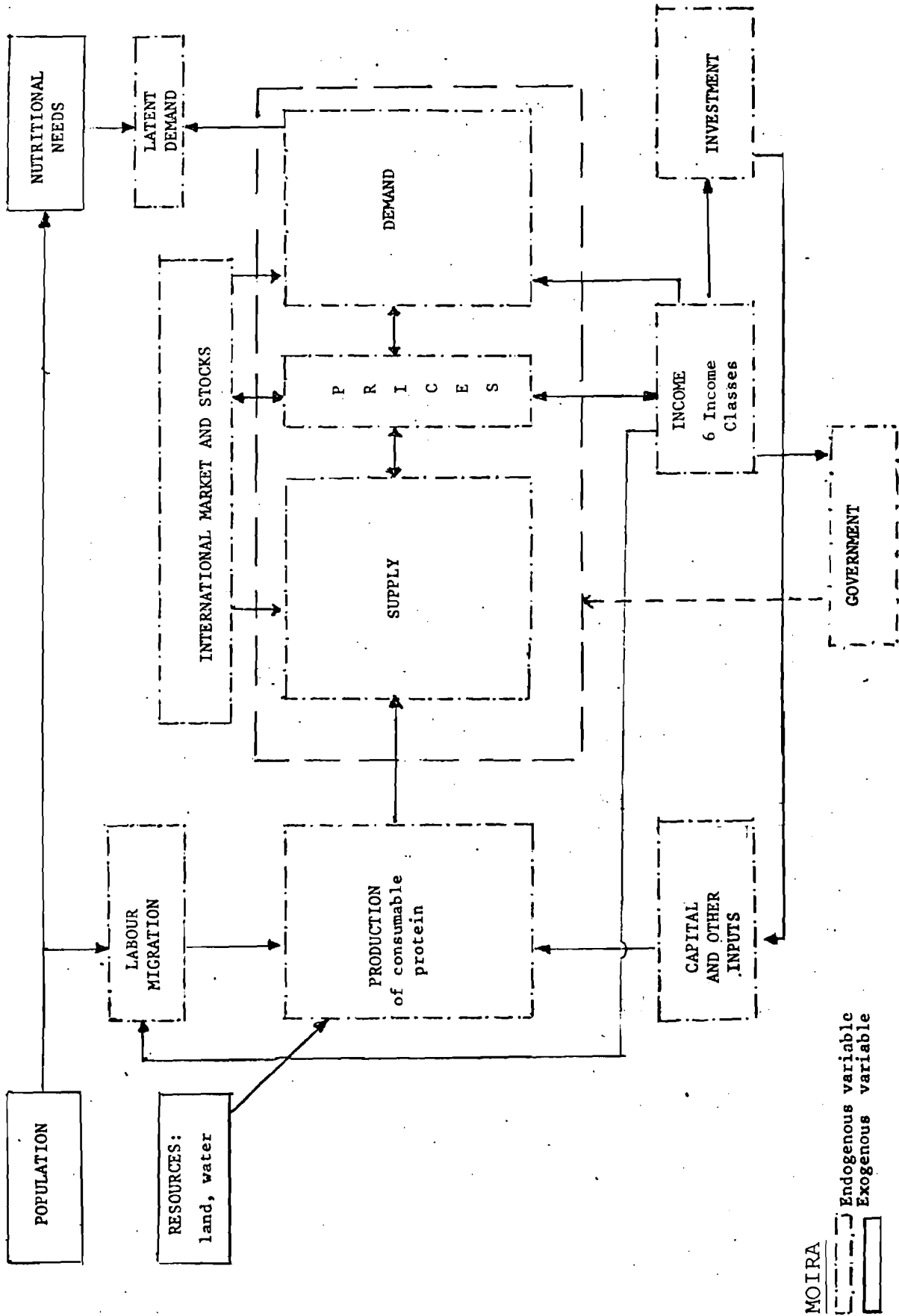
Model: A.C. Picardi, W.W. Seifert: The Tragedy of the
                 Common in the Sahel. (35)

Coverage: Sahel-Zone.

Generaliza-   Socio-economic structure.
tion level:

Aggregation: --

Method: System dynamics.

Type of   Dynamic, deterministic.
System:

Usage: Projections of alternative futures for solving
                 social problems.

Time: Data basis 1960-70, horizon 2060.

Validation: Weak, some data used from 1960-70.

Short   The agricultural model of the Sahel zone focuses on
discussion: a special problem on the dynamics of pastoralism,
                 a problem crucial to the region. A closed chain
                 of actions demonstrates that the short-run benefits
                 to the individual herdsman contradict to the long-
                 run interests of the tribe. The herdsman increases
                 his stock to ensure against hunger for him and his
                 family.

                 Each individual herdsman overstocks, the range is
                 overgrazed and as a result all must share the costs
                 of overgrazing. These behaviours are passed on
                 through succeeding generations so the cycle begins
                 again. The aim of the simulation was to find a
                 way out of this cycle.

                 The basis of investigations was the pastoral zone
                 of Niger. Here it was shown that so far aid pro-
                 grams have made the situation worse rather than
                 better, e.g., veterinary services, in order to
                 decrease the death rate of the livestock have
                 intensified the above-mentioned cycle. The authors
                 propose a combined technical-economic-and-cultural
                 program to solve the problem given stabilization
                 of birth rate.

Model:	A. Bottomley et al: A World Agricultural Model: An Input-output Research Proposal. (6)
Coverage:	World, country by country.
Generalization level:	Economies of nations.
Aggregation:	Nations, 10, 21 resp. 60 sectors.
Method:	Input-output.
Type of System:	Static, deterministic.
Usage:	Prediction of international interdependencies.
Validation:	None.
Time:	Basis years different, predictions for 1980-90.

Short discussion:

For each country the authors constructed 10 x 10 I/O tables, which are then disaggregated into 21 x 21 tables. Six agricultural commodity groups, fishing, three kinds of fertilizer, pesticides and processed foods and as input factors nine kinds of land are considered.

An international trade matrix is needed, which will be elaborated only for the more aggregated 10 x 10 model. Some of the difficulties in constructing such a system are noted:

1. I/O tables don't exist for all countries. Some "average" tables were constructed using existing I/O tables of countries, which have a similar economic structure.

2. The existing tables have been aggregated in different ways so they must be revised for consistency.

3. Existing tables have been constructed using different price systems.

4. All technical coefficient matrices must be updated (and the existing ones refer to different years).

5. A large problem is the lack of data which is necessary to such a disaggregated system.

Because of these problems, the system becomes increasingly unreliable.

The project is still in process. According to recent information the model will be elaborated in a 60 x 60 version.

I.C. Agricultural Sector-Models

Model:	A World Price Equilibrium Model (Multi-commodity multi-region case). (51)
Coverage:	World by twenty-eight regions.
Generalization level:	Trade of commodities between regions.
Aggregation:	Supply, demand and price of 18 agricultural commodities.
Method:	Econometric.
Type of system:	Static, deterministic.
Usage:	Projection of world market equilibrium prices for commodities under free market assumptions, considering some policy changes also.
Time:	Data basis 1969-70, projections for 1980.
Validation:	Sensitivity analysis.
Short discussion:	This study was the first attempt to project world market equilibrium prices. The structure of the model is as follows:

For each commodity and country, domestic price is determined as a function of the world market price, domestic price support levels and transportation costs. Supply, calculated on the basis of the commodities' own price elasticities, at given domestic prices induces the value added for agriculture, which in turn affects the labour transfer between agriculture and other sectors. As population is exogenously given, non-agricultural population can be calculated. Non-agricultural value added is estimated by taking into account the changed proportion between the agricultural and non-agricultural population. With an estimation of the value added for agricultural and non-agricultural sectors, one can estimate the disposable incomes. Having estimated incomes, prices and population, demand for each commodity and each country can be determined. As the sum of supply and demand on the world level is assumed to equal zero, world prices are determined as an approximation of an equilibrium. These new world prices affect domestic prices, and a new iteration begins for the same year.

In this model only direct price elasticities have been considered; the equilibrium prices on the different commodity markets are determined independently. In another model variant (with less

Short
discussion
cont.

commodities and regions) cross price elasticities were also introduced. The results show that the original changes in prices were dampened. Smaller differences were caused by the introduction of income feedbacks on individual commodities.

With different model variants, eight different projections are presented. Three of them consider policy changes also, e.g., enlargement of the EEC, increased protection, and no domestic price supports. The results are discussed in detail.

INTERNATIONAL MARKET

DEMAND

P
R
I
C
E
S

SUPPLY

18 agricultural
commodities

INCOME of agric.
population

NATIONAL INCOME

GOVERNMENT

LABOUR: agric./non-
agricul.
MIGRATION

FAO COMMODITY WORLD PRICE

MODEL

Endogenous
Exogenous
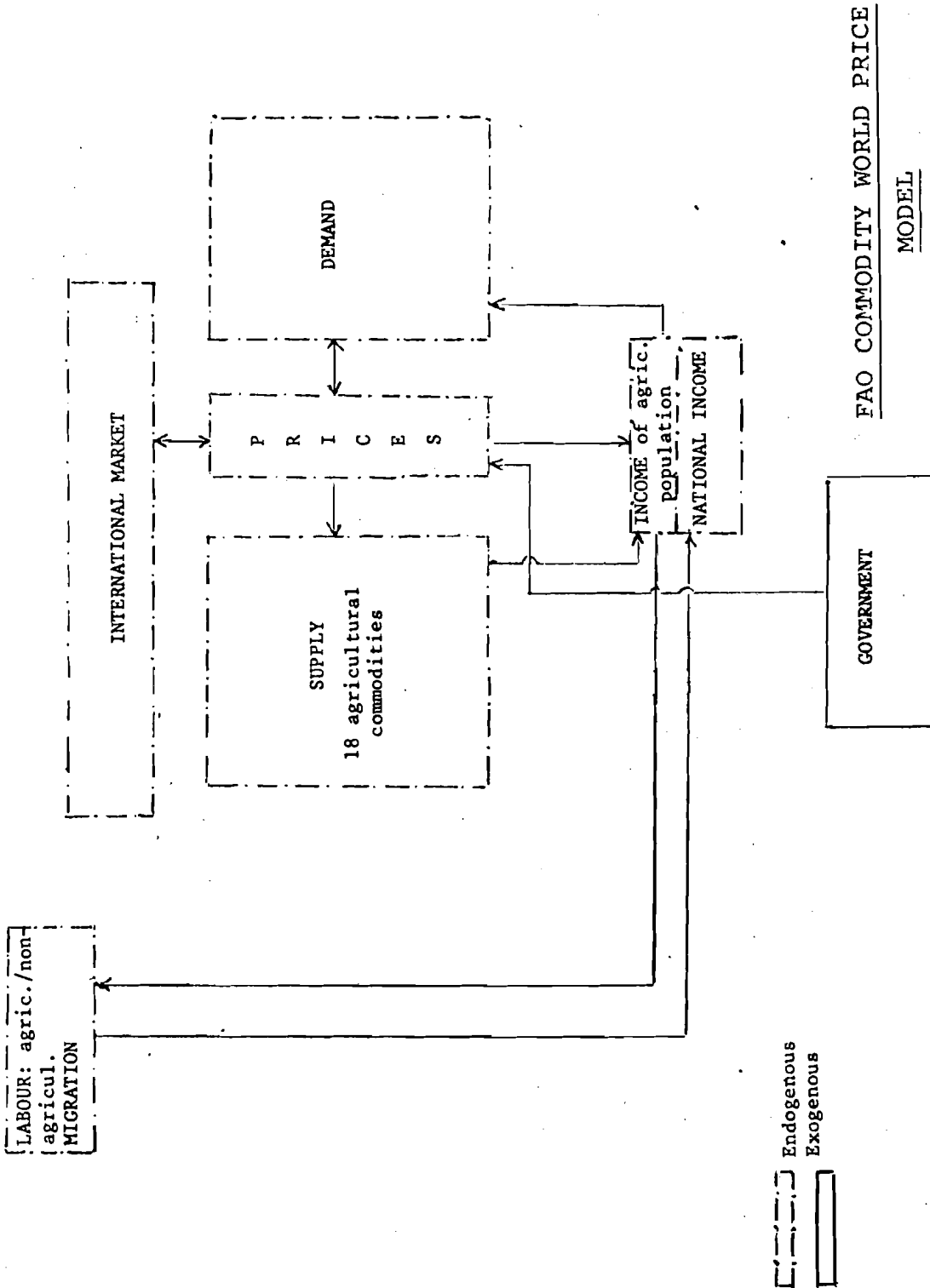
Model: T. Takayama, H. Hashimoto: The Eight Agricultural
Commodity and Twenty Region World Food Economy
Model for 1974, and a Two-period (1973-74) Model
for the Eight Commodity Two Region Case. (50)

Coverage: World by twenty regions.

