WORKING PAPER

SIMPLIFIED NATIONAL MODELS

THE CONDENSED VERSION OF THE FOOD AND AGRICULTURE MODEL SYSTEM OF THE INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS

G. Fischer
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IIASA
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PREFACE

It is obvious that a model system such as is described in this paper cannot be built without substantial assistance. This model was constructed as a team effort of the Food and Agriculture Program, FAP. The members of FAP during the period in which the model was built were Ferenc Rabár (program leader), Csaba Csáki, Anton Visser, Jaroslav Hirš, Bożena Łopuch, Ulrike Sichra, Anton Timman and both authors. Many others who are too numerous to mention also contributed to the work; however, the contribution of Michiel Keyzer from the Free University of Amsterdam is too substantial not to be singled out here. Likewise, Karl Ortner from the Agrarwirtschaftliches Institut in Vienna was very helpful, especially in obtaining the expenditure shares.

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1. INTRODUCTION

The aim of this paper is to give a concise description of the simplified national models as they were developed in the Food and Agriculture Program (FAP) at the International Institute for Applied Systems Analysis (IIASA).

The work on these models was begun in September 1978 and by late summer 1979 the models had reached a preliminary working stage. The reasons for building such a simplified model system are manifold. First of all, it became apparent that the disaggregated and detailed models of all originally selected countries could not be completed by the end of the program. To provide a self-contained product the simplified version was set up at that time. This system is consistent with the detailed one, but works with a more condensed product list (10 commodity aggregates instead of the 19 envisaged for the detailed version), with a smaller set of countries and with substantially simplified supply and demand components. After completion, the more detailed and sophisticated models can be substituted for this simplified version and, therefore, the system will become more and more realistic.

Although we are fully aware of the shortcomings of the simplified version, we hope that it will prove to be a useful demonstration tool. As such, the model will help to make the methodology used more understandable and to stress both its advantages and shortcomings. It also should be possible to indicate what kind of questions the FAP system will be able to answer. And finally, it should enable those modelling groups who complete their work in advance of other teams to link their model with the condensed version and thus test its performance.

The paper is organized in the following way: Chapter 2 contains a description of those countries which are included in the simplified version. In Chapter 3 a brief explanation of the overall structure of the model system is given and the basic requirements for linking the system are outlined. Data sources and aggregation procedures are explained in Chapter 4. Chapter 5 contains a description of the production module used in this system; input levels in agriculture and the allocation model are explained, followed by a discussion of nonagricultural production. Finally, in Chapter 6 some remarks on the exchange module are made, particularly on the Expenditure Share System used for modelling national demand.

2. COUNTRIES MODELLED

The countries included in FAP's model system were selected according to two criteria. The first was that they should comprise about 80 percent of world population, agricultural production, land base, and export and import of agricultural products. In Table 1 the relevant figures are given for the countries selected. While these vary considerably from country to country, the total is close to 80 percent for each of the indicators. The second criterion for selection was that countries included in this study represent all stages of economic development and all regions of the world.

The countries included in the FAP Model System can be grouped into four categories with regard to the detail and state of the modelling work.

The first of these currently consists only of India and is already using the detailed model version within the simplified system in order to make it linkable. The commodities for this version must be aggregated according to the 10-commodity list.

The second category comprises all those countries for which the national teams working on the detailed models are also building the simplified version. Austria, the EC countries, Sweden and the USA make up this group.

Category three consists of countries for which the respective simplified model was built by members of FAP with assistance from corresponding collaborating groups, who in turn are currently carrying out the construction of the

Table 1. Percentage of world population, production of agricultural commodities, land base, and agricultural trade in 1976.[1)]

Name of country	Population	Production 2)	Land base	Import 2)	Export 2)
Argentina	0.63	1.96	1.70	0.14	2.86
Australia	0.34	1.60	1.31	0.25	5.00
Austria	0.19	0.38	0.11	0.62	0.31
Bangladesh	1.86	0.70	1.12	0.34	0.11
Brazil	2.78	4.65	4.03	0.75	5.55
Canada	0.57	1.21	1.97	1.99	3.25
China	21.38	13.22	17.36	1.64	1.81
CMEA	8.98	16.72	17.49	12.72	5.74
EC	6.41	11.85	3.26	38.83	26.05
Egypt	0.95	0.72	0.32	0.94	0.56
India	15.48	6.73	14.63	1.06	1.30
Indonesia	3.44	1.60	1.48	0.64	1.02
Japan	2.77	1.76	0.38	8.36	0.05
Kenya	0.34	0.16	0.22	0.06	0.33
Mexico	1.51	1.47	1.31	0.35	0.82
New Zealand	0.08	0.49	0.03	0.14	2.09
Nigeria	1.59	0.54	1.59	0.50	0.40
Pakistan	1.79	0.93	1.37	0.34	0.34
Sweden	0.20	0.31	0.17	1.13	0.42
Thailand	1.07	1.13	1.11	0.18	1.23
USA	5.31	12.33	9.79	8.07	18.85
Total	77.65	80.47	80.75	78.78	77.97

1) The figures are taken from Figure 4 in Ferenc Rabar (1979), "Local problems in a global system".

2) Value in 1976 prices.

detailed model. This applies to CMEA countries, Bangladesh, Indonesia, Kenya, Pakistan, Thailand and China.

The largest number of countries makes up group four. These countries are being modelled by members of FAP. It consists of Argentina, Australia, Brazil, Canada, Egypt, Japan, Mexico, New Zealand and Nigeria.

It must be pointed out here that the subsequent chapters only apply to the countries of group four, group three (except the CMEA and China), the EC countries, and, to a somewhat lesser extent, Austria and Sweden. The different approaches to the other countries will be described by the respective modelling teams in separate papers. The country grouping given above reflects the state of June 1979 and is likely to change as more national teams join FAP's modelling effort.

It is worthwhile to mention that the country list shown in Table 1 represents the minimum number of countries included in the FAP model system. The linkage system would allow additional countries to be added, provided the minimum linking requirements, as discussed in the next chapter, are met.

3. MODEL STRUCTURE*

In order to meet the requirements of FAP's linkage system, a national model should:

- be a closed model in the sense that it covers the whole economy,
- consist of three modules; one for demand, another for supply and a third where the process of policy decision-making is described,
- be recursively dynamic; i.e., supply is assumed to be determined at the time consumers make their buying decisions,
- operate in one-year time increments,
- trade commodities only according to a common commodity classification,
- be basically of descriptive nature and
- be built for a medium time horizon (15-20 years).

Figure 1 shows a flow chart of the model's operation at the national level. Starting with given balance of trade deficit, international prices, supply, expenditure shares and policy targets, the model is solved for domestic equilibrium prices and quantities (see "exchange model 1"). Then capital stock by income class is adjusted through determination of investment. Labor force by income class is also

*The structure of FAP's model system with the linkage methodology has been extensively discussed by Michiel Keyzer in a series of research memoranda (see e.g. Keyzer 1977, Keyzer 1980).