Generaliza-   Trade of commodities between regions.
tion level:

Aggregation: Eight commodity groups.

Method: Quadratic programming.

Type of   Static, deterministic
system:

Usage: Prediction and simulation of trade flows in the
short run, (impacts of different stock sizes on
prices).

Validation: Some simple ex-post checking comparative calcul-
lations.

Time: 1973-74 cropping year, resp. 1973 and 1974
separately.

Short   While constructing a quadratic programming tableau,
discussion: demand and supply functions for the eight commodities
have been estimated for each region. For commodities
for which supply or demand functions could not be
estimated, fixed quantities were used. Transporta-
tion costs are taken from other sources. Demand
and supply price differences (here defined as
wholesale prices and farm prices, respectively)
were available for only three countries, so for
other regions, U.S. differences have been used.

The demand functions have been estimated in per
capita terms. By multiplying per capita amount
by population size the region's level was obtained.
When estimating supply and demand functions,
prices were taken as exogenous. Cross-price effects
were considered. For some commodities (e.g. wheat)
the demand for such uses as food, feed and seed
was estimated separately and then total demand
was derived. (The procedure by which this was
done is not clearly elaborated.) Relatively
few supply equations were estimated, and those
which were made, were done only as a function
of the current prices.

Carry-over quantities were taken into account.
Assuming different U.S. stock sizes, the model
was solved for optimum prices, (five cases are
discussed).

Short
discussion:
cont.

In the two-period version of the model the carry
over quantities become endogenous. The model is
solved only for two regions, (USA and the rest of
the world) for 1973 and 1974 separately.

The model describes a very simplified world market
of commodities. If it is solved for one year,
the model can't reflect any behavioral reactions.
The transportation costs are not accounted for;
this causes a leakage in the monetary system of
the model. Those money flows connected with
transportation have neither starting points nor
endpoints.

I.D. Agricultural Commodity Models

Model:	A.S. Rojko and M.W. Schwartz: Modelling the World Grain-Oilseeds-Livestock Economy to Assess World Food Prospects. (43)
Coverage:	World by twenty seven regions (eight developed, three centrally planned and sixteen developing regions).
Generaliza-tion level:	Trade relations in the grain-oilseeds-livestock sector.
Aggregation:	Eleven commodities.
Method:	Programming.
Type of system:	Static, deterministic.
Usage:	Projection of the grain-oilseed-livestock economy at exogenously given population and income growth; at continuing technology improvement, assuming normal weather, small fluctuations in stocks, and that present agricultural and trade policies will continue.
Time:	Basis year 1970, projections for 1985.
Validation:	None.
Short discussion:	The modellers intend to construct a linear (or quadratic) programming model, from which the objective function is not yet specified. The following constraints have been laid out for each region: demand and supply equations, regional equilibrium conditions, supply-demand price equations, demand-trade price equations, price equations variable levy, and regional price equations.

All constraints are linear, most of the bounds are trend projections of exogenous variables. The model is completely static, so the area being used to produce some of the competing crops becomes a function of the current prices. It is not clear how the different price elasticities have been estimated.

The interactions between the regions are described by the trade prices (transportation costs are not mentioned) and a world equilibrium for each traded commodity. Stocks are either treated as residuals or are predetermined.

The model pays great attention to the vertical con-nections in grain-feed-livestock-dairy production.

Two specific questions were investigated in simu-lation runs:

Short
discussion:
cont.

1. What will happen to production, consumption and trade if the U.S. export price of grain is fixed, and

2. what will be the result if Brazil substantially increases its oilseed production.

Some results are available.

Model: A. Schmitz, D.L.Bawden: A Spatial Price Analysis
                of the World Wheat Economy: Some Long-Run Pre-
                dictions. (47)

Coverage: World, by four regions and eleven countries.

Generaliza-
 tion level: Wheat supply-demand and price over regions and
                countries.

Aggregation: A. All wheat uses,
                B. Food wheat only, by countries/regions

Method: Quadratic programming.

Type of   Static, partly stochastic.
 system:

Usage: Prediction of supply, demand, equilibrium prices,
                and trade flows of wheat.

Validation: None.

Time: Basis year: 1965 projection for 1980.

Short   The model contains estimates of the supply and
 discussion: demand equations and projections to 1980 of wheat
                supply and demand by countries, regions and pre-
                dicts the wheat trading patterns and transfer
                costs among all countries by changing some policy
                parameters. The model is solved for equilibrium
                prices, production, consumption and trade flows
                by country - using a quadratic programming algorithm.
                Price is the equilibrating mechanism by which the
                solution is derived.

                The model predicts the future wheat situation in
                each country under alternative economic and political
                assumptions.

                o   Wheat is viewed as a homogenous commodity
                o   Storage is exogenous

                Demand equations are estimated for eleven geographi-
                cal regions (USA, EEC, Canada, etc.), and for
                another four regions (including USSR and China)
                fixed point estimates are given. Two types of
                equations are specified: [1] all wheat uses are
                aggregated [2] only food demand is considered and
                other uses are added as a fixed quantity after
                estimation. Basis of distinction was the data
                availability. As demand is a function of price
                only, population, income and trend coefficients
                are multiplied by 1980 values for the variables
                themselves and the estimated intercept value is
                then adjusted.

Short
discussion:
cont.

Supply is also estimated for 11 regions and fixed
for four areas. The functions are formulated as
combinations of estimated acreage and wheat yields,
which were calculated and projected separately.
Acreage equations were estimated by expected prices
and by distributed lag formulation. For the major
exporter the regressand is wheat acreage, for
others, it is the ratio of wheat acreage to the
total cultivated acreage. Projection procedure is
the same as described for demand. Yields are
estimated as a function of time and projected on
the basis of trends although the results are not
very satisfactory.

For the four regions production and consumption were
projected by a time trend so neither demand nor
supply functions have been estimated.

Transfer costs however were estimated.

Different models (with different estimations and
projections) have been solved.

The basic model reflects the results of a low-
yield projection, a common internal price for the
EEC, and effective U.S. acreage controls.
All quantitative results are detailed.

Group I models reflect results of some non-policy
alternatives (e.g. changing import-export gap of
USSR and China and yield changes in the countries).

Group II models reflect results of some policy
alternatives, (changes in the U.S. acreage allot-
ment and EEC target prices), the 10 models variants
differ in rather an arbitrary way.

Model:	S. Reutlinger: A Simulation Model for Evaluating Worldwide Buffer Stocks of Wheat. (40)
Coverage:	World.
Generaliza-tion level:	Buffer stocks of wheat.
Aggregation:	---
Method:	Stochastic simulation.
Type of system:	Dynamic, stochastic.
Usage:	Optimization of values of wheat storages to stablize world market prices.
Validation:	None.
Time:	Not explicitly determined 30 years.

Short
discussion: The world is viewed as a unified market. Fluctu-
ations in world consumption and prices are assumed
to depend only on world production fluctuations
and the extent of storage capacity. The simulation
was carried out under two different storage rules.
The first one provides that production in excess
of 355 million tons is put into storage (to the
extent that there is vacant capacity), and grain
is released from storage if production is less
than 345 million tons. The second rule set this
lower limit at 355 million tons. The production
is assumed to have a triangular probability dis-
tribution with mean 350 million metric tons. The
price elasticity of demand is assumed to be lower
in the case of short supplies and higher in the
case of abundant supplies. Variable storage costs
and discount rates have been estimated. Different
storage capacities (and the costs) were considered.
The simulation covers thirty years on 300 sequences
of production. The benefits for consumers and
producers have been calculated. Also the inter-
national allocation of costs and benefits were
investigated.

Limitations of the model:

1. The mean production remains unchanged over time.

2. Demand and supply are treated statically.

3. Production is characterized only by random changes and not by systematic cycles.

4. The storage rules are crude.

Model:	D.Eaton, W. S. Steele, J.L. Cohen and C.S. ReVelle: A Method to Size World Grain Reserves. Initial Results. (11)
Coverage:	World.
Generalization level:	Grain buffer stocks.
Aggregation:	--
Method:	Econometric, programming.
Type of system:	Dynamic, stochastic.
Usage:	Determination of the smallest maximum storage level of buffer stocks which can provide reliable food security. (Reliability means here the probability at which the given reserve size will provide food security in extreme events of productive shortfall.)
Time:	Data base 1960-1974, projections for 1975-2000.
Validation:	Statistic analysis of data base.
Short discussion:	Buffer stocks were investigated assuming (a) free trade, (b) perfect substitution of all grains in reserve, (c) no transportation or distribution barriers and (d) that reserve was global. The supply stabilization role of buffer stocks was not considered.

On the basis of curve fitting and statistical analysis of past production data:

1. the expected volume of production;

2. the variability of production around the expected volume, and

3. effects of surplus or shortage in one year upon the production in the next year, were confirmed.

Assuming the continuation of past patterns, future production was simulated. A multi-objective linear programming algorithm was applied to determine the optimal size of grain reserve, which is needed for reliable world food security. The proportions of increasing reserve size, costs and reliability were taken into consideration. Trade off curves were constructed to clarify the costs of increasing the reserve size and its effect on food security. It was shown that the final increments are less cost-effective than the first increments.

Model: D.G. Johnson and D. Sumner: An Optimization
                 Approach to Grain Reserves for Developing Countries.
                 (15)

Coverage: World, regions and countries.

Generaliza-   Grain buffer stocks of independent regions.
tion level:

Aggregation: --

Method: Mathematical optimization.

Type of   Dynamic, stochastic
system:

Usage: Optimization of reserve size assuming stochastic
                 supply, deterministic demand, "normal" amount
                 of foreign trade and constant price elasticity
                 of demand.

Time: Data base 1943-1973, projections: 1968-1990.

Validation: Parameters are estimated from statistical data
                 base but (because of the normative character
                 of the model?) ex-post predictions were not
                 confronted with real data.

Short   The study presents a method for optimizing grain
discussion: reserves for single regions, which can be countries,
                 country-groups or the world. Though a free com-
                 petitive world market is assumed, it is not explicitly
                 considered. Foreign trade is assumed to remain
                 always at the "normal" (initial) level.

                 Production is described as a stochastic process,
                 having a multinominal distribution with expected
                 values building an exponential trend. The dis-
                 tributions are assumed to be independent across
                 the years. The consumption side of the model is
                 based on a constant price elasticity demand func-
                 tion with a constant exponential rate of growth
                 over time. Consumption, determined as above is
                 made equal to the difference of supply and carry-
                 over of this year, while supply is the sum of
                 production of this year and carryover from the
                 previous year. Net welfare is maximized, speci-
                 fied as a function of consumption (and so indirectly
                 of storages), volume-proportional storage costs
                 and of a constant discount factor.

                 The model generates carryovers for each year
                 according to the supply level of the year and to
                 different probability levels of meeting demand.
                 (Except the last year of the projected period,
                 when storages are set zero.)