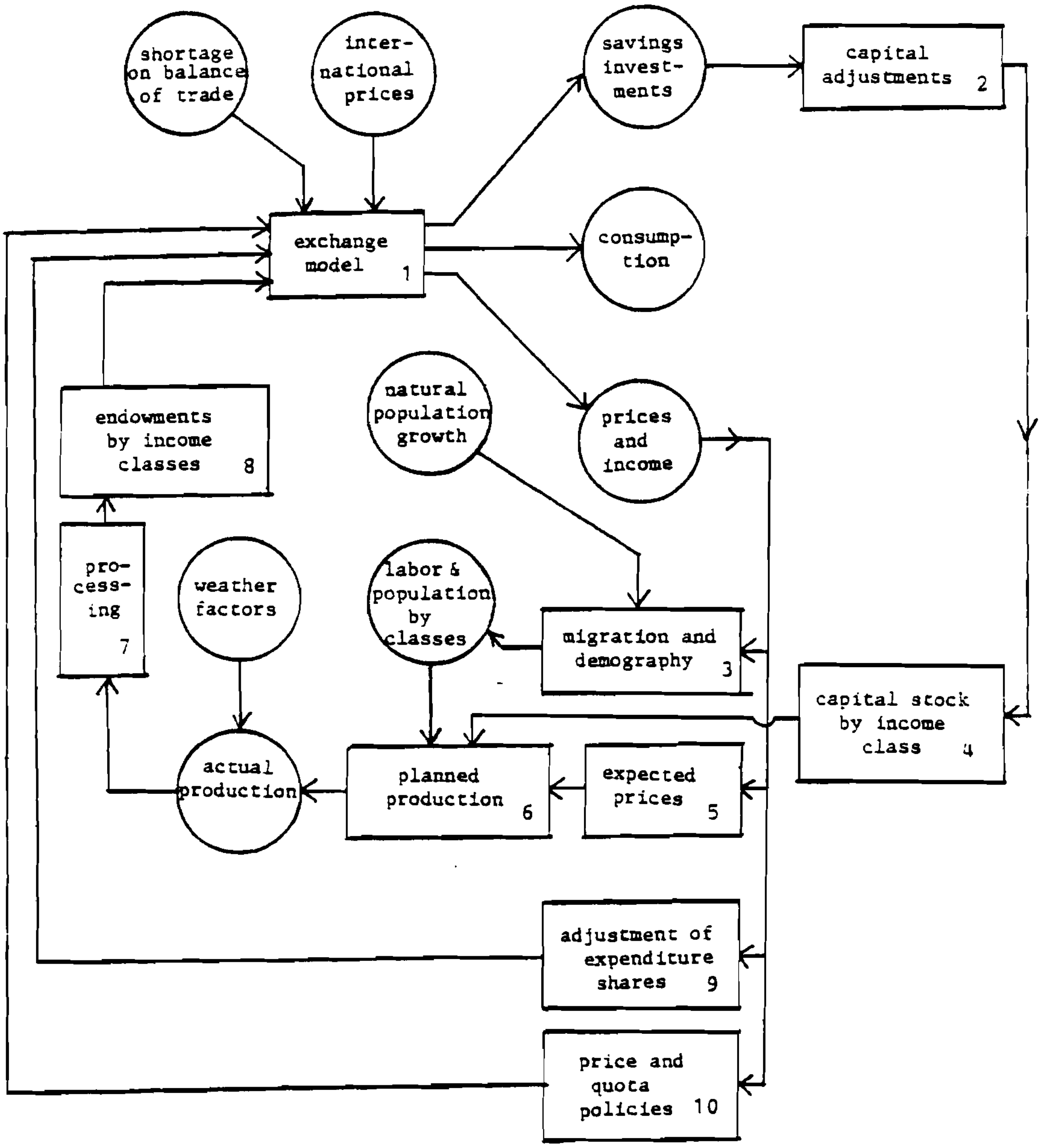

Figure 1. Operation of the model at national level. (Source: M. Keyzer. Main Structure of the "Supply" Component in a Simplified Model. Unpublished paper, IIASA, Laxenburg, Austria.)

calculated, given population growth and income distribution. Both labor force and capital stock, together with other inputs, expected producer prices and weather factors, determine actual production by income class. The transformation of these produced items to processed goods yields endowment per income class. According to the new equilibrium prices and income distribution, new policy targets are set and the expenditure share system is adjusted. Afterwards, simulation for the next year can start. The linking of all national models occurs when a set of international equilibrium prices is simultaneously calculated with the domestic equilibrium prices using an iterative procedure.

Table 2 indicates the commodity aggregates in which all countries exchange goods. As can be seen, for the simplified model the commodities are aggregated to nine agricultural products and one comprising all nonagricultural production activities.

This nonagricultural commodity is, of course, an oversimplification of real world phenomena, especially from the point of view of international exchange, as it is composed of tradable and untradable products.

The model system allows for different income classes in each country. The improvement in model performance due to such a disaggregation has to be balanced against the substantial increase in resources needed to build a model of this kind. This model version uses two income classes for the developing countries and one for developed countries.

Table 2 Commodity List

Condensed Model		Detailed Model	
Commodity	Unit of Measurement	Commodity	Unit of Measurement
1 Wheat	1000 m.t.	1 Wheat	1000 m.t.
2 Rice, milled	1000 m.t.	2 Rice, milled	1000 m.t.
3 Other Cereals	1000 m.t.	3 Other Cereals	1000 m.t.
4 Bovine and Ovine Meats	1000 m.t. (carcass weight)	7 Bovine and Ovine Meats	1000 m.t. (carcass weight)
5 Dairy Products	1000 m.t. (fresh milk equivalent)	10 Dairy Products	1000 m.t. (fresh milk equivalent)
6 Other Animal Products	1000 m.t. (protein equivalent)	8 Pork	1000 m.t. (carcass weight)
		9 Poultry and Eggs	1000 m.t. (protein equivalent)
		13 Fishery Products	1000 m.t. (protein equivalent)
7 Protein Feeds	1000 m.t. (protein equivalent)	5 Protein Feeds	1000 m.t. (protein equivalent)
8 Other Food	mill. US$ (1970)	4 Oils and Fats	1000 m.t. (oil equivalent)
		6 Sugar Products	1000 m.t. (refined sugar)
		11 Vegetables	mill. US$ (1970)
		12 Fruits and Nuts	mill. US$ (1970)
		14 Coffee	1000 m.t.
		15 Cocoa, Tea Products	mill. US$ (1970)
		16 Alcoholic Beverages	mill. US$ (1970)
9 Non-food Agricultural Production	mill. US$ (1970)	17 Clothing Fibres, Hides & Wool	mill. US$ (1970)
		18 Industrial Crops	mill. US$ (1970)
10 Non-Agricultural Production	mill. US$ (1970)	19 Non-Agricultural Production	mill. US$ (1970)

4. DATA BASE

In this chapter the sources and preparation of the data are discussed. Since the system of models built comprises the total economy of a large number of countries, a substantial amount of work had to be put into data preparation. The major sources of data that were used are listed below and will be discussed in subsequent chapters:

FAO Supply Utilization Accounts (SUA):

The SUA contain information on production, usage, trade and producer prices of agricultural commodities. They were given to us by the FAO, Rome, on magnetic tapes.

FAO Production and Trade Yearbook:

The magnetic tapes of the Production and Trade Yearbook issued by FAO in 1976, as well as several printed volumes, were used to compile data on fertilizer usage and prices of agricultural products.

FAO Fertilizer Reviews:

This material was used to collect data on fertilizer prices.

ILO Labor Force Projections:

A magnetic tape containing 1950 - 2000 population and labor force projections was used to arrive at population growth rates and labor participation rates.

World Tables:

A set of macroeconomic data was taken from a magnetic tape issued by the World Bank.

Yearbook of National Account Statistics:

The World Tables were augmented by data series from this United Nations publication.

The Economic Accounts of Agriculture:

This FAO publication was the main source of data on fertilizer expenses and intermediate consumption of nonagricultural goods by agriculture.

ILO, Household Income and Expenditure Statistics and FAO, Review of Food Consumption Surveys:

These sources were used to compile data on expenditure shares and processing margins.

Apart from the data sources mentioned above, we used national statistical yearbooks to the extent necessary and/or possible.

4.1. FAO Supply Utilization Accounts

4.1.1. Brief Description of the FAO Supply Utilization Accounts

The SUA present time series on about 1000 commodities related to agriculture. They also cover population, macroeconomics, land use, crop production, livestock production, agricultural inputs, fishery production and forestry. Of this large amount of data, about 500 commodities refer to agricultural production.

In principle, the accounts fit the standard accounting framework:

$$\text{Production} = \text{Final Demand} + \text{Intermediate Demand} + \text{Exports} - \text{Imports}.$$

Final Demand is split into several items:

- stock change
- seed/breeding
- feed consumption
- waste
- food consumption
- demand by manufacturing industry.

Intermediate Demand for a main product is labeled "PROCESSED" and reappears as "INPUT" in the accounts of one or more derived commodities. Each time series in the data base is fully identifiable by a set of five code numbers specifying:

- country
- commodity
- item
- dimension
- starting year.

In our data base, the years 1961-1976 are covered for 56 countries. There are about 100.000 records available, each record containing one time series and the necessary code information.

4.1.2. Aggregation of FAO Supply Utilization Accounts

4.1.2.1. Principles of Aggregation of FAO Supply Utilization Accounts.

The selection of an appropriate method ensures maximum reduction of the amount of data while minimizing the loss of information in accordance with the purpose of the model.

The part of the SUA used describes supply and demand for about 500 commodities. The accounts must be processed to generate supply and demand for the 19 aggregate commodities of FAP (see Table 2), to be called the FAP commodity list. The aggregation requires that only one quantitative measure be given for each commodity. This means that different stages of processing should be represented as price differences (processing margins) and not as physical transformations. This still leaves the decision open on where in the processing chain the output should be measured. In most cases, the raw material stage (farmgate level) is the most appropriate one, especially when one main product is used to make different derived products (wheat vs. bread, pastry, macaroni). There are, however, a few exceptions to this rule. One case is sugar. The same derived product, sugar refined, can be made from entirely different main commodities: sugar beets, sugar cane, maize, etc. When looking at trade and consumption figures of sugar refined, it is generally not clear to which of the primary commodities these items must be attributed. Therefore, sugar refined was chosen as a target for aggregation.

Another problem arises when one main product contributes to different commodities in the FAP commodity list. This applies to livestock products, which therefore were aggregated in terms of meat, offals, fat, hides, and milk, as well as for oil crops, which frequently were split into oil and protein feed.

To clearly point out the reason for our concern: After applying the proposed transformations it is possible to aggregate the reduced accounts using prices or unit values, or any other suitable weights. If this were done before bringing different related commodities in one group to a common level of processing, double counting of the physical quantity contained in the processing item would result. The problems of aggregation discussed above should not lead the reader to the assumption that not aggregating the data in the described way would be a better alternative. If commodities were grouped in this manner, the quantity contained in the processing item would be counted double; on the other hand, one cannot simply leave out derived products, since the information given there is needed to arrive at proper trade and consumption figures.

4.1.2.2. Reduction of Complex Commodity Structures.

In the first stage of the overall aggregation task, we tried to identify the tree structures underlying the SUA. Within each of the commodity trees we defined a so-called "target commodity", i.e., the particular node in the tree structure which was to replace the tree after the application of the transformation. Although some of the commodity trees look fairly complex, they can always be divided into subtrees which leave us with two basic configurations:

1) Commodities having only alternative derived commodities.

2) Commodities having only joint derived commodities.

Therefore, only the back-calculation of each of these two cases must be taken into account.

CASE A: Alternative Derived Products.

This term describes the method of back-calculation used when the higher level commodity is processed in different forms, giving various derived products (e.g., fruits can be canned, converted to juice, preserved, etc.). We denote the primary commodity by A (its items by A_i), and the derived products by B_l, $l=1,\dots,m$ (their respective items by $B_{l,i}$). This commodity tree can be replaced by a new commodity C, where the relevant items are defined as:

$$C_i = A_i + \sum_{l=1}^{m} B_{l,i}/EXTR_l \quad , \qquad i \in I \quad , \tag{4.1}$$

where $EXTR_l$ is the "extraction rate" describing the physical transformation of commodity A into commodity B_l. Extraction rates are usually included in the SUA as item 4. For those cases where an extraction rate was not available, a set of default values was prepared. Formula (4.1) was applied to the following items (index set I):

06 imports

07 from stocks

08 to stocks

09 exports

10 feed

11 seed/breeding

12 waste

14 food

15 other utilization.

Dollar values, which are given only for imports and exports, are simply added to the respective items.

CASE B: Joint Derived Products.

The method used when processing of a commodity results in several derived products simultaneously, e.g., wheat in flour and bran, is referred to as JDP. To account for qualitative differences in the derived joint products, we used a weighting scheme for back-calculation. Each commodity is assigned a weight (W_A for the original commodity and W_{Bl} for derived products). For reasons of consistency, the following identity holds:

$$W_A = \sum_{l=1}^{m} EXTR_l * W_{Bl} \quad . \tag{4.2}$$

The commodity tree is then converted to a single target commodity using:

$$C_i = A_i + \sum_{l=1}^{m} B_{l,i} * \frac{W_{Bl}}{W_A} \quad , \qquad i \in I \quad . \tag{4.3}$$

The set of indices I is the same as described above.

The general case of commodities which have both joint and alternative derived commodities can easily be handled by applying the above formulas to the appropriate subtrees.

4.1.2.3. Aggregation of the Transformed Accounts.

After the fairly complex task of converting the SUA data to a common stage of processing and elimination of intermediate consumption, the resulting simplified SUA records were converted to volumes and aggregated according to the FAP commodity list. The kind of weights which were used for converting to volumes depends on the unit of measurement of the FAP commodities. For those commodities which cover a wide range of different products (e.g., fruits, vegetables, industrial crops, etc.), average 1969 to 1971 export prices (in US $) were used as weights. Oil content and protein content were used for oil crops and protein feeds respectively. The units of measurement for each commodity (aggregate) can be found in Table 2.

Although the aggregation of the SUA as described above might seem to be straightforward, it should be mentioned here that problems arise as soon as the process is looked at more closely. Some of the problems encountered were:

- Lack of information about the destination of "PROCESSED" items
- Data inconsistencies
- Insufficient information about the origin of secondary oil and fats for many countries
- Differences between countries and inconsistencies with regard to the milk commodity trees
- Insufficient information about "N.E.S." commodities (i.e., residual within a particular group of commodities).

Since detailed treatment of all these peculiarities is beyond the scope of this paper, the interested reader is referred to a separate report on the aggregation of the SUA (Fischer and Sichra, forthcoming).

4.2. Population and Labor Force Data

The ILO Population and Labor Force Projections which were used contain time series in steps of five years from 1950-2000 on total population (by age groups), as well as labor force (by age groups and activities). The FAO reports yearly figures on total population from 1961 to 1976.

Using these two data sources, we produced the following six time series:

(1) Total Population (from FAO)

(2) Rural Population

(3) Urban Population

(4) Total Labor Force

(5) Agricultural Labor Force

(6) Labor Force in Nonagricultural Sector

Furthermore, the ILO data were used to estimate linear trend functions for population growth and labor participation rates.

4.3. Other Data Sources

The various other data needed, e.g., macroeconomic data, fertilizer usage, intermediate consumption, expenditure shares, etc., were taken from a number of different sources.

4.3.1. Macroeconomic Data

The macroeconomic data were mainly derived from the World Tables. Gaps in these time series were filled with information from the Yearbook of National Account Statistics. The Economic Accounts for Agriculture (FAO) and, as far as available, national statistical yearbooks, were also used for checking and enlarging the data base.

4.3.2. Quantity and Value of Fertilizer Input

Due to lack of more detailed information on fertilizer input, only the following two time series are used in this study:

- Consumption of Nitrogen Fertilizer (1000 m.t. nitrogen)
- Unit value of fertilizer (1000 national currencies per m.t. nitrogen).

The latter is the ratio of total value of all fertilizer input to quantity of nitrogen. Using this time series instead of nitrogen price assumes a fixed rate of application of all non-nitrogen to nitrogen fertilizer. It is obvious that this approach has shortcomings but it was taken due to lack of more detailed data. While there was no problem in obtaining information on fertilizer consumption (FAO, Fertilizer Reviews; FAO Production Yearbooks), price information was often scarce. The principal data sources used to arrive at this unit value series were:

(1) Data on Fertilizer Expenses from the Economic Accounts for Agriculture.

(2) Fertilizer Prices and Indices of Fertilizer Prices paid by farmers, taken from the Fertilizer Reviews.

(3) Fertilizer Prices given in the FAO Production Yearbooks.

4.4. Calculation of Time Series for Capital Stock.

For most of the countries considered, data on capital stock could not be found. This section describes how these time series were calculated.

Capital stock data series were to be obtained for both the agricultural and nonagricultural sector. It was assumed that gross fixed capital stock held by the private sector and by the government (excluding military goods) is the measure which best fits the model-building requirements. The information used on a country-to-country basis includes gross investments at constant prices, the investment price deflator, the value of annual depreciation and GDP at prices of 1970. Additional information was obtained from capital output ratios which, however, often could be found only on a regional basis (comprising several countries) and only for some reference years. These ratios were compiled from several sources and can be found in Table 3.

Two methods were employed for calculating capital stock time series. The one which was finally chosen for a particular country depended on the availability of information needed and on the plausibility of the result. As a plausibility check, a comparison was made between the capital output ratios implied in the result and those used in other studies. Another prerequisite for using one of these methods was that the calculated depreciation rate be positive. The two methods are briefly described below and a summary of the result is given in Table 3.

Method 1

Assumptions were made for the values of:

d^T_{70} = depreciation rate for total capital stock in year t, for t=1970

β_{Kt} = share of capital stock used in agriculture in total capital stock in year t, for t=1970

ϵ_{Kt} = the ratio of the depreciation rate for agricultural capital stock to the one for total capital stock in year t, for $\forall$t.

The calculation was done according to the following formulas:

$$K^T_t = D^T_t / d^T_t \quad , \qquad \text{for } t = 1970 \quad , \qquad (4.4)$$

$$K^T_t = K^T_{t-1} - D^T_{t-1} + I^T_t \quad , \qquad \text{for } \forall t,\ t \neq 1970 \quad , \qquad (4.5)$$

$$K^A_t = \beta_{Kt} * K^T_t \quad , \qquad \text{for } t = 1970 \quad , \qquad (4.6)$$

$$K^A_t = (1.0 - \epsilon_{Kt} * d^T_{t-1}) * K^A_{t-1} + I^A_t \ , \qquad \text{for } \forall t,\ t \neq 1970 \quad , \qquad (4.7)$$

$$K^{NA}_t = K^T_t - K^A_t \quad , \qquad \text{for } \forall t \quad , \qquad (4.8)$$

where

K^T_t = capital stock of total economy in year t

K^A_t = capital stock of agriculture in year t

K_t^{NA} = capital stock of nonagriculture in year t

D_t^T = total depreciation in year t

I_t^T = total investment in year t

I_t^A = investment in agriculture in year t.