Short
discussion:
cont.

Also an international insurance program is pro-
posed to provide security against grain produc-
tion variability. The program would guarantee that
all shortfalls in the grain production of some
country could be made up by insurance payments if
the production was below some percentage of the
expected value. It was shown that this program
could reduce the size of optimal carryovers of
individual regions while improving supply stability.

Some results are presented for 1975, considering a
series of regions. For India and Africa also
time series (1968-74) are published. The investi-
gations were carried out in two variations:
including and neglecting international insurance
programs.

II. NATIONAL MODELS

II.A.   Economic and Socio-Economic Models

Model: BACHUE-Philippines, Economic-Demographic Modelling
for Development Planning. (42).

Coverage: Philippines.

Generaliza-   Socio-economic structure.
tion level:

Aggregation: Thirteen production sectors, ten rural and urban
income classes, 8 categories of labour.

Method: System simulation, input-output.

Type: Dynamic, deterministic.

Usage: Projection, simulation of policy impacts on
increasing income of the poor to meet basic needs.

Time: Basis year 1972, projections for 40 years.

Validation: Sensitivity analysis

Short
 discussion: The BACHUE-Philippines is the first model of ILO's
planned series to be elaborated for developing
countries using a prototype model, called BACHUE-1.
(BACHUE is a goddess of love, fertility and har-
mony between man and nature in the Colombian
mythology). The model simulates the behavior of
the demographic-economic system of the country
based on three subsystems: (1) economic,
(2) labour market and income distribution and
(3) demographic sub-models. It focuses on the
interrelation between population characteristics
and the distribution of household incomes, both
directly and indirectly through demand patterns.
The economic subsystem emphasizes employment and
income distribution interactions. Separate labour
markets are specified for urban and rural areas,
for modern and traditional sectors, and for skilled
and unskilled labour. Migration is modelled also.
The core of the economic model is a thirteen-sector
input-output system (data on 1965), which generates
sectoral output and value added. Supply constraints
are introduced as overall targets for total output,
possible growth rates or as balance of payment con-
straints. The final private demand is determined
by population size and structure, and checked by
possible supply.

Wages and incomes are endogenous, but most prices,
investments, exports and some aspects of the pro-
duction process are exogenous.

The model neglects the production side as compared

with the more detailed demographic and consump-
tion side.

Under alternative assumptions a series of projec-
tions were carried out. The alternatives covered
higher and lower output rates, some food policies
and agricultural development policies. Effects
of educational and family planning programs,
migration policies, wage subsidisation policies,
technological change and government expenditures
were simulated.

All results are provided.

BACHUE MODEL
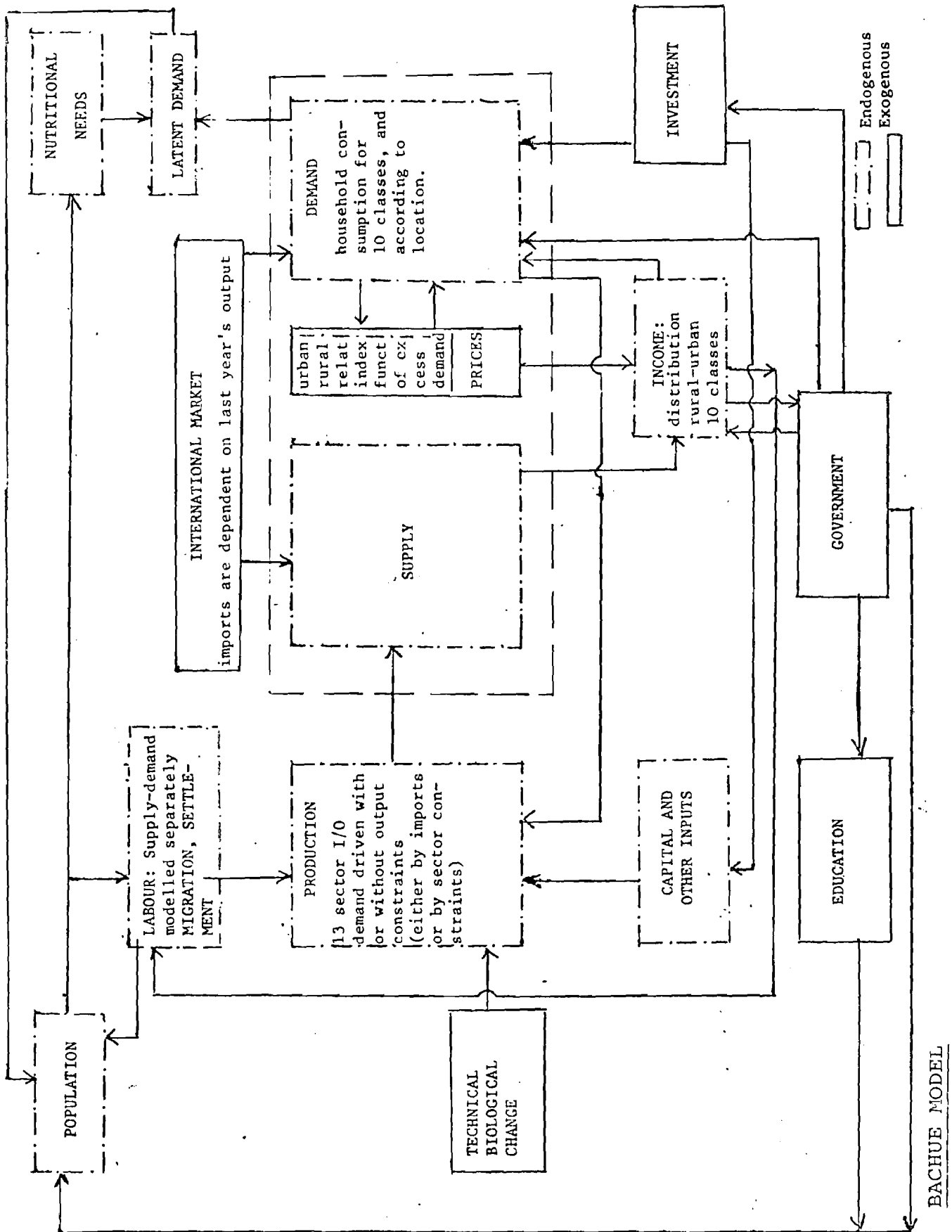
Model:	B. Martos, Wuu-Long Liu: Long-Term Socio-Economic Country-Simulation. (25).
Coverage:	Egypt.
Generaliza-tion level:	Economy of a developing country.
Aggregation:	Seven sectors, population groups by age and sex.
Method:	System simulation.
Type of system:	Dynamic, deterministic.
Usage:	Predictions under alternative assumptions about the agricultural policies by changing economic policy variables, but not including policy instruments for a planning period.
Time:	Data base 1964-69 projections for 1970-80.
Validation:	Sensitivity analysis and ex-post prediction for data years.
Short discussion:	The model of Egypt is able to represent the following main problem areas: agriculture, economy, labour force and employment, and population. The system of 140 equation is recursive and dynamic, however, all lags are one year in length. It is a typically supply-driven model, based on the GNP balance. The economy is divided into seven sectors: agriculture, intermediate and consumer goods industry, capital goods industry, construction, services, education and other government services. Production is determined by productive capacity, assuming full utilization. No effects of insufficient demand were considered. Total private consumption is determined in terms of population and per capita consumption. The latter is calculated as a function of the growth rate of per capita GNP, with the assumption that per capita consumption does not decrease.
	Foreign trade is described in the model in a simplified, non-causal manner. All prices are exogenous.
	For the non-agricultural and modern agricultural sectors the labour market is included in the model. Employment in other sectors is handled as a residual.
	The population block of the model generates population size in sex and age breakdown.

Several policies were considered: land reclamation programs, allocation of investments among sectors, growth of GNP per capita, consumption and export targets, population policies.

The simulations include: (1) quasi-continuation of past trends in the policy formulation; (2) goals of increasing employment and decreasing unemployment ratio and population growth; and (3) a development strategy to meet the increasing demand of food by increasing land reclamation. All numerical results are provided. It should be mentioned that the model is applicable only when a general labour surplus exists in the entire planning period. In their further research the authors plan to include income distribution, underemployment, endogenous prices and policy instruments as well.

INVESTMENT
computed as resi-
dual after private
& govt. consumpt.
allocation
exogenous

DEMAND

cons/capita exog.

INTERNATIONAL MARKET
exports exog.,imports: difference between
demand & domestic availability(no constraint)

P
R
I
C
E
S

INCOME
no distribution

wages exog.

SUPPLY

GOVERNMENT

LABOUR: excess sup-
ply is assumed
MIGRATION

PRODUCTION
7 sectors deter-
mined by prod.
capacity assuming
full utilization

CAPITAL AND
OTHER INPUTS

EDUCATION

POPULATION

Endogenous
Exogenous

LTSM MODEL

Model:	R.G. Ridker; Resource and Environmental Consequences of Population Growth in the United States. (Resources for the Future Model) (41).
Coverage:	U.S.
Generaliza- tion level:	Socio-economic structure.
Aggregation:	185 production sectors.
Method:	Input-output, econometric.
Type of System:	Dynamic, deterministic/stochastic
Usage:	Projection of socio-economic development in four scenarios: high/low economic growth, high/low population growth. (The population growth rates correspond two resp. three children per family.)
Time:	Projections up to 2000-2020.
Validation:	No information.
Short discussion:	RfF covers many important aspects of development, and pays great attention to environmental feedbacks. The sub-models are: Economy, Minerals and Fuels, Energy, Pollution, Congestion and Outdoor Recreation, Water, Agriculture, Urban Environmental Problems, other Environmental Concerns, and International Relations.

The agricultural sub-model, a complexly elaborated framework is designed to evaluate the resource requirements and environmental consequences considering several levels of population, income and technology. Five scenarios were specified, combining not only population and economic growth but also some technology alternatives. Some levels of fertilizer and pesticide usage, hormones and medications in animal feed were considered. For some key agricultural products, such as grains and soybeans, U.S. foreign trade was projected assuming that a) exports will continue to increase as in recent years and b) exports will increase at a slower rate. Also policy implications (of subsidisation, taxation, production control etc.) were investigated.

The core of RfF is a very detailed (185 sectors) input-output model, dynamized by allowing the technical coefficients to change over time. Final

demand is projected by using stochastic methods. The pollution is attributed to each sector by using I/O methods.

Three kinds of simulation runs have been carried out: the first type concerns the specification of the demographic and economic assumptions (changing final demand and production capacity), the second type concerns the degree to which industrial materials are recycled within the economy, and the third type is related to the average waste treatment practices employed.

Model:	S. Gupta and R.D. Bhakta; An Economic Model for Argentina. (13).
Coverage:	Argentina.
Generaliza- tion level	National economy.
Aggregation:	Six agricultural sectors, six non-agricultural sectors, rural and urban wages.
Method:	Econometric.
Type of system:	Dynamic, deterministic.
Usage:	Analysis of the relevant forces shaping the economic development; prediction; simulation of policy changes (full employment exercises, assess- ment of the feasibility of the Argentina Plan).
Time:	Data base 1960-1969, predictions for 1971-79.
Validation:	Ex-post prediction for sample period.
Short discussion:	The model is a simultaneous system of the following sub-models: agriculture, non-agriculture, comsump- tion, price formation, exports, imports, wage determination, treatment of exogenous variables, monetary sector and national income accounting balance. Some of the equations are alternatively specified for purposes of analysis or prediction. For predictions some new equations have been speci- fied to reduce the number of exogenous variables.

"The model defines the national income identity and thus [posits the] equality between savings and trade gaps at current prices.... The model does, of course, allow presentation of the two gaps at con- stant base period price, with GNP deflator as residual... the ex-ante "saving gap" and "trade gap" have been equalized by reallocating resources via price changes."