All these variables are measured in 1970 US $.

Method 2

For a few countries in which no agricultural investment data were available, a different method using less information had to be set up. For that purpose, equation (4.4) was used for 1970, equations (4.5), (4.6) and (4.8) for all other years. Consequently, values for the depreciation rate of total capital stock and the share of agricultural capital stock on total capital stock had to be exogenously given for all years.

In Table 3, some indicators of the plausibility of this calculation are given. The capital output ratios of both sectors and of the overall economy are considered good indicators and are comparable to those used in other studies. Additional insight might be obtained by looking at the depreciation rates and the fractions of capital stock used in agriculture to total capital stock. The latter can be compared with the fraction of total GDP produced by agriculture.

Table 3. Estimates of the capital-output ratio for the total economy, the agricultural sector and the nonagricultural sector, GDP of agriculture in percent of total GDP, capital stock of agriculture in percent of total capital stock and the percent of total capital stock and of capital stock of agriculture being discarded.

Estimate computed by[1]	Type of Indicator[2]	Latin America 1966	1970	1980	Argentina 1966	1970	1974	Brazil 1966	1970	1974	Mexico 1966	1970	1974
UN-The future	K^T		1.366	1.541									
Mesarovic-Pestel	K^T	2.238	2.158										
Strübele	K^T	2.490	2.470										
Doblin	K^T												
FAP	K^T				1.884	2.026	2.306	1.863	1.964	1.932	1.789	1.841	1.890
Doblin	K^A												
National Statistical Office	K^A												
FAP	K^A				1.806	2.216	2.773	2.401	2.867	2.541	1.744	1.837	2.136
FAP	K^{NA}				1.900	2.055	2.250	1.808	1.883	1.871	1.795	1.842	1.863
FAP	k				13.562	12.173	10.810	9.312	8.222	9.125	11.591	11.300	11.300
FAP	c				13.000	13.000	13.000	12.000	12.000	12.000	11.300	11.300	11.300
FAP	d^T				2.13	2.60	1.60				4.70	4.70	4.30
FAP	d^A										3.76	3.76	3.44

Table 3 continued

Source[1)]	type of indicator[2)]	North America 1966	1970	1980	Canada 1966	1970	1974	Oceania 1966	1970	1980	Australia 1966	1970	1974	New Zealand[3)] 1966	1970	1974	Japan 1966	1970	1974
UN-The future	K^T		2.130	2.320					1.840	2.000									
Mesarovic-Pestel	K^T	2.240	2.160																
Strübele	K^T	3.450	3.620														2.37	2.52	
Doblin	K^T																		
FAP	K^T				2.722	2.766	2.534				2.721	2.853	3.159		2.862		3.056	2.675	2.978
Doblin	K^A																		
National Statistical Office	K^A																		
FAP	K^A				3.252	4.133	4.688				2.355	2.838	5.218		2.345		4.788	3.567	1.869
FAP	K^{NA}				2.701	2.724	2.481				2.748	2.854	3.080		2.968		2.959	3.567	1.869
FAP	k				3.767	3.012	2.432				7.047	6.119	3.693	22.118	17.089	17.970	5.397	5.621	10.131
FAP	ß				4.500	4.500	4.500				6.100	6.100	6.100	13.998	13.998	13.998	7.50	7.50	7.50
FAP	d^T				4.10	4.10	4.10				3.44	3.00		2.91	2.80		4.34	5.01	
FAP	d^A				3.69	3.69	3.69				6.64	1.25					3.47	3.47	

Table 3 continued

Source[1)]	Type of indicator[2)]	Western Europe 1966	1970	1980	Belgium-Luxembourg 1966	1970	1974	Denmark 1966	1970	1974	France 1966	1970	1974	FRG 1966	1970	1974
UN-The Future	K^T		1.846	2.000												
Mesarovic-Pestel	K^T	2.585	2.731													
Ströbele	K^T	2.970	3.170													
Doblin	K^T													3.600	3.600	4.000
FAP	K^T				3.132	3.024	2.946	2.697	2.752	2.800	3.211	3.091	3.070	3.635	3.511	3.691
National Statistical Office	K^T														3.600	4.000
Doblin	K^A													5.200	5.100	4.800
National Statistical Office	K^A														5.100	4.600
FAP	K^A				4.672	4.367	4.184	3.351	3.765	3.502	2.890	3.084	3.494	4.289	5.042	5.100
FAP	K^{NA}				3.072	2.975	2.906	3.629	2.673	2.949	3.235	3.091	3.045	3.609	3.462	3.644
FAP	k				3.757	3.741	3.150	9.325	7.311	7.839	6.998	6.313	5.536	3.814	3.284	3.257
FAP	B					5.00		10.00	10.00	10.00	6.30	6.30	6.30	4.50	4.50	4.50
FAP	d^T				3.30		3.30	3.01	2.90		3.29	3.50		2.83	3.10	
FAP	d^A				2.64		2.64	2.42	2.42			1.79				

Table 3 continued

Source[1)]	Type of indicator[2)]	Ireland 1966	1970	1974	Italy 1966	1970	1974	Netherlands 1966	1970	1974	United Kingdom[4)] 1966	1970	1974
UN-The future	K^T												
Mesarovic-Pestel	K^T												
Ströbele	K^T												
Doblin	K^T												
FAP	K^T	2.613	2.613	2.832	3.148	2.978	3.031	3.062	3.032	3.178			
National Statistical Office	K^T										3.500	3.757	3.882
Doblin	K^A												
National Statistical Office	K^A										2.413	2.637	2.618
FAP	K^A	2.413	2.542	2.610	2.656	2.922	3.205	4.866	4.167	3.596			
National Statistical Office	K^{NA}										3.550	3.785	3.915
FAP	K^{NA}	2.650	2.624	2.868	3.210	2.983	3.016	2.949	2.962	3.150			
FAP	k	15.897	13.955	13.822	10.097	8.661	7.714	5.900	5.821	6.377	2.451	2.459	2.551
FAP	β		13.600			8.500		9.375	8.000	7.216			
FAP	d^T	3.10	3.10	3.10	2.90	2.90	2.90	2.94	2.80				
FAP	d^A	2.48	2.48	2.48	2.32	2.32	2.32	2.21	2.21				

Table 3 continued

Source[1]	type of indica-tor[2]	Africa 1966	1970	1980	Nigeria[5] 1966	1970	1974	Kenya[5] 1966	1970	1974
UN-The Future	K^T		.738	1.164						
Mesarovic-Pestel	K^T	1.433	1.449							
Strübele	K^T									
Doblin	K^T									
FAP	K^T				2.327	1.873	2.109	1.673	1.873	2.128
Doblin	K^A									
National Statistical Office	K^A									
FAP	K^A				1.118	1.006	1.690	1.479	1.367	1.313
FAP	K^{NA}				3.436	2.521	2.774	1.756	2.072	2.428
FAP	k				47.856	42.797	28.702	30.071	28.776	26.940
FAP	β				22.995	23.002	23.002	26.59	21.00	16.62
FAP	d^T									
FAP	d^A									

Footnotes to Table 3:

1) SOURCES:

UN-The future: W. Leontief, et al., The future of the world economy, A United Nations study, Oxford University Press, 1977.

Mesarovic-Pestel: Mesarovic, M., and E. Pestel (eds.), Multilevel computer model of world development system, Volume II, IIASA Symposium Proceedings, SP-74-2, Laxenburg, Austria, 1974.

Doblin: Doblin, C., Capital Formation, Capital Stock, and Capital Output Ratios (Concepts, Definitions, Data, 1850-1975), IIASA Research Memorandum, RM-78-78, Laxenburg, Austria, 1978.

Ströbele: Ströbele, W., Untersuchungen zum Wachstum der Weltwirtschaft mit Hilfe eines regionalisierten Weltmodelles, Dissertation, Technische Universität, Hannover, 1975.

National Statistical Office: Publications of the respective National Statistical Office:
- (i) Statistisches Bundesamt, Statistisches Jahrbuch 1976 fur die BRD, Verlag Kohlhammer, 1976.
- (ii) Central Statistical Office, National Income and Expenditure 1967-1977, Her Majesty's Stationery Office, London, 1978.