Agriculture is divided into two subsectors: livestock and crops (subdivision for livestock: cattle herd, cattle slaughter, residual; and for crops: wheat, corn, sorghum and others).

As cattle cycles are of great importance for Argentina, the model considers it in two alternative ways:a)taking into account only connections bet- ween cattle prices and age-structure of the stock. b) taking into account connections with corn and fodder prices as well.

One purpose of modelling crop production was to

investigate how much land is to be brought under cultivation for a given crop considering its profitability vis-a-vis other crops and total availability of land. The study discovered that labour has had practically no impact on the level of agricultural outputs.

Consumption is determined for specific items and broad grouping in terms of total and private consumption.

For six groups of agricultural products export equations were estimated, mainly as functions of production and domestic consumption of the products.

Prices were determined for eight sectors, mainly as functions of the general price level. This is explained in terms of last year's quantity of money and changes in nominal exchange rates.

All projection results as well as the estimated equations are published.

Model: A.B. del Rio and L.R. Klein: Macroeconomic
                    Model Building in Latin America: The Mexican Case.
                    (10).

Coverage: Mexico

Generaliza-   National economy
tion level:

Aggregation: Three sectors, foreign trade of ten special
                    commodity groups, wage and non-wage incomes,
                    private and governmental investments, rural and
                    urban population.

Method: Econometric.

Type of   Dynamic, deterministic.
system:

Usage: Analysis of special features of Mexican economy,
                    predictions under two different assumptions about
                    the behavior of the federal government; (defla-
                    tionary or expansionary policies).

Time: Data base 1950-69, projections for 1971-76.

Validation: Ex-post prediction for 1968-70.

Short   The main problem-areas included in the model are
discussion: the following:

                    1. Internal and external sources of instability;

                    2. The dominant role, played by the federal
                    government;

                    3. The general unevenness in economic life (like
                    rural versus urban production, eneven income
                    distribution etc.);

                    4. Demographic and economic effects of high pop-
                    ulation growth;

                    5. The effects of proximity to U.S. markets;

                    6. The process of creating capacity through capital
                    and technological imports;

                    7. The comparative shorter decision-making periods,
                    simple economic organisms and behaviour vis-a-
                    vis the developed countries.

                    The model is a simultaneous system of 143 equations
                    of which 40 are behavioral. Each behavioral equa-
                    tion is linear. The model can be split up into
                    the following submodels: generation of aggregate
                    demand (domestic and foreign), generation of value
                    added output, capital formation, creation of

Short
discussion:
cont.

capacity, demographic processes and labour supply,
income distribution, and price formulation.

One finding of the study is that the creation of
capacity and the amount of idle capacity are
crucial problems for Mexico. The amount of idle
capacity is cyclic. Potential and idle capacities
have been estimated for rural and urban sectors.

Actual value-added outputs of the three main sectors
(primary, secondary and tertiary) are demand deter-
mined. Production is generated by a tri-sectoral
input-output model. (The modellers plan to intro-
duce a subdivision of 110-115 sectors).

The agricultural sector and agricultural products
are neglected both in the production and consump-
tion blocks, but the export of three agricultural
products, (cotton, coffee and sugar) is modelled.
Great attention is paid also to government activi-
ties and labour supply-migration problems. Thus
the agricultural issue is handled more indirectly
than directly in the model.

Because of the lack of data the model fails at
estimating income distribution. Thus consumption
functions are simple and don't reflect the different
behaviors of consumers who have wage and non-
wage incomes.

Two long-term simulations were carried out: with
high economic growth and low growth, respectively.
The former one included more public investments,
larger imports and smaller exports.

Results are available.

II.B. Economic and Socio-Economic Models
Focussing on the Food and Agriculture System

Model: G.E. Rosmiller et al: Korean Agricultural Sector
                    Analysis and Recommended Strategies 1971-85
                    (KASM) (1) (7) (44) (45).

Coverage: Republic of Korea.

Generaliza-   Socio-economic structure.
tion level:

Aggregation: Sixteen aggregated economy sectors, four agricul-
                    tural subsectors, four land categories, nineteen
                    agricultural commodities, twelve factor inputs,
                    rural and urban population.

Method: General system simulation (input-output, recursive
                    programming, econometric).

Type of   Dynamic, deterministic.
system:

Usage: Projection and analysis of policy variations:

                    1. based on the government plan;

                    2. based on improved allocation of resources
                    among programs with higher food grain price;

                    3. based on allocation of resources among pro-
                    grams, consistent with a free market policy
                    regarding the price of domestic and imported
                    food grains.

Time: Base year 1969, projections for 1971-85.

Validation: Sensitivity tests. Some experiences are available
                    on "clarity and workability" of the model.

Short   The major components of the model are as follows:
discussion:
                    1. a population and migration component, which
                    describes the agricultural and non-agricultural
                    labour supply by age and sex groups.

                    2. a crop technology change component, which
                    contains production functions to express crop
                    yields as functions of both conventional factor
                    inputs and structural change variables.

                    3. a resource allocation a production component,
                    which is a block-recursive linear programming
                    model of the farmer's resource allocation deci-
                    sions. This block, which is very disaggregated,
                    operates on seasonal production activities to
                    allow double cropping and labour constraints
                    of peak seasons. However, this block is also al-
   ways computed for a one year period. By maximizing

profits, two special restrictions are taken into account: the farmer's risk aversion and his restricted flexibility.

4. a demand-price-trade component determines the demand of agricultural population as a function of the last year's prices and present income (assuming subsistance behaviour of farm families), thus current food price results by the confrontation of supply and food demand of the non-agricultural population. This component is more aggregated than the production component. World prices act as limits for domestic price variations.

By use of the population component, nutritional requirements can be computed, but they are not compared with the effective demand.

5. the national economy component is a sixteen sectoral I/O model from which coefficients corresponding to agriculture can reflect its structural changes.

On the basis of the simulation results different strategies were developed for the Korean government. Some of these have already been applied. The model is highly dynamic and non-linear in some equations. Because of the weakness of the data base a lot of guessimates were used.
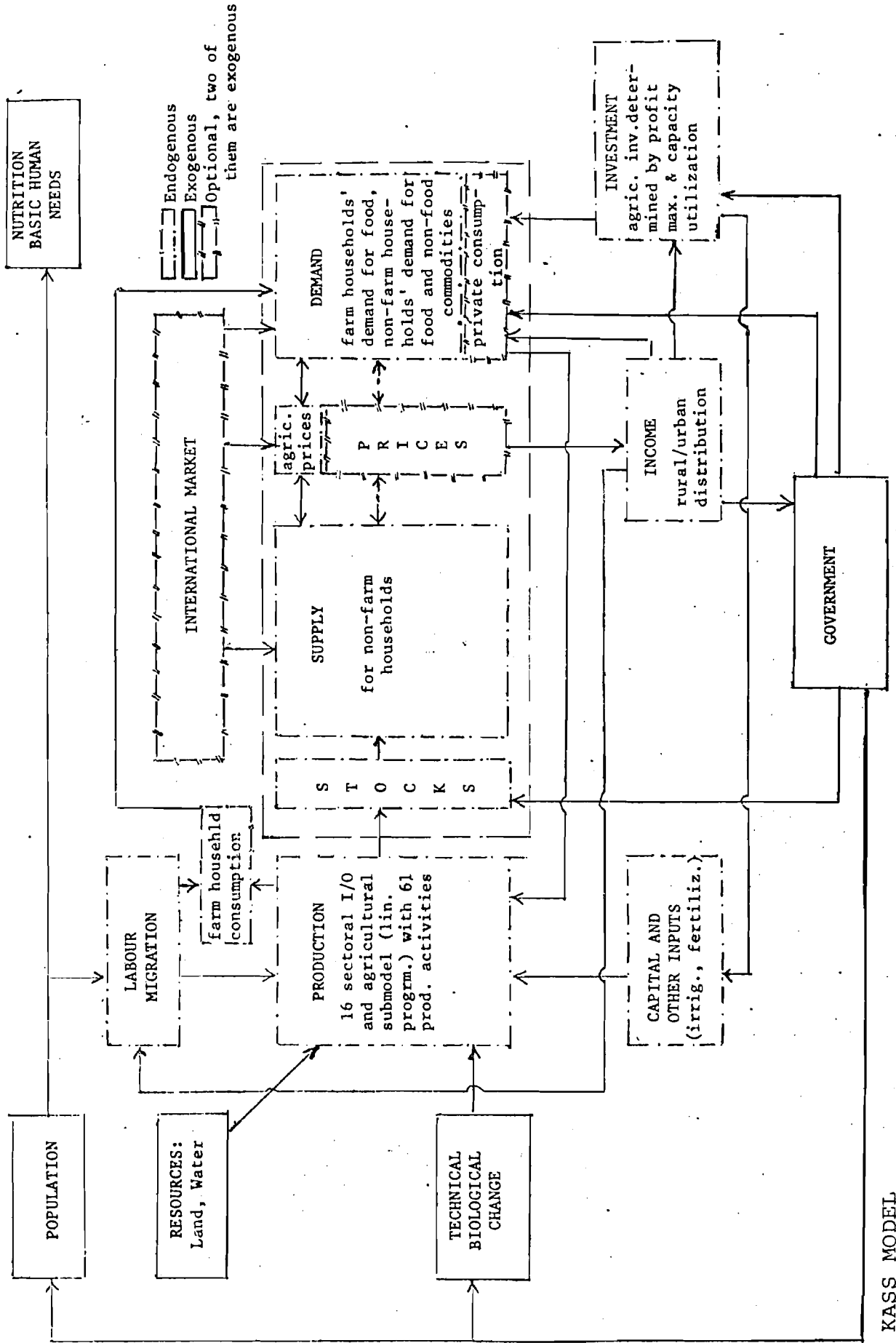
KASS MODEL

Model: T.J. Manetsch ed: A Generalized Simulation
                    Approach to Agricultural Sector Analysis with
                    Special Reference to Nigeria. (23) (24).

Coverage: Nigeria.

Generaliza-   Socio-economic structure.
tion level:

Aggregation: Two regions, ten sectors, nine commodity groups,
                    population classes by age, sex and occupation.

Method: General system simulation, (input-output, econo-
                    metric).

Type of   Dynamic, deterministic.
system:

Usage: Projections assuming different policy-sets;

                    1. export tax-policies and,

                    2. public expenditures.

Time: Data basis 1953-65, projections for 1983.

Validation: Ex-post prediction for 1959-67, sensitivity analysis.

Short   The model contains about 2000 equations in a build-
discussion: ing block system. The blocks consist of an agri-
                    cultural block for Northern Nigeria, an agricultural
                    block for Southern Nigeria, a population block and
                    a block for the rest of the economy. The latter
                    block expresses the effects of different agricul-
                    tural policies to the whole of the economy, and
                    indeed, this links the two agricultural submodels.

                    Both Northern and Southern Nigeria are divided
                    into four crop regions. The submodel of the
                    Northern part of the country deals with cattle
                    and annual crops in terms of production, land-
                    labour allocation, marketing, modernization,
                    consumption and budget. For the Southern part
                    perennial and annual crops are determined, (land
                    allocation, modernization, agricultural marketing,
                    production, processing, price generation).
                    In both regions these activities are depicted for
                    a number of crops. Demand for agricultural and
                    non-agricultural commodities in each region is
                    determined as a function of the disposable income
                    per capita and of price elasticities. Population
                    is generated by the population model.

                    On the basis of rural-urban income differentials
                    migration is determined. This affects the labour

supply in both the agricultural and non-agricultural sectors.

The parameters of the models are partly a priori, partly estimated and partly provided by the researcher's judgement (guesstimates).

The rest of the economy block is a ten sectoral I/O framework, and has been developed later in greater detail. To get a better operational model, the table is elaborated for main and residual crops and differenciates for small industry and small trade services. The I/O table's base year is 1959.