FAP: Calculations and assumptions by members of the food and agricultural program (FAP), IIASA.

2) The indicators have the following meanings:

K^T: capital-output ratio for total economy (capital stock divided by GDP, both at constant prices)
K^A: capital-output ratio for agriculture
K^{NA}: capital-output ratio for nonagriculture
k: GDP of agriculture in percent of total GDP
β: capital stock of agriculture in percent of total capital stock
d^T: percent of total capital stock which is discarded
d^A: percent of capital stock of agriculture which is discarded

3) For New Zealand no data on GDP of agriculture have been reported.

4) Capital stock data for the UK were obtained from the statistical publication by the Central Statistical Office, <u>National Income and Expenditure 1966-77</u>, A publication of the Government Statistical Service, 1978.

5) For Kenya as well as for Nigeria no depreciation is reported. Hence the depreciation rate was not needed.

5. SUPPLY MODULE

The supply module consists of two components. One is used for determination of supply of agricultural products. This is the more elaborate one and is described in the subsequent section. The other component, which is discussed in section 5.2., consists of a production function for the nonagricultural sector.

5.1. Supply Module for the Agricultural Sector

One of the limitations of the condensed model version is the fact that the same structure of the supply module introduced in this section is imposed on all countries modelled at IIASA. This, however, was not done because it is believed that the agricultural sectors of all those countries have a similar structure. This assumption had to be made because of lack of manpower. On the other hand, the inadequacy of available data also restricted the choice of which method to use.

The agricultural sector model has to meet some basic requirements. First of all, since our aim is to study alternative courses of policy actions, the model must include those instruments which allow for such policy modifications. Due to the constraints on manpower mentioned above, only the most important policy instruments affecting supply of agricultural products could be considered. The model should enable the user to assess the following broad categories of policies: price policies, production quotas and policies influencing the mobility of labor and capital between the agricultural and nonagricultural sector.

Another requirement of the model is that it describe as accurately as possible farmers' responses to these policies. In other words, a descriptive model has to be built. This, in turn, means that as many model parameters as possible should be statistically estimated.

The level of annual production in agriculture is typically determined in a sequence of decisions arrived at by a large number of decision making units. It is clear that this process cannot be modelled in its full complexity, given the constraints mentioned above. Instead, two simplifying assumptions were introduced. One is that only a single decision making unit exists. This leads to the aggregation of all production units of a country to a "representative farm". It was further assumed that the sequence of decision making consists of only two stages. In the first stage, the quantity of the major inputs to be used in all production activities is decided upon. In the subsequent stage, these inputs are allocated to the various production activities. With the latter decision, the level of production is simultaneously determined.

In the following, each subcomponent of the supply module for the corresponding decision making stage is described in respective order of occurrence. For the first stage, a set of equations was estimated, making the input level of a given factor a function of some economic variables. These variables are measures of performance of the economy in general and the agricultural sector in particular during the last year. To arrive at the allocation decision (second decision stage), a nonlinear programming model is used.

5.1.1. Input Levels in Agriculture

Input levels for the total agricultural sector will be determined for three input categories: labor, capital and fertilizer. These inputs are allocated to the various products in the second decision stage.

Cultivated area could not be considered explicitly in the second decision stage because of missing data. For some commodities, acreage allocation is not included in the SUA, so that the sum of total cultivated area obtained from the SUA does not coincide with the total observed cultivated land as given in other sources. Acreage allocation is missing for fodder production,* some perennial and a few other crops. Thus, only a part of total cultivated acreage could have been determined and further used in the allocation process, and the simultaneity in the land allocation could not have been modelled appropriately. Therefore, it was considered that the best course of action was not to include land as a separate variable for the time being.

All other inputs are dealt with in the model in either one of two ways. The feed items are assumed to be fed in fixed proportions to the corresponding production level of the various animal categories. The rest of the inputs, i.e., those inputs not yet mentioned, are determined in fixed proportion to total production and are assumed to have no allocative effect.

*Fodder production is only partly included in the SUA.

The basic assumption here is that the input levels of the three factors labor, capital and fertilizer are not necessarily determined according to the neoclassical hypothesis. Hence, the input determining functions are specified in the conventional way and not explicitly derived from a profit-maximizing model.

For each of these three input factors and for all countries, a set of functions was estimated. An informal discrimination procedure based mainly on the plausibility of the coefficients, the appropriateness of the fit and whether the residuals indicate autocorrelation was followed country by country in order to select those functions showing preferable results.

It should be emphasized that whenever the input determining functions include prices as exogeneous variables the functions have to be homogeneous of degree zero in those variables.

5.1.1.1. Labor Input into Agriculture.

Labor input into agriculture is measured by the number of persons employed in this sector. Due to lack of data, a more precise measure for agriculture manpower could not be used. It would have been preferable to take into account how many hours each of these persons works in agriculture during a year, or even in different time spans within a year, what portion of the labor force is skilled and unskilled and how many of those working in agriculture are proprietors and what the size of their holdings is. The following functional forms for labor input into agriculture were estimated:

$$L_t^A = \alpha_{L1} * \left(\frac{GDP_{t-1}^A}{GDP_{t-1}^{NA}}\right)^{\alpha_{L2}} * L_t^T \quad , \tag{5.1}$$

$$L_t^A = \alpha_{L1} * \left(\frac{Z_{t-1}^A}{Z_{t-1}^{NA}}\right)^{\alpha_{L2}} * L_{t-1}^A \quad , \tag{5.2}$$

$$L_t^A = \alpha_{L1} * \left(\frac{GDP_{t-1}^A}{GDP_{t-1}^{NA}}\right)^{\alpha_{L2}} * L_{t-1}^A \quad , \tag{5.3}$$

$$L_t^A = \alpha_{L1} * \left(1.0 + \exp * \left(\alpha_{L2} * \left(\frac{Z_{t-1}^A}{Z_{t-1}^{NA}}\right)\right)\right) * L_t^T \quad , \tag{5.4}$$

$$L_t^A = \left(1.0 - \frac{\alpha_{L1}}{1+\exp(-\alpha_{L2}*t)}\right) * L_t^T \quad , \tag{5.5}$$

where

L_t^A = agricultural labor force in year t (in 1000 of persons)

L_t^T = total labor force in year t (in 1000 of persons)

GDP_t^A = gross domestic product of agriculture in year t (in million national currency at current prices)

GDP_t^{NA} = gross domestic product of nonagriculture in year t (in million national currency at current prices)

Z_t^A = income per agricultural laborer in year t $\left(= \frac{GDP_t^A}{L_t^A}\right)$

Z_t^{NA} = income per nonagricultural laborer in year t $\left(= \dfrac{GDP_t^{NA}}{L_t^{NA}} \right)$

t = time (t = year minus 1965).

The estimation* results are summarized in Table 4. Function (5.1) measures the share of total labor force working in agriculture in terms of the ratio of last year's agriculture to nonagriculture gross domestic product. This function fit data badly for all countries† and the parameters often showed unexpected signs. Hence, it was not chosen for any country. The second function, function (5.2), explains the ratio of current to last year's agricultural labor force by using relative income per agricultural laborer (income per agricultural laborer divided by income per nonagricultural laborer) in the previous year. For many countries, income per laborer in agriculture increased relative to that of a nonagricultural laborer for the period under consideration. On the other hand, the ratio of current to last year's agricultural labor force declines for many countries. Consequently, the coefficient α_{L2} had the wrong sign for all countries except Ireland and New Zealand. In these two countries, the ratio of current to last year's agricultural labor force does not indicate any trend.

For most countries, equation (5.3) was selected. This

*All functions--also those presented in the following sections--were estimated assuming an additive error term. This assumption leads to a nonlinear estimation procedure.

†The goodness of fit is indicated by the value of the residual sum of squares (SSQ).

Table 4. Functions determining labor force of agriculture.

Country #	Name	Number of equation selected[1]	Value of α_{L1} (t-values in parentheses)		α_{L2}		Value of sum of squares (SSQ)
9	Argentina	5.5	1.637	(9453.0)	0.00088	(250.2)	$1.89*10^{-8}$
10	Australia	5.3	1.050	(34.7)	0.02841	(2.3)	$2.46*10^{-4}$
15	Belgium-Luxembg.	5.3	1.217	(13.9)	0.08512	(3.6)	$1.73*10^{-4}$
21	Brazil	5.3	1.020	(470.7)	0.00239	(2.6)	$4.27*10^{-7}$
33	Canada	5.3	1.140	(13.0)	0.05225	(2.2)	$7.12*10^{-4}$
54	Denmark	5.3	1.047	(13.4)	0.03795	(1.3)	$4.85*10^{-5}$
68	France	5.3	1.085	(19.0)	0.05292	(2.6)	$1.43*10^{-4}$
78	FRG	5.3	1.271	(10.3)	0.09816	(3.4)	$7.11*10^{-4}$
104	Ireland	5.2	0.990	(81.0)	0.02480	(1.7)	$1.39*10^{-4}$
106	Italy	5.3	1.018	(23.7)	0.03728	(1.9)	$1.68*10^{-4}$
110	Japan	5.3	1.061	(73.7)	0.04303	(8.4)	$1.03*10^{-4}$
114	Kenya	5.3	1.043	(24.4)	0.01907	(4.5)	$1.74*10^{-4}$
138	Mexico	5.3	1.043	(173.8)	0.01026	(3.9)	$0.5543*10^{-5}$
150	Netherlands	5.3	1.030	(59.9)	0.01875	(3.0)	$3.87*10^{-5}$
156	New Zealand	5.2	0.988	(162.7)	0.01433	(1.4)	$9.07*10^{-5}$
159	Nigeria	5.5	0.670	(1861.0)	0.05340	(253.2)	$5.369*10^{-7}$
229	U.K.	5.3	0.967	(9.0)	0.02280	(0.1)	$1.13*10^{-3}$
59	Egypt	5.5	0.873	(53260.0)	0.01825	(2775.0)	$1.5722*10^{-7}$
101	Indonesia	5.3	1.014	(1434.0)	0.00615	(5.[illegible])	$3.2254*10^{-6}$
165	Pakistan	5.5	0.803	(14310.0)	0.00979	(407.8)	$1.5982*10^{-8}$
216	Thailand	5.5	0.363	(3919.0)	0.04332	(443.6)	$2.2541*10^{-8}$

[1] The equations can be found in the text on page 37.

equation is similar to (5.2), except that the ratio of agricultural to nonagricultural gross domestic product is the determining variable. The coefficient α_{L2} indicates the percentage change of the ratio of current to last year's agricultural labor force due to a percentage change in the ratio of gross domestic product of the two sectors. This value varies in those countries for which this equation has been selected from 0.0024 (Brazil) to 0.0982 (FRG).

Equation (5.4) was not selected for any country, either. It measures the portion of total labor force working in agriculture as a function of relative income per agricultural laborer. For the same reasons mentioned in the discussion about function (5.2), this function does not show a good fit. Measuring the same portion just by a time trend, (equation 5.5), improves the fit but is unsatisfactory, too, for no economical variable explains migration. Hence, it is just used for Argentina for which it was deemed to be the best result.

Total labor force is obtained from population statistics. For ex ante runs, it is calculated as a portion of total population. This portion, the participation rate, is exogeneously determined.

5.1.1.2. Investment in Agriculture and Capital Stock of Agriculture

Investment in agriculture was estimated as share of total investment. The following functional forms were used:

$$\frac{\tilde{I}_t^A}{\tilde{I}_t^T} = \left[\alpha_{I1} \Big/ \left(1.0 + e^{-\alpha_{I2} * t}\right)\right] * \left(\frac{GDP_{t-1}^{A,CO}}{GDP_{t-1}^{NA,CO}}\right)^{\alpha_{I3}} , \qquad (5.6)$$

$$\frac{\tilde{I}_t^A}{\tilde{I}_t^T} = \alpha_{I1} * \left(\frac{P_{t-1}^A}{P_{t-1}^{NA}}\right)^{\alpha_{I2}} * \left(\frac{GDP_{t-1}^{A,CO}}{GDP_{t-1}^{NA,CO}}\right)^{\alpha_{I3}} , \qquad (5.7)$$

$$\frac{\tilde{I}_t^A}{\tilde{I}_t^T} = \left[\alpha_{I1} \Big/ \left(1.0 + e^{-\alpha_{I2} * t}\right)\right] * \left(\frac{GDP_{t-1}^{A}}{GDP_{t-1}^{NA}}\right)^{\alpha_{I3}} , \qquad (5.8)$$

$$\frac{\tilde{I}_t^A}{\tilde{I}_t^T} = \left[\alpha_{I1} \Big/ \left(1.0 + e^{-\alpha_{I2} * t}\right)\right] * \left(\frac{P_{t-1}^{A}}{P_{t-1}^{NA}}\right)^{\alpha_{I3}} , \qquad (5.9)$$

where

$\tilde{I}_t^A$ = gross investment in agriculture in year t (in million national currency at current prices)

$\tilde{I}_t^T$ = total gross investment in year t (in million national currency at current prices)

GDP_t^A = gross domestic product of agriculture in year t (in million national currency at current prices)

$GDP_t^{A,CO}$ = gross domestic product of agriculture in year t (in million national currency at prices of 1970)

GDP_t^{NA} = gross domestic product of nonagriculture in year t (in million national currency at current prices)

$GDP_t^{NA,CO}$ = gross domestic product of nonagriculture in year t (in million national currency at prices of 1970)

p_t^A = price index of agricultural commodities in year t

p_t^{NA} = price index of the nonagricultural commodity in year t

t = time variable (t = year - 1965).

In the first equation, equation (5.6), agricultural investment share is determined by the ratio of last year's gross domestic product of agriculture to that of nonagriculture and by a factor* which assymptotically increases over time to the value of α_{I1}. Since gross domestic product is measured at 1970 prices, the share is solely influenced by the output ratio. This function gave reasonable results only for the United Kingdom (see Table 5),† for which both ratios increase over time.

According to equation (5.7), agricultural investment share is determined by the ratio of agricultural to nonagricultural price indices in the previous year and by last year's output ratio of the two sectors. With this function, good results were obtained for all those countries for which the investment share declines over time together with the ratio of agriculture to nonagriculture output (see Table 5). The ratio of last year's price indices of the two sectors indicates that investment in agriculture increases relatively to nonagriculture if the terms of trade between the two sectors change favorably for agriculture. This effect, however, could not be measured for France and Italy. There,

*This refers to $\alpha_{I1}/(1.0 + e^{-\alpha_{I2}*t})$.
†The same procedure for selecting the most suitable function for a country was followed as described in the previous section.

Table 5. Estimation of Agricultural Investment Share.

Country #	Name	Number of equation in text[1]	Value of α_{I1}	α_{I2}	α_{I3}	Value of sum of squares
			(t-values in parentheses)			
9	Argentina	no estimation[2]				
10	Australia	5.7.	0.1257 (0.2290)	0.9026 (1.145)	0.3542 (0.1975)	0.15243
15	Belgium-Luxembourg	5.8.	0.7290 (0.2695)	0.04286 (0.3627)	0.8941 (0.6892)	0.10035
21	Brazil	no estimation				
33	Canada	5.7.	0.3083 (0.8149)	0.5953 (1.728)	0.5471 (1.437)	0.10252
54	Denmark	5.9.	0.08636 (5.079)	0.1006 (1.002)	1.094 (1.974)	0.10861
68	France	5.7.	0.1049 (1.737)	0.000 Bound	0.2777 (1.243)	0.01247
78	F.R.G.	no estimation				
104	Ireland	5.7.	2.804 (1.098)	0.2562 (0.7137)	1.794 (3.724)	0.05309
106	Italy	5.7.	0.5144 (1.681)	0.000 Bound	0.9194 (3.447)	0.01401
110	Japan	5.7.	0.2319 (2.404)	0.3420 (0.5834)	0.6007 (3.633)	0.03668
114	Kenya	5.7.	0.2007 (2.531)	1.169 (1.254)	0.6268 (1.684)	0.06704
138	Mexico	no estimation				
150	Netherlands	5.9.	0.06073 (1.445)	0.1206 (0.3493)	0.5738 (0.4413)	0.19309
156	New Zealand	no estimation				
159	Nigeria	no estimation				
229	U. K.	5.6.	0.2331 (0.8865)	0.1074 (2.548)	0.4528 (1.425)	0.01741
59	Egypt	no estimation				
101	Indonesia	no estimation				
165	Pakistan	5.7	0.5729 (3.790)	0.000 Bound	1.527 (4.563)	0.07951
216	Thailand	no estimation.				

[1] The equations can be found on page 41.
[2] No estimation could be carried out because of lack of data.

the coefficient α_{I2} equals zero and hence, for these two countries this equation has to be interpreted similarly to function (5.6).

In equation (5.8), it is hypothesized that both agricultural prices and output have the same effect on agricultural investment share. Therefore, the ratio of agricultural to nonagricultural gross domestic product measured at current prices is used as determining variable. In addition, the multiplicative factor increases assymptotically over time to the value of α_{I2}. This function gave satisfactory results only for Belgium-Luxembourg.