The population block is aggregated by age groups, sex and occupation.

Two types of agricultural policies were simulated:

1. export-tax policies for influencing the producer prices of export crops;

2. impacts of public expenditures.

The model has 22 distinct investment variables, which serve either as policy inputs or as control variables. About 20 controls are available to determine regulation of commodity prices, tax rates and production input subsidies. By allocating different combinations of public resources to the investment variables and by giving alternative values to the regulatory variables, further non-trivial policy runs have been planned.

The main weakness of the model stems from the lack of data. It contains no capital market. There are only rural and urban income classes included, so the nutrition problem cannot be analyzed in detail.

Model:	L.M. Goreaux, A.S. Manne: Multi-Level Planning: Case Studies in Mexico (12).
Coverage:	Mexico.
Generaliza-tion level:	Agriculture, economy and energy sector.
Aggregation:	Of the agricultural submodel: 4 regions, 33 crops, more than 2000 cropping activities (according to regions, calendars of cultivation practices by crops, classes of land by soil types, modes of irrigation and degrees of mechanization).
Method:	Multi-level linear programming.
Type of system:	Static, deterministic.
Usage:	Planning of optimal price policies, trade policies, employment programs, investment allocations.
Time:	1968, 1974.
Validation:	none.
Short discussion:	The overall project included modelling activities for different spheres of Mexico's socio-economic development. Four models have been elaborated. DINAMICO: a multi-sector multi-skill model; EXPORTA, a multi-sector model for optimal growth and export policies; ENERGETICOS, a process analysis of the energy sectors and CHAC, a programming model of the agriculture. Both sectoral models have regional submodels. These specific models can be linked to the DINAMICO.

Only the CHAC model is discussed here. (The model takes its name from the Mayan rain god). CHAC, a sectorwide model, describes total national supply and use of the principal short-cycle crops for one period. (Livestock, fisheries and perennial crops are included in the I/O table of DINAMICO).

Production is determined by region and by crop. Factor prices are partly exogenous, partly en-dogenous. Demand for land, labour and water are defined at seasonal intervals. Commodity prices are endogenous. The market is competitive, however, some monopolistic features, export quotas, upper and lower limits (e.g. exogenous export and import prices, etc.) can be introduced. The market is cleared up by maximizing the sum of the producer and consumer surplus. Demand is a linear function of price and per capita income. Cross price

elasticities are not considered.

CHAC concentrates mainly on the technological, allocation and investment problems. No risk, or other undeterministic factors are taken into account. Processing is not included. CHAQUITO, an aggregated version is also available.

Policy simulations were run with foreign exchange premiums, changes in interest rate, changes in wage level, and subsides on chemical inputs, etc.

The model is of great importance from the methodological, as well as the practical point of view. Some compromises in the modelling work resulted in a loose system of models of different levels. Different submodels contain various levels and are differently disaggregated. A more serious problem is that the accounting system is not uniform (DINAMICO is a total accounting system in value terms, CHAC is not total accounting and includes physical terms).

The structure, aggregation levels, and policy simulations of the model enable its application in the planning process.

II.C. Agricultural Sector Models

Model: The Programming Models of Center for Agricultural
                    and Rural Development (CARD models). (14)

Coverage: U.S.

Generaliza-   Agricultural production.
 tion level:

Aggregation: Ca. 100 regions, 15 crops, and 4 livestock products.

Method: Programming.

Type of   Static, deterministic.
 system:

Usage: Analysis, projection and policy simulation.

Validation: None.

Time: Date of 1940-70, solutions for 1965, 1975, 1980 and
                    2000.

Short   All of the CARD models (except one) are large linear
 discussion: programming models. The smallest has 960 equations
                    and 2700 variables, and the largest 10,000 equations
                    and 75,000 variables.

                    The models generally contain more than 100 produc-
                    ing regions, 20 - 30 consumer regions, 3 - 15 com-
                    modity groups, some models also have water supply
                    regions (50) and soil quality classes (3). All
                    models assume free market equilibrium, a condition
                    which is relaxed in cases of policy simulations.
                    Prices are calculated independently of the models.
                    The first group looks for optimal production alloca-
                    tion by maximizing net revenues or minimizing pro-
                    duction costs without taking account of different
                    government policies. The second group of models
                    simulates some policy impacts, referring to dif-
                    ferent spheres of agriculture and has predictive
                    features too.

                    The prototype model assumptions:

                    1. N unique, spatially separated but interdependent
                    production regions.

                    2. All producers in a specific region must pro-
                    duce the same (homogenous) products (or product
                    mixes). Quality is uniform in each region.

                    3. In a specific region all producers have the
                    same input-output coefficients.

                    4. Input-output coefficients are constant.

                    5. Different types of land uses can be substituted

at a constant rate within each region.

6. Total production is limited only by the fixed quantities of land available.

7. All producers are profit maximizers.

8. Production period is one crop year. Consumption must be met from current production.

9. Consumption is determined exogenously.

This basic model, based on 1954 data optimizes crop allocation. The constraints are available land and minimum required production for each crop. There are two extensions for 1965:

(a) population growth rate was changed, thus affecting crop requirements and labour availability;

(b) more crops and areas were included.

The following models have differing assumptions:

Land qualities and crop production: solved for 1965

Three land quality groups and consumer regions were introduced. Transportation costs were considered in the objective functions. Crops acreage constraints, government quotas and some effects of price changes were also investigated.

Within the previous model framework, Aggregate effects of government policies were examined for 1965. Emphasis was placed on estimating government costs under different land retirement programs. Government price supports and expenditures for reducing production and retiring land not under specific acreage quotas were the alternative policies tested. Shadow prices were also considered.

The capacity, interregional adjustment and land use model, 1975 projection,includes specific conditions for technical change, population growth (demand), feed requirements for livestock production (this latter constraint had been omitted in the previous models). The model allows technical improvements in different areas.

The adjustment in crop and livestock model for 1954 and 1965 differs with respect to previous models. Livestock is detailed (4 groups). A distinction is made between crop producing areas and livestock-producing, product consuming regions. Interregional competition not only among crops but among crops and livestock groups is reflected in the model.

The model incorporating farm size and land classes

for 1965. Three groups of farm sizes and three land qualities are introduced. This results in additional constraints of costs of fertilizer, pesticides and irrigation. Labour and capital constraints become important, particularly division of labour requirements between seasons and family labour.

Trade offs in farm policies: 1975 projection.

Three price levels (low, medium, high) and four retirement programs (zero, max. 25%, max. 50% and max. 75% of land can be retired) thus 12 policies in all are analyzed.

Farm policy and rural income and employment model

for 1975. The task is how to solve the problems of irrigation and decreasing employment in rural areas. Alternative government farm policies were analyzed to determine their effects on farm income and on employment and income generation in rural areas. The policy alternatives have been the following: free market conditions, land retirement conditions and the so called bargaining power alternatives (farmers versus national commissions with appropriate powers).

Water demand, land use, farm policy models on basis

of 1940 - 70, projection to 2000.

This is the first model to include water resources. Because water supply and consumption areas can be different, the transportation submodel includes water transfer activities. This fact is taken into consideration also when optimizing resource allocation. Nine alternative policies (of water price levels and land retirement programs) were investigated.

Environment quality and land and water use for the

year 2000. Introduced restraints also on nitrogen, phosphate, pesticides and soil loss. Under these assumptions the questions, investigated are the following ones:

1. If U.S. have enough land and water resources to meet food needs if environmental quality restraints are imposed.

2. Which is the optimal spatial allocation.

3. Optimal selection among alternative producing technologies.

Quadratic programming model of spatial equilibrium

for 1965. Omitting assumption 9 of protptype
model the objective function becomes a quadratic
one.

Transport problems for U.S. grain projected for 1980,

formulated for 48 states.

CARD PROTOTYPE MODEL

DEMAND

P
R
I
C
E
S

POPULATION

LABOUR

RESOURCES:
land

PRODUCTION for
crops only.
lin. program. mod.
opt. production
allocation among
104 areas.

TECHNICAL
BIOLOGICAL
CHANGE

CAPITAL AND
OTHER INPUTS
fertilizer/pesti-
cides

Endogenous
Exogenous
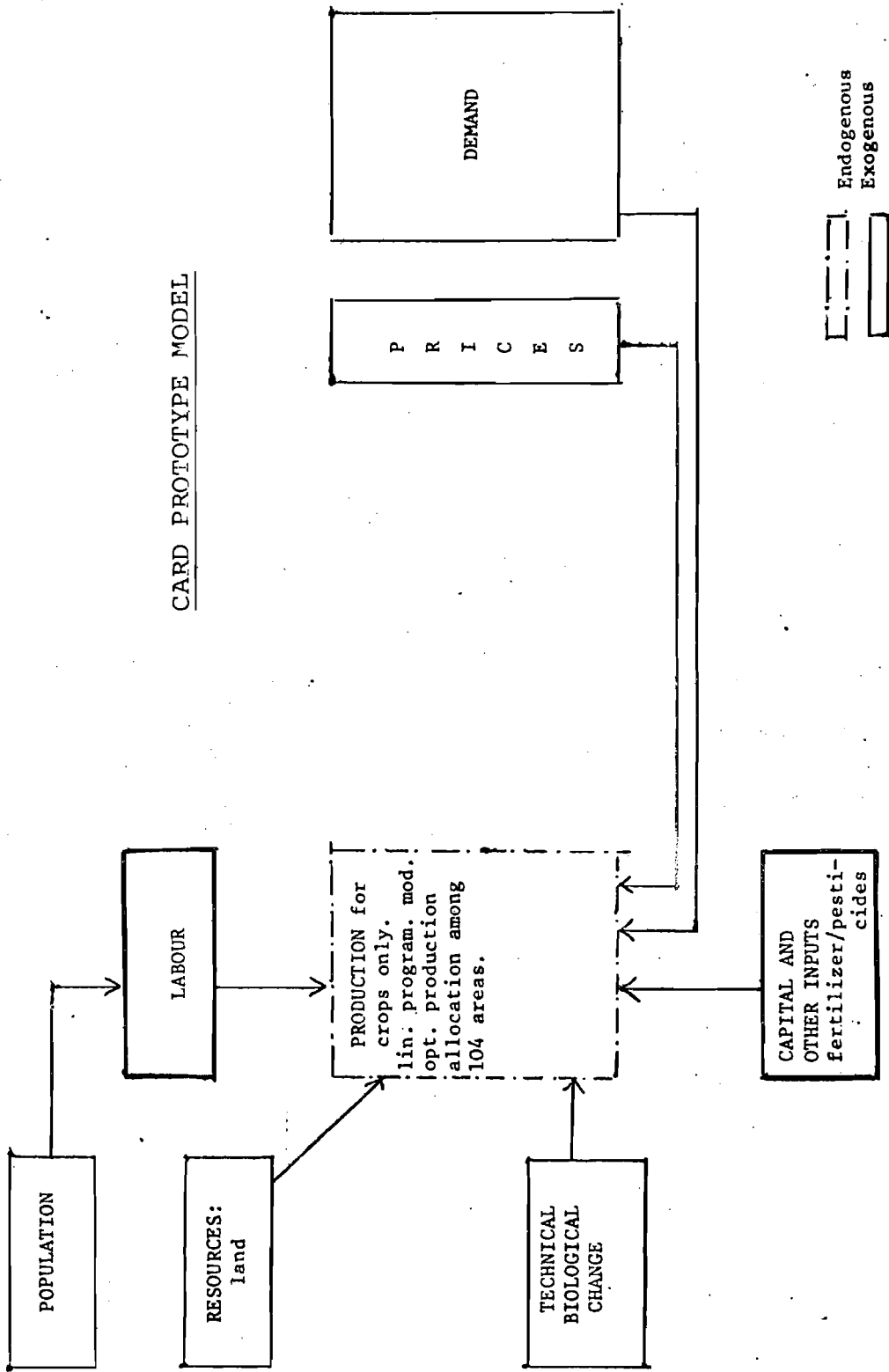
Model:	J.R. Monypenny: APMAA 1974: Model, Algorithm Testing and Application. (22, 30)
Coverage:	Australia (New South Wales).
Generalization level:	Agricultural production.
Aggregation:	19 production activities, 3 farm size groups.
Method:	Linear programming.
Type of system:	Static, deterministic.
Usage:	Planning optimal allocations of crop production and livestock production under different policy alternatives.
Time:	Data base: 1967-71, solution for 1974.
Validation:	Sensitivity analyses.
Short discussion:	The APMAA (Aggregative Programming Model of Australian Agriculture) model is not completely elaborated yet. APMAA 1974, a prototype model, is estimated on data of New South Wales. The project will later include other states.

The model depicts the supply side of the agricultural production on the basis of representative farms of different types and sizes. The objective function maximizes farmer's profit with respect to behavioral, financial and resource constraints. Production, financial and resource activities and changes in the behavioral constraints are also included in the model. The behavioral constraints depict the farmer's perception of production risk. Production includes ten kinds of cropping activities, seven kinds of livestock and two kinds of pasture characteristics. Prices, yields and variable costs are exogenous.

The model is strictly deterministic, also in description of farmer's reaction to risks. Little attention was paid to model effects of changing weather conditions. In fact, only the simulated slump in the price of wool indicates that Australian agriculture is very susceptible to weather changes.

Plans have been made to confront supply with an exogenous demand via a transportation model. The model does not include any connections between agriculture and other sectors of the economy, but according to a recent proposal, it may later be linked with regional input-output models.

Model: Models for Optimization of National Plan of Public
                    Purchases of Agricultural Commodities. (36)

Coverage: Soviet Union.

Generaliza-   Agricultural production.
  tion level:

Aggregation: Certain number of regions and commodities.

Method: Linear programming.

Type of   Static, deterministic.
  system:

Usage: Construction of optimal plan for public purchases
                    of agricultural commodities by maximizing profit-
                    ability.

Time: One planning period (not explicitly given).

Validation: None.

Short
  discussion: Three model variants will be discussed, on the
                    basis of their formal specification. Since the
                    first variant can be considered as a base model,
                    it is analysed more thoroughly and only differ-
                    ences are shown of the other variants.

                    The model includes the following groups of con-
                    straints: for all products a fixed target for
                    public purchases is predetermined which has to be
                    met; for all other purchases a minimum target is
                    prescribed. Both kinds of targets have to be
                    reached region by region.

                    The third group of constraints ensures that each
                    region's sales do not exceed its production.
                    Further there are constraints which guarantee the
                    value added for each region, taking into account
                    gross income, production costs and a coefficient,
                    which represents the expected efficiency determined
                    differently for different regions. The objective
                    function expresses overall profitability of produc-
                    tion, which is to be maximized.

                    The second variant takes account of available
                    resources of the regions. As in this model the
                    target of public purchases is represented by a
                    lower bound and not by a fixed quantity, the sum
                    of all sales, and not the sales beyond public
                    purchases, are bound. This allows for a more
                    flexible proportion of different uses than in the
                    first variant. Other constraints as well as the
                    objective function are the same as before.

Short
discussion:
cont.

In addition to the constraints included in these models, the third variant considers investments and also their required efficiency, the resources available in each region as well as their overall sum.

Finally we have to mention that the model discussed above is a part of the system of agricultural planning in the Soviet Union. Other linear programming models of this system deal with production allocation, investment allocation, transporation, etc.

Model:	National Planning Bureau Models for Agriculture. (16, 28)
Coverage:	Hungary.
Generaliza-tion level:	Agricultural production.
Aggregation:	Agricultural production according to the types of organization forms (state farms, cooperative farms, private and household plots), soil categories, cropping patterns, most important crop and livestock varieties.
Method:	Linear programming.
Type of system:	Static, deterministic.
Usage:	To aid decision making on resource allocation, on production structure, on regional allocation of production and on policy instruments.
Time:	According to the planning period 1976-80 for the terminal year, respectively embedded into a long range (15-20 years) plan.
Validation:	None.
Short discussion:	The model depicts 45 crops, 15 livestock products 48 energy and maintenance activities and 3 types of fertilizer on the production side. It is possible to include processing too. The constraints refer to commodity, resource, input, financial balances and to technological changes.

The resource requirements are calculated under the assumption of fixed coefficients. These as well as other coefficients of the models are adjusted figures which are based on the trend of technological development and judgement of the present situation. The inputs are represented by fertilizer, labour (annual or peak requirements), machinery, buildings, feed (according to main feed types), and water. The available resources for agriculture or its sectors, regions and products, are mostly given in physical units. In certain cases the lower bounds of their usage are also restricted. For example, a certain level of employment must be given to the members of the cooperative farms (or minimum requirements of commodity production.) The non-agricultural sectors as well as the con-sumers' and industrial demand are handled exo-genously.

The foreign trade is represented by import and export variables, separated according to Western, Socialist and Third World markets. The foreign trade in inputs is not considered. By use of upper and lower bounds foreign trade variables are also restricted. The stock changes are modelled too.

The model uses a set of different prices (producer prices, export prices, etc.). All prices are fixed and exogenous.

In the objective function the main agricultural policy goals are expressed, as:

- maximization of gross domestic product from agriculture,

- maximization of national income from agriculture,

- maximization of foreign balance of payment,

- maximization of hard currency earnings from agriculture,

- minimization of production expenses with a required level of production and positive balance of payment.

Further research deals with embedding this kind of model into long-range planning. A framework which includes 3 five-year periods has already been constructed. As before, production is determined for the terminal years of each period, however, investment will be allocated simultaneously for the whole period year-by-year. This simultaneity means that the optimization covers not only direction and measure of actions but also the distribution of these actions in the time. The appropriate connections between periods are ensured by equations referring to the investment and resource allocation in time.

The main characteristics of these models are that they concentrate on investigation of material and financial means required for achieving given targets using sensitivity analyses.

Model: H. de Haen and Th. Heidhues: Recursive Program-
ming Models to Simulate Agricultural Development;
Application in West Germany. (9)

Coverage: State Niedersachsen, FRG.

Generaliza-   Agricultural production.
tion level:

Aggregation: 4 regions, 2 farmsize groups.

Method: Recursive programming.

Type of   Dynamic, deterministic.
system:

Usage: Analysis of agricultural development assuming two
levels of marginal propensity to consume.

Time: 1949-65

Validation: Ex-post prediction, however, for some variables
there exist no comparable observations.

Short   The Gottingen group elaborated four recursive pro-
discussion: gramming models which differ in the aggregation
level and problems analyzed. The later models,
however, can be viewed as improved and extended
versions of the earlier ones. The first model
refers to farms (Heidhues, 1966), the second
to farm groups, (Steiger, 1968), the third to a
single state (Niedersachsen de Haen, 1971) and the
fourth is a national agricultural sector model
(DFG-Team). Here we will discuss only the regional
model by de Haen. In this model the state is
divided into four regions, and in each of them
two farm-size groups are considered. The model has
the characteristic of a micro-economic analysis,
which is applied at the aggregate level. Parti-
cular attention is paid to the competitive
situation of various production areas, to capital
accumulation and mechanization, and to employment
and income generation. The decision-makers in
the model are farmers, who make their decisions
within constraints which hold either for the farm
or farm-size group or for the region or for the
state.

The farmers decide about crop and livestock pro-
duction, savings and investments, loans, cash
holdings, etc. The past and future are connected
by the expectation mechanism, the base on which
farmers operate. Because of this mechanism the
model is dynamic; realizations of the last year
(in part) determine the expectations (and decisions)
of the current year. The results provide a better

Short   understanding of regional production patterns,
 discussion: technological developments in the period under
 cont.   investigation, and income and capital accumulations.

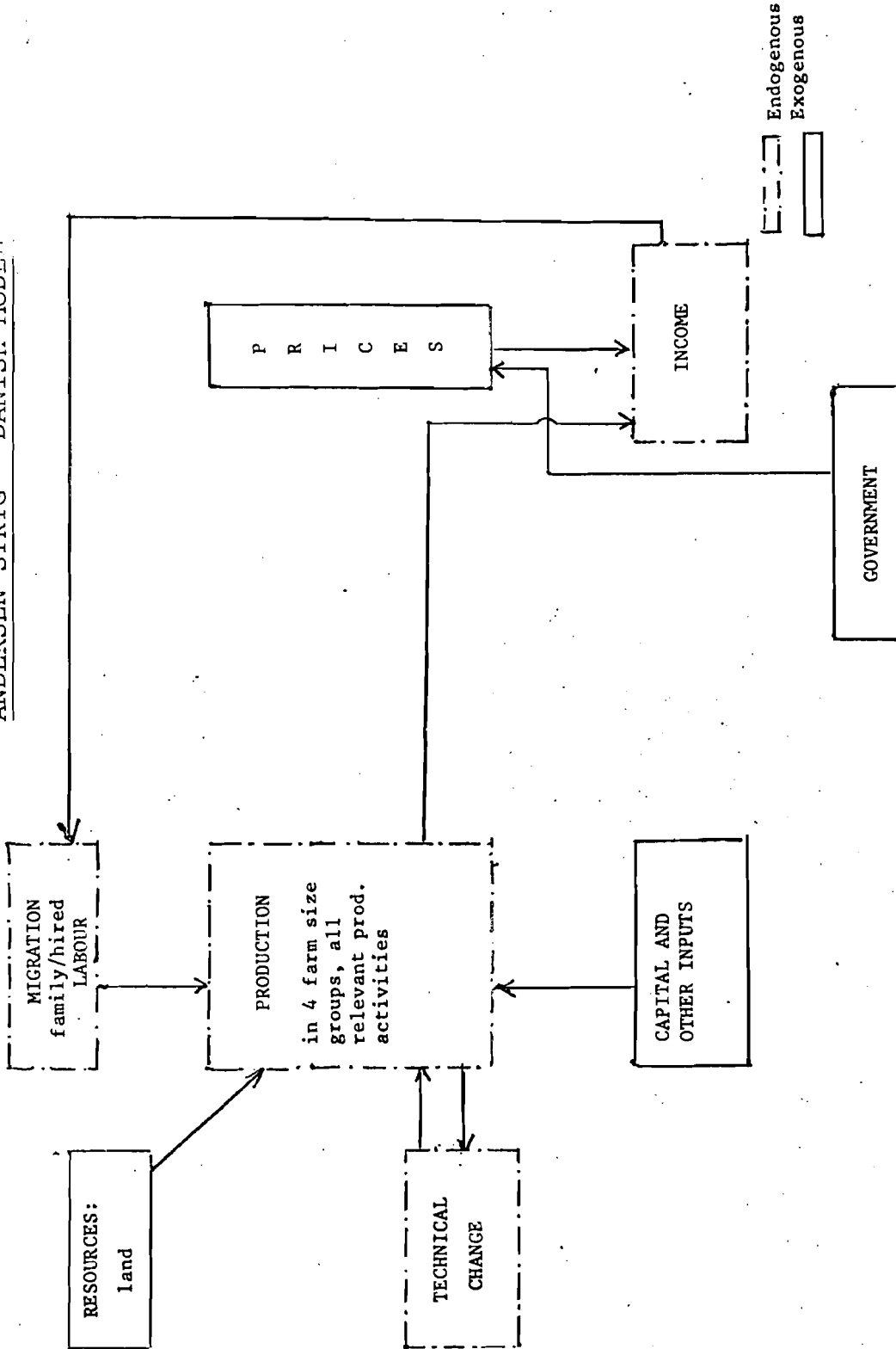|	
Model:	F. Andersen, P.E. Stryg: Interregional Recursive LP Model Used in Forecasting Danish Agricultural Development up to 1985. (2)
Coverage:	Denmark
Generaliza- tion level:	Agricultural production.
Aggregation:	Four farm size groups, eleven regions, all relevant production activities.
Method:	Recursive programming.
Type of system:	Dynamic, deterministic.
Usage:	Prediction of production and changes of farm size structure, according to the new conditions caused by the new EEC agricultural policy.
Time:	Data base 1956-70, projection for 1970-85.
Validation:	Ex-post prediction for 1956-70.
Short discussion:	The model is an attempt to describe the probable regional development of the agricultural structure and production. It operates on regions and different farm size groups on three-year sub-periods, where the results of one subperiod affect the technical coefficients and bounds of the next period. (For example, the technical coefficients for a given sub-period t are equal to the average resource capacities and size of production per farm in sub-period t-1.)
	The most interesting feature of the model is the endogenous depiction and projection of the development of farming structure (number of farms and their acreage distribution), caused by the competitive strength of the farm groups and by the outmigration into other industries. These changes are restricted by regional constraints concerning the re-allocation of acreage among farm size groups (i.e. by some flexibility constraints).
	The exogenous data of the model are projected on trends which assume continuation of the most current economic growth rate. This rate in turn determines the factor prices, the regional incomes and labour uses per activity. Taking account of the EEC market agreements (which determine product prices); and assuming that technical development will continue at the same rate as in the past, etc., projections were carried out.