Agricultural investment share in Denmark and the Netherlands could best be estimated using equation (5.9). This function is similar to (5.8) except that the ratio of last year's price indices of the two sectors is used as independent variable. In both countries, the investment share increases over time and so does the ratio of the price indices.

Total investment in year t is assumed to be equal to last year's total savings. For ex ante runs, the latter is determined by an exogenously given savings rate which is based on historical values, i.e.,

$$I_t^T = s_{t-1} * \left(GDP_{t-1}^T + \text{trade deficit in t-1}\right) \quad , \qquad (5.10)$$

where s_t is the savings rate and GDP_t^T is the gross domestic product of the total economy, both in year t. Gross investment and an exogenous depreciation rate* (obtained

*These values can be found in Table 3.

from calculating capital stock time series as described in section (4.4)) are used to calculate capital stocks. For the agricultural sector the formula becomes:

$$K_{t+1}^{A} = K_{t}^{A} * \left(1 - d_{t}^{A}\right) + I_{t+1}^{A} \quad , \tag{5.11}$$

where

K_t^A = capital stock of agriculture in year t

d_t^A = depreciation rate for agricultural capital stock in year t

I_t^A = gross investment in agriculture in year t $\left(I_{t+1}^{A} = \tilde{I}_{t+1}^{A}/p_{t}^{NA}\right)$.

Capital stock in nonagriculture is calculated in the same way, i.e.,

$$K_{t+1}^{NA} = K_{t}^{NA} * \left(1 - d_{t}^{NA}\right) + I_{t+1}^{NA} \quad , \tag{5.12}$$

where the superscript NA indicates the nonagriculture sector.

For all those countries for which no investment share could be estimated because of lack of data, the share of capital stock used in agriculture is exogenously determined. This parameter, call it β, was also obtained when calculating capital stock time series (see Table 3) and is used for ex ante runs as well.

5.1.1.3. Fertilizer Input Functions

As already indicated in section 4.3.2., the simplifying assumption is made that nitrogen, potash and phosphorus are applied in fixed proportions; hence, it suffices to consider nitrogen alone as a variable. The unit value of nitrogen consists not only of the nitrogen price but also of the value of potash and of phosphorus applied together with a unit of nitrogen.

Altogether, seven different functional forms have been estimated for all countries. They are:

$$TF_t = \alpha_{F1} * \left(P^r_{Ft}\right)^{-\alpha_{F2}} * \left(GDP^{A,CO}_{t-1}\right)^{\alpha_{F3}} \quad , \qquad (5.13)$$

$$TF_t = \alpha_{F1} * \left(\left(\frac{P^A_{t-1}}{P^{NA}_{t-1}}\right) \Big/ P^r_{Ft}\right)^{\alpha_{F2}} * \left(GDP^{A,CO}_{t-1}\right)^{\alpha_{F3}} \quad , \qquad (5.14)$$

$$TF_t = \alpha_{F1} * \left(P^r_{Ft}\right)^{-\alpha_{F2}} * \left(GDP^{A,CO}_{t-1} * \frac{P^A_{t-1}}{P^{NA}_{t-1}}\right)^{\alpha_{F3}} , \qquad (5.15)$$

$$TF_t = \left[\alpha_{F1} \Big/ \left(1.0 + e^{-\alpha_{F2} * t}\right)\right] * \left(GDP^{A,CO}_{t-1}\right)^{\alpha_{F3}} , \qquad (5.16)$$

$$TF_t = \left[\alpha_{F1} \Big/ \left(1.0 + e^{-\alpha_{F2} * t}\right)\right] * \left(\frac{P^A_{t-1}}{P^{NA}_{t-1}} * P^r_{Ft}\right)^{\alpha_{F3}} , \qquad (5.17)$$

$$TF_t = \left[\alpha_{F1} \Big/ \left(1.0 + e^{-\alpha_{F2}*t}\right)\right] * \left(GDP^{A,CO}_{t-1} \Big/ p^{r}_{Ft}\right)^{\alpha_{F3}} , \quad (5.18)$$

$$TF_t = \left[\alpha_{F1} \Big/ \left(1.0 + e^{-\alpha_{F2}*t}\right)\right] * \left(\frac{p^{A}_{t-1}}{p^{NA}_{t-1}}\right)^{\alpha_{F3}} , \quad (5.19)$$

where

TF_t = total fertilizer (nitrogen) bought by agriculture in year t (in 1000 mt)

$GDP^{A,CO}_t$ = constant gross domestic product of agriculture in year t (in million national currencies at 1970 prices)

p^A_t = price index of agricultural products in year t

p^{NA}_t = price index of the nonagricultural commodity in year t

p^r_{Ft} = relative unit value of fertilizer (nitrogen) in year t, calculated as the ratio $p_{Ft}/\left(p^{NA}_t/p^{NA}_{70}\right)$ with p_{Ft} being the unit value of fertilizer in t

Table 6 shows the function selected for each country. Again, the same informal procedure as described in section 5.1.1. was used for discriminating between different models.

Because fertilizer input varies considerably from year

Table 6. Fertilizer input functions

#	Country Name	Number of equation in text[1]	Value of α_{F1} (t-values in parentheses)	α_{F2}	α_{F3}	Value of sum of squares
9	Argentina	5.17	115.6 (2.5710)	0.253600 (1.0160)	0.84350 (2.4860)	0.0322
10	Australia	5.16	275.1 (6.0100)	0.040300 (0.6160)	0 Bound	0.14869
15	Belgium-Luxembourgh	5.16	178.5 (0.2871)	0.004235 (0.1815)	0.06285 (0.1946)	0.0042
21	Brazil	5.19	1254.0 (0.9433)	0.2769 (0.2963)	1.459 (2.6130)	0.4278
33	Canada	5.19	331.5 (2.517)	0.1882 (0.5998)	0.4211 (2.254)	0.1406
54	Denmark	5.13	67.58 (0.3740)	1.50000 Bound	0.3099 (1.0350)	0.0161
68	France	5.17	4265.0 (2.3990)	0.191500 (2.0330)	0.6614 (2.2610)	0.0118
78	F.R.G.	5.14	0.01267 (0.5322)	0.163100 (0.9003)	1.1610 (6.1330)	0.0075
104	Ireland	5.16	1.3200 (0.1936)	0.255500 (0.3096)	0.8390 (0.7896)	0.2266
106	Italy	5.18	137.8 (1.0600)	0.142000 (3.4600)	0.1872 (1.8600)	0.0032
110	Japan	5.15	0.1311 (0.1000)	0.059540 (0.0750)	0.5623 (0.0700)	0.1025
114	Kenya	5.16	0.000133 (2.4530)	0.283600 (0.5902)	1.5000 Bound	0.1307
138	Mexico	5.15	0.01407 (0.1175)	1.290000 (4.2170)	0.8260 (1.0150)	0.0684
150	Netherlands	5.17	611.1 (26.830)	0.101900 (5.1980)	0.8117 (4.0300)	0.0038
156	New Zealand	5.17	18.06 (0.4935)	0.191300 (0.1380)	0.7219 (0.8723)	0.9119
159	Nigeria	5.14	2.2760 (4.2680)	0.849900 (3.0650)	0 Bound	0.5546
229	U. K.	5.19	1126.0 (1.1740)	0.037700 (0.6368)	0.1841 (0.3864)	0.0709
59	Egypt	5.16	33.470 (0.4472)	0.4879 (3.3560)	0.3579 (1.0780)	0.0035
101	Indonesia	5.17	5668.0 (1.6310)	0.2839 (0.5306)	0.7517 (5.2310)	0.1421
165	Pakistan	5.16	0.0001874 (3.5650)	0.2477 (0.8813)	1.5000 Bound	0.0528
216	Thailand	5.18	20.560 (0.2598)	0.1227 (0.7710)	0.1920 (0.3550)	0.1432

[1] The equations can be found on pages 46 and 47.

to year, seven functions had to be estimated in order to achieve a reasonable fit. These functions can be split into three categories. The first of these comprises all those functions according to which there is both a price and a quantity influence on fertilizer input. These are the functions (5.13), (5.14), (5.15), and (5.18). In these functions, the quantity produced last year--as indicated by constant gross domestic product--is a measure of what farmers would like to produce in the coming year and, thus, determines the quantity of fertilizers to be purchased. The higher their desired output, the more fertilizer they apply. This decision, however, is also influenced by the relative fertilizer price, p^r_{Ft} and/or by last year's terms of trade of agriculture, i.e., by the ratio of last year's price index of agriculture to that of nonagriculture. Again, the ratio of lagged price indices is taken as a measure of what farmers expect with regard to relative prices in the coming year.