ANDERSEN-STRYG – DANISH MODEL

RESOURCES:
land

MIGRATION
family/hired
LABOUR

PRODUCTION

in 4 farm size
groups, all
relevant prod.
activities

TECHNICAL
CHANGE

CAPITAL AND
OTHER INPUTS

P
R
I
C
E
S

INCOME

GOVERNMENT

Endogenous
Exogenous

Model:	I. Singh: Recursive Programming Models of Agricultural Development (48)
Coverage:	Punjab (India).
Generalization level:	Crop production.
Aggregation:	11 crops.
Method:	Recursive programming.
Type of system:	Dynamic, deterministic.
Usage:	Estimation and analysis of resource usage, production patterns, technological change, factor productivity and factor proportions.
Time:	1952-65
Validation:	Ex-post prediction.
Short discussion:	The model includes the following elements:

1. Annual objective functions: expected net cash revenue from crop sales, (defined as the expected revenue from crop sales minus costs of inputs and investment charge for resources). This function is maximized by optimal allocation of resources.

2. A technology matrix represents the input-output structure of home and cash consumption, farm production, investments, etc.

3. A technical constraint structure represents the regional resources and financial limitations.

4. A behavioral constraint structure represents farmers' reactions to the results of earlier cropping and investment choices.

5. A set of feedback functions relates the parameters of the current programming problem to previous decisions, giving the model its dynamic character.

The model was applied in static, comparative static and dynamic ways. The model was applied dynamically to simulate economic history, to simulate policy alternatives, and to project into the future. Great attention was paid to the effects of the "green revolution".

The model is based on annual data, but certain seasonalities (e.g. labour use) were investigated as well.

The model is more appropriate to simulate technological changes than policy alternatives.

Model: V.K. Pandey, T. Takayama: Temporal Equilibrium
                  Analysis of Rice and Wheat in India. (32)

Coverage: India.

Generaliza-   Supply and demand of 2 commodities, but generali-
tion level: zable to the whole agricultural sector.

Aggregation: Two commodities.

Method: Quadratic programming.

Type of   Static, deterministic.
system:

Usage: Planning of concrete alternatives to develop a
                  suitable temporal price and allocation model,
                  incorporating demand, supply and price variables
                  with constraints on prices and land to provide
                  a temporal solution in terms of optimal consump-
                  tion, production, year-to-year carryover quantities
                  and equilibrium prices, with imports and exports.

Validation: None.

Time: Data base: 1955-56, 1968-69.
                  Solution for 1968-72.

Short   The goal is to maximize the intertemporal net
discussion: social revenue (expressed by a function of market
                  price, storage costs, carryover quantities, demand,
                  supply, discount rate connected with storage)
                  for each commodity and each year.

                  The constraints are as follows: supply feasibility,
                  no excess demand, equilibrium infra-temporal price,
                  equilibrium intertemporal price. (Demand is defined
                  as per capita availability!) In another model
                  variant some modifications were considered (1) upper/
                  lower bounds on prices, (2) limit of price differ-
                  entials between the products, (3) land avail-
                  ability restrictions.

                  Three alternative policy simulations were carried
                  out, and results are presented.

Model:	S.P. Pant, T. Takayama: An Investigation of Agricultural Planning Models, a Case Study of India's Food Economy. (33)
Coverage:	India
Generalization level:	Supply and demand of two commodities, but generalizeable to the whole agricultural sector.
Aggregation:	14 regions, 2 crops.
Method:	I/O, programming.
Type of system:	Dynamic, deterministic.
Usage:	Planning by simulation of effects of different supply quantities with and without government storage policies.
Time:	Data base: 1965-70, solutions for 1971-72, 1975-76.
Validation:	None.
Short discussion:	Four connected models are discussed as possible tools for planning the agricultural development. All are illustrated for two commodities, wheat and rice.

1. The input-output model is based on assumptions regarding growth of GNP and investment. The rate of growth is given by the government plan for 1965-70 and 1970-75. The model considers three other hypothetical growth rates. Corresponding to each growth rate two levels of investment are assumed.

The aggregate demand was allocated to sectors and the sectoral allocation of the macro-investment was based on derived expansion ratios. Using the Leontief-inverse-matrix, the final demand vectors (with different alternative estimates) generate the domestic output for the various sectors and alternatives.

The programming model tested the feasibility of the derived food-grain production estimates.

2. The linear programming analysis investigates the optimal allocations of the two commodities. The objective function minimizes the sum of total costs of production and transport costs. The model's constraints are total land availability, regional upper bound on acreages for each crop, minimum regional demand for each crop and region.

Short
discussion:
cont.

A comparison of I/O with the program results shows that the optimum of the linear programming model does not reach the level of the I/O growth model, thus the agricultural extension programs of regions must be pushed by governments.

3. The spatial equilibrium analysis, as a further step in the procedure of planning, determines absolute and relative price levels of the inter-regionally traded agricultural commodities.

The problem is solved by the quadratic spacial price equilibrium model. The analysis assumes:

i. All the consumers have their own utility function.

ii. All the producers have their production feasi-bility set.

iii.The output of each producer is transportable to each region, and

iv. relations of local production and local uses to local price are known for each region, given the trade functions and factor costs. The model determines: (a) absolute price in each region, (b) quantity of exports and imports of each region, (c) which region exports, imports, (d) volume and directions of trade. The demand functions have been estimated, with regressand per capita con-sumption (assumed to equal per capita availability!) and with regressors: per capita income and price (deflated wholesale price).

Estimation is based on all of India, and assumes that parameters are the same in all regions as well. These assumptions were tested and accepted. Supply is treated as a fixed point estimate on three different levels generated (a) by the linear programming model, (b) by the I/O model, and (c) by the I/O modification.

4. Spatial and temporal equilibrium analysis: the method is the same as at the model of Pandey Takayama, but combined with the spatial equili-brium model. Six regions are taken into account. Demand and supply are treated as in model 3 above. Additional assumptions: Government's storage target is known, storage costs are constant, upper limit for storage capacity and minimum level for procurement for storage are fixed and known. Optimal solution is given over space and time for consumption, distribution, prices and storage. Different model-variants with different supply quantities, with and without government storage policies are discussed.

Model: U. Bertele and F. Brioschi: The Italian Food
                   Sector: An Input-Output Model. (5)

Coverage: Italy.

Generaliza-   Food sector.
tion level:

Aggregation: Thirty-two food subsectors.

Method: Input-output.

Type of   Static, deterministic.
system:

Usage: Analysis of I/O relationships.

Time: 1972.

Validation: None.

Short   The thirty-two subsectors of the model are con-
discussion: sidered in four categories: primary sectors,
                   (agriculture, fishing, mining); food industry
                   for animals; animal-breeding and food industry
                   for human beings.

                   Each of the thirty-two sectors is given by means
                   of three tables:

                   1. The first table assigns input variables to
                   industries.

                   2. The second table relates industries to output
                   variables.

                   3. The third table partitions output variables
                   among different uses.

                   This modelling effort resulted in a very dis-
                   aggregated input-output table and collection of
                   large amount of statistical data not available
                   before.

                   It is of great importance that the model deals with
                   physical (rather than financial) interrelationships
                   within the food sector.

Model: S.N. Kulshreshtha, V. Holub: An Aggregate
Econometric Model of Canadian Agriculture. (18)

Coverage: Canada

Generaliza-   Agricultural sector.
tion level:

Aggregation: 3 commodity groups.

Method: Econometric.

Type of
  system: Dynamic, deterministic.

Usage: Prediction of the most probable future situation
of the sector.

Time: Data base: 1946-71, prediction for 1980.

Validation: Ex-post prediction for sample years.

Short   The model contains the following blocks: field
 discussion: grains, non-grain crops, livestock, and aggre-
gated block of them, income determination, and
farm employment blocks. It is a system of 27
linear equations, from which 7 are identities.
The model describes both supply and demand adequately.
Exports and prices for the included products are
considered. No relationships of other sectors
of the economy are considered. The model does
not adequately deal with capital variables. It
contains only two exogenous capital variables
and no investment functions. Technological change
is represented by an index, showing the ratio
of all agricultural output to all inputs. A
very simple weather index is used. Some dynamic
characteristics of the model, like impact multi-
pliers, stability, etc., were investigated.

Model:	J.M. Ruch, A. Monfort, G. Winter: Un modèle agricole à long terme de simulation.(46)
Coverage:	France.
Generaliza-tion level:	Agricultural production.
Aggregation:	Four commodity groups
Method:	Econometric.
Type of system:	Dynamic, deterministic.
Usage:	Prediction of the most probable situation of French agriculture and simulation of some variants resulting from changes in the agricultural price policy.
Time:	Data base: 1960-73, projections till 1985.
Validation:	Weak, parameter estimation on manipulated time series.
Short discussion:	The model contains three simultaneously connected blocks: demographic, capital, and production re-venue. They determine agricultural population, demand for credit and investments and agricultural production. Agricultural production is the sum of production of (1) cereals, (2) perennials and other vegetables, and (3) livestock, (beef, veal, milk and other products).
	The most detailed block is that of capital and investments. Because of uneven data availability, the different blocks are based on different years and have different periodicities. The data of the population block refer to six year periods, the production block to four-year periods, and only the capital block possesses an annual data base. This unevenness requires that when connecting two different blocks one has to interpolate or extrapolate. Similar procedures are required when projecting.

Model: AGRIMOD: Development of a Dynamic Simulation
                    Model of Food Production for the U.S. (19, 20, 21)

Coverage: U.S.A

Generaliza-   Agricultural sector
tion level

Aggregation: 10 commodity groups of crops, 5 product groups
                    of livestock, 13 types of land, 3 kinds of ferti-
                    lizer and investments.

Method: Econometric, programming.

Type of   Dynamic, deterministic
system:

Usage: Analysis of the implications of alternative policies
                    on food supply; identification of the impact of
                    possible natural resource and energy constraints
                    on the food supply and on prices; evaluation of
                    the effects of policies relating to the import and
                    export of food and resources; assessment of the
                    long term impacts of policies on diets and
                    nutrition.

Time: Data base: 1955-1970; prediction for 1990-1995.

Validation: Ex-post prediction for the sample period.

Short   The model consists of seventeen submodels fully
  discussion: integrated in four major sectors connected by
                    three markets.

                    The input sector model consists of three sub-
                    models: (a) The investment model describes govern-
                    ment, private monetized and private non-monetized
                    investments. Total monetized agricultural invest-
                    ment is keyed to total national investment which
                    is exogenous. (b) The fertilizer industry model
                    is dynamic and describes the production of nitrogen,
                    phosphorous and potassium, taking account of prices
                    of raw materials and changes in technology. (c) The
                    land model has two levels. At the first level,
                    13 types of land are modelled as capital stock
                    variables; the second level contains the crop
                    location-specific disaggreation of arid and humid
                    cropland.

                    The farm input market consists of two submodels:
                    (a) The farm input demand model, which is an
                    optimal resource allocation model, specified as
                    a non-linear programming problem. (b) The model
                    of market for inputs to crop production determines
                    equilibrium prices and quantities of non-capital
                    stock inputs (i.e. fertilizers, pesticides, etc.)

Short
discussion:
cont.

The crop production sector contains a model which
determines the total annual production of each
crop in each region taking into account not only
the input factors, traded on the previous market
but also the impact of weather and climatic
change. Labour is not included as a productive
factor.

The crop market is essentially the wholesale farm
commodities market. This contains the following
submodels (a) consumer demand model, (b) livestock
producer's demand model (c) government policies,
stockpiles and carryovers (d) export-import model
(e) crop market. Of these submodels the third
one is of great importance since it includes a
set of alternative structures that correspond to
different policy objectives and different mechanisms
for achieving them.

The food supply sector consists of the following
submodels: (a) fish supply model (b) livestock
products supply model (c) food processing industry
model and (d) food supply model.

The retail food market consists of the (a) con-
sumer demand model and of the (b) retail food
market.

Demand functions are specified for seventeen pro-
ducts considering direct and cross price elasti-
cities.

The consumption analysis sector generates average
per capita consumption measured in calories and
grams of protein per day, disaggregated by income
levels. Farm wage rates as well as GNP per capita
are exogenous.

In all the three markets described by the model,
equilibrium prices are determined assuming perfect
competition, while exports and imports (with the
only exception of imported sugar) are exogenous.

Neither simulation results nor some submodels'
results are yet available.

Model: D.E. Ray and E.O. Heady: Simulated Effects of
                 Alternative Policy and Economic Environments on
                 U.S. Agriculture. (39)

Coverage: U.S.

Generaliza-   Agricultural sector
  tion level:

Aggregation: 6 commodity groups (livestock, feed grains, wheat,
                 cotton, tobacco and soybeans)

Method: Econometric.

Type of   Dynamic, deterministic.
  system:

Usage: Projection, analysis of implications of alternative
                 policies, (free market, changes in input prices
                 and production elasticities, changes in price
                 support levels, limitations on acreages).

Validation: Ex-post prediction for sample period.

Time: Data basis for estimation 1932-67, prediction
                 to 2000.

Short   The model covers U.S. agriculture by seven sub-
  discussion: models. Six of them represent commodity-groups
                 (livestock, feedgrains, wheat, soybeans, cotton,
                 and tobacco) and the seventh one is a national
                 level accounting block which operates as a super-
                 ordinated connection unit.

                 The sub-models are composed of three recursive
                 blocks: pre-input, input and output. The endogenous
                 variables are acreage and resource demand,
                 commodity production, supply, demand, price and
                 gross income. Policy variables are exogenous.

                 The production functions are of the C-D type,
                 estimated by the factor-share method. These are
                 the only functions where coefficients are not
                 constant for the whole time span, but only for
                 10 year periods.

                 The demand is directly dependent on current prices.
                 The supply depends indirectly on last year's
                 prices through resource demand and production.

                 With the same model alternative futures were
                 simulated from 1975 to 2000. (Published by
                 Th. M. Reynolds, E.O. Heady and D.O. Mitchell,
                 Card Reports 56, 1975). The most probable
                 future scenario and maximum future efficiency
                 were investigated. The former scenario involved
                 two runs, including and neglecting government

Short
disussion:
cont.

subsidy programs. The efficiency-variation
involved five runs with increased productivity,
farm size efficiency and more efficient produc-
tion due to changes in the location of crop
production.

Simulation results are discussed in detail.

Model:	D.E. Ray and T. F. Moriak: POLYSIM: A National Agricultural Policy Simulator. (37, 38)
Coverage:	U.S.
Generaliza-tion leve:	Agricultural sector.
Aggregation:	Four crops (feedgrains, wheat, soybeans, cotton) and seven livestock groups: (beef, hogs, sheep and lambs, chickens, turkeys, eggs and milk).
Method:	Simulation from base estimates.
Type of system:	Dynamic, deterministic
Usage:	Analysis of alternative agricultural policies, simulated by the model (free market policy, acreage set aside policy, loan rate policy, target price policy, government stock management policy or any combination of these).
Time:	Data basis not homogenous (estimations derived from various sources) projections till 1980.
Validation:	As "outside" estimation results are used, the validity of the model depends on them.
Short discussion:	POLYSIM is a recursive system of eleven product-submodels in addition to an aggregating block and a block of equations, representing government activities. (Through these equations policy alternatives can be induced.) With the exceptions of identities and variable levels determined by physical relationships and indexing procedures, the causal relations are tied together with the use of elasticity estimates. These elasticities represent the influences of changes in supply and demand shifters and changes in relative prices. All non-price related supply and demand shifters are expogenous and fixed. Since the short-run and the long-run responses of supply and demand to a price change are often different, the con-struction of the model enables the use of cumu-lative price responses through adjustment co-efficients.

Both supply and demand are dependent on some base estimates of themselves, which can be either the previous year's value or some projection, taken as baseline data. (The baseline projections are provided by the user.) Through this construc-tion the model always generates values, which are comparable to the baseline values.

Short
discussion:
cont.

Crop prices depend only on the percentage of change
in calculated crop supplies and the base supply.
(Supply contains production, imports and carry
overs.) Livestock prices are determined by the
production levels. Domestic demand depends only
on price changes.

By estimating total cash receipts, total produc-
tion expenses and government payments, net farm
income can be calculated.

One great advantage of the model is that it is
capable of simulating several different farm
policies without changing the program.

The model focuses on supply-demand relations, con-
sidering mostly price effects, but neglecting the
production and consumption processes in the sense
that neither input factors such as labour and
capital, nor income effects on the production and
the consumption sides are included.

The model doesn't explicitly describe connections
between the agricultural and non-agricultural
sectors.

Model:	F.J. Nelson and W. Cochrane: Economic Conse-quences of Federal Farm Commodity Programs, 1953-72. (31)
Coverage:	U.S.
Generaliza-tion level:	Agricultural sector.
Aggregation:	Crop and livestock subsectors.
Method:	Econometric.
Type of system:	Dynamic, deterministic.
Usage:	Analysis of different time paths generated by the model which represent the historical econo-mic policies and an assumed free market develop-ment. The question investigated: what would have happened if no government policy measures had been introduced.
Time:	1953-72.
Validation:	Ex-post prediction.
Short discussion:	A simultaneous econometic model (59 equations) was used to generate the time series of some selected variables for the past. The main task of the model was how farmers would react to alternative government policies. The production side is very thoroughly elaborated. Supplies have been affected by risk and uncertainty also. An interesting feature of the model is that farm technological change is treated endogenously.

Those farm programs analysed include: price sup-port, acreage diversions, land retirements and foreign demand expansions. When simulating the free market case, the corresponding policy variables take their appropriate zero values.

The model is solved for endogenous supply, demand and prices simultaneously.

Great attention is paid to the analysis of the implications of results (quite a few are now avail-able.) The main use of the model is "to learn from the past".

Model: K. S. Parikh: India in 2001 (34)

Coverage: India.

Generaliza-   Agricultural sector
tion level:

Aggregation: 14 commodity groups, rural-urban population.

Method: Econometric.

Type of   Dynamic, deterministic.
system:

Usage: Projection of food situation.

Time: Projections for 2001.

Validation: None.

Short   The study was directed at the question of whether
discussion: India can meet its food demands in 2001. To
                  answer this question the model determines the
                  demand at different population growth rates, urban-
                  rural distributions, and production possibilities
                  without assuming political or unexpected technolo-
                  gical changes.

                  Prediction on consumer demand: Starting with two
                  population projections the urban-rural distri-
                  bution of the population is determined by an
                  urban growth model. Projections of per capita
                  expenditures are elaborated for four variations,
                  (with high and low population growth; high and
                  low economic growth). Knowing the differences
                  in per capita expenditures between urban and
                  rural population and assuming that the Engel-
                  curves remain unchanged in the following 30 years
                  the modellers have estimated the demand for 14
                  commodity groups for the four population/economic
                  growth situations.

                  Prediction of agricultural production: Knowing
                  the current irrigation and crop yield response
                  to fertilizers on the crop areas; and assuming
                  that present cropping patterns will continue and
                  that irrigation will be the same as planned for
                  1980, the modellers have estimated the minimum
                  amount of fertilizers required to produce the
                  outputs desired. The results suggest that even
                  in the most pessimistic case (high population
                  and low economic growth) the amount of fertilizers
                  required to meet the consumer demand can be pro-
                  duced.

Model:	D.N. Basu: Consumption Pattern and Life Style: 2000 A.D. (4)
Coverage:	India
Generaliza-tion level	Consumer demand for food.
Aggregation:	14 expenditure classes, 28 commodity groups.
Method:	Econometric methods.
Type of system:	Dynamic, deterministic.
Usage:	Prediction of the changes in the consumption basket of Indian people, under alternative assumptions of population and economic growth.
Time:	Data base 1964-71 projection till 2000.
Validation:	None.
Short discussion:	To get a real picture about consumer patterns, the population has been divided into rural and urban population and into fourteen monthly per capita expenditure classes.

Correspondingly eight scenarios have been investigated for 2000. The number of people in each class and their per capita expenditures was estimated at high/low population growth, high/low economic growth and increased/decreased income inequality between rural and urban population. Assuming that the consumption pattern of persons in a particular expenditure class remain unchanged in the period investigated, relative prices of different goods and services don't vary significantly over the period and effects of other variables (as household size, lag in adjustment between income and expenditure, etc.) are not significant, the average per capita (and aggregated) monthly consumption was estimated for 28 items per income class.

Thus the difference between the current consumption basket and the projected one is the result of shifting of population distribution among the expenditure classes. Changes of tastes are not considered.

Model:	W. B. Clapham, Jr. and R. Bose: Land Resources and Food Production Model for the Indian Subcontinent. (8)
Coverage:	Indian Subcontinent.
Generalization level:	Crop production.
Aggregation:	10 regions, 5 crops, 5 cropping patterns.
Method:	(Partly statistically based) dynamic simulation.
Type of system:	Dynamic, deterministic.
Usage:	Projection of agricultural production at different levels of investment in land.
Time:	Data base: 1969-73, projections for 30 years.
Validation:	Parameters are partly estimated.
Short discussion:	Appropriate to the Mesarovic-Pestel system the model has connections (as input or as output variables) to other blocks in this framework, namely with the economic, population, food use, water, climate and livestock models.

In the land resources and food production model the subcontinent is divided up in ten regions. The crop production is represented by five crop types and by five cropping types (irrigated, dry, double cropping, etc.). At this level of aggregation 10 blocks are built.

The blocks are the following:

1. Land overview: describes relationship between land use and land potential.

2. Land maintenance: calculates amount of investment necessary to maintain status quo and amount of land maintained at each level.

3. Land development: describes changes in land use from less intensive to more intensive.

4. Land stewardship: describes losses of agricultural land due to failure of society in maintaining it in production capacity.

5. Urbanization: describes losses of land as a function of population growth.

6. State variable management: block contains the accounting functions.

7. Allocation of land and fertilizer: is done by regions and by crops.

Short
discussion:
cont.

8. Production function block: determines the amount
    of production of crops.

9. Forage.

10. Timber production.

This specification of crop production model is
intended to be used in the Mesarovic-Pestel global
model.

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