Equation (5.16), which describes fertilizer input as a function only of quantity produced, falls into category two. A further characteristic of this equation is that the multiplicative factor increases assymptotically over time to the value of α_{F1}.

The two functions not yet discussed determine fertilizer input just by prices and a time trend which makes the multiplicative factor increase assymptotically to α_{F1}. The prices considered are either the ratio of last year's price index of agriculture to that of nonagriculture or the same ratio multiplied by the relative fertilizer price, p^r_{Ft}.

5.1.2. Allocation Model

In the previous subsection, the functions according to which farmers decide upon the quantities of labor, capital and fertilizer to be employed in the current year's production activities were described. In this subsection, the subsequent stage of decision-making is dealt with.

It is assumed that farmers--here represented by a single decision unit--allocate those three inputs, i.e., labor, capital, and fertilizer, according to some economic performance indicator. As indicator, the difference between expected gross revenue and expected feed cost was chosen. This difference is regarded as a first approximation of all the considerations taken into account by farmers when they decide on production. All those inputs not explicitly considered in the allocation process, e.g., pesticides, energy, repair, etc., are assumed to have either no or only a small influence on production and hence, their quantity used is assumed to be linearly related to total output. The costs of these inputs are subtracted as a lump sum from the value of production, together with the costs of investment and fertilizer.

5.1.2.1. Description of the Allocation Model

The allocation model may best be described as a nonlinear programming model with a nonlinear criterion function and linear inequality constraints. Most of its coefficients are statistically estimated (those written in Greek letters). Some others (those written in Latin letters) are derived from national accounts and engineering information. The allocation model is an annual decision model.

In section 3, a brief description of those commodity aggregates in which all countries trade goods is given (see also Table 2). If we were to adopt this classification for the supply module, we would have to model some commodities as being produced separately which are actually joint products.*

For this reason, it was decided to deviate from the trading commodity list when necessary and to group commodities in a manner more suitable to modelling production (see description of index i on page 54). This differing aggregation of commodities causes some problems, especially with regard to price splitting. However, this subject will be taken up later and discussed in more detail; at this point, it suffices to say that after production has been determined, the commodities are regrouped so that they once again adhere to the trading commodity list.

*For example, oil of soybeans would be produced as part of commodity 8, and protein feed of soybeans as part of commodity 7.

The allocation model can be written for any year t as follows:

$$\max_{K_{it}, L_{it}, F_{it} \text{ for } \forall i}$$

$$z_t = \sum_{i=1}^{3} p_{it}^{*} * \tilde{Y}_{it}$$

$$+ \left(p_{17,t}^{*} + \sum_{j \in J} b_{j,17,t} * p_{jt}^{*} - \sum_{k \in K} a_{k,17,t} * \tilde{p}_{kt}^{*}\right) * \tilde{Y}_{17,t}$$

$$+ \left(p_{6,t}^{*} + \sum_{m \in M} b_{m,6,t} * p_{mt}^{*} - \sum_{k \in K} a_{k,6,t} * \tilde{p}_{kt}^{*}\right) * \tilde{Y}_{6,t}$$

$$+ \left(p_{7,t}^{*} + b_{8,7,t} * p_{8,t}^{*O}\right) * \tilde{Y}_7 + p_{8,t}^{*NO} * \tilde{Y}_{8,t} + p_{9,t}^{*} * \tilde{Y}_{9,t} \quad , \tag{5.20}$$

where

$$\tilde{Y}_{i,t} = \tau_i * \left(K_t^A\right)^{\varepsilon_{it}} * \left(L_t^A\right)^{\delta_{it}} * \left(F_i^A\right)^{\rho_i} * \left(\frac{K_{it}}{K_t^A}\right)^{\gamma_i} * \left(\frac{L_{it}}{L_t^A}\right)^{\beta_i} * \left(\frac{F_{it}}{F_t^A}\right)^{\eta_i} \quad , \quad \text{for } i \in \text{crop product} \quad , \tag{5.21}$$

with

$$\delta_{it} + \varepsilon_{it} + \rho_i = 1 \quad ; \quad \varepsilon_{it}, \delta_{it} = f(t) \quad , \quad i \in \text{crop product}$$

and

$$\gamma_i + \beta_i + \eta_i < 1 \quad , \qquad i \in \text{crop product} \quad ,$$

where

$$\tilde{Y}_{it} = \tau_i * \left(K_t^A\right)^{\varepsilon_{it}} * \left(L_t^A\right)^{\delta_{it}} * \left(\frac{K_{it}}{K_t^A}\right)^{\gamma_i} * \left(\frac{L_{it}}{L_t^A}\right)^{\beta_i} \quad ,$$

$$\text{for } i \in \text{animal product} \quad , \tag{5.22}$$

with

$$\delta_{it} + \varepsilon_{it} = 1 \quad ; \quad \varepsilon_{it} \quad , \quad \delta_{it} = f(t) \quad , \qquad i \in \text{animal product} \quad ,$$

and

$$\gamma_i + \beta_i < 1 \quad , \qquad i \in \text{animal product} \quad ,$$

and where

$$K = \{1,2,3,5,7,8,11,13,14\} \quad , \tag{5.23}$$

$$M = \{12,14,16\} \quad , \tag{5.24}$$

$$J = \{11,13,15\} \quad , \tag{5.25}$$

subject to

$$\sum_i L_{it} - L_t^A \leq 0 \quad , \tag{5.26}$$

$$\sum_i K_{it} - K_t^A \leq 0 \quad , \tag{5.27}$$

$$\sum_i F_{it} - F_t^A \leq 0 \quad . \tag{5.28}$$

Description of index i:

1	wheat
2	rice
3	coarse grain
4	bovine and ovine meat
5	dairy products
6	other animals
7	protein feed of crop origin
8	other food products of crop origin (exclusive of oil)
9	nonfood agricultural products of crop origin
11	fat of bovine and ovine animals
12	fat and oils of other animals
13	meat meal
14	fish meal
15	skin, wool and hair of bovine and ovine animals
16	skin and hair of other animals
17	aggregate of bovine and ovine production (meat plus dairy products).

Description of variables:

$\tilde{Y}_{it}$ = net production of commodity i in year t (gross production minus seed use (also hatching eggs for i=6) and waste).

Note: $\tilde{Y}_{17,t} = 0.147 * \tilde{Y}_{4,t} + 0.035 * \tilde{Y}_{5,t}$, i.e. bovine and ovine meat and milk are aggregated by using their respective protein content.

K_t^A = capital stock in agriculture in year t

L_t^A = labor force in agriculture in year t

F_t^A = fertilizer (nitrogen) input in year t net of the quantity used for roughage production

K_{it} = capital employed in production of commodity i in year t

L_{it} = labor employed in production of commodity i in year t

F_{it} = fertilizer applied to crop i in year t

p_{it}^* = expected price of commodity i in year t

$p_{8,t}^{*O}$ = expected price of oil of crop origin in year t

$p_{8,t}^{*NO}$ = expected price of non-oil part and crop origin of commodity 8 in year t

$\tilde{p}_{kt}^*$ = price of feed commodity k in year t.

Description of parameters:

a_{kit} = units of feed k required by a unit of livestock aggregate i in year t

b_{mit} = unit of product m jointly produced with a unit of commodity i in year t.

The first term in the criterion function (5.20) indicates expected gross revenue from the three grain products: wheat, rice and coarse grain. The second and third terms represent expected gross revenue minus expected feed cost from production of bovine and ovine animals and of other animals, respectively. The expected gross revenue from protein feed crops is shown by the next term. Since most of the protein crops also contain oil, its value is added to commodity seven. Accordingly, the second to the last term is the expected gross revenue from the aggregate "other food of crop origin exclusive of oil", and the last one indicates expected gross revenue from all agricultural nonfood crops.

In the criterion function, the a-coefficients stand for feed requirements per animal unit and the b-coefficients for joint production. The simplifying assumption is made that the coefficients for joint production are decided upon prior to the allocation decision. In other words, it is assumed that farmers do not determine the optimal mix of joint production--for those products for which it is not technically fixed--simultaneously with the overall production level. It is thought that these coefficients are determined according to various economic indicators.* The calculation of both sets of coefficients is discussed in more detail in the following two subsections.

Production of any commodity is indicated by $\tilde{y}_{it}$ and is defined as gross production minus seed use (where appropriate) and waste. The term seed use might be somewhat misleading because it comprises all those quantities required for reproduction. Production is considered to be a function of capital, labor and fertilizer as can be seen from equations (5.21) and (5.22). The difference between the two sets of equations is that animal production does not explicitly depend on fertilizer input.† Any single equation i of (5.21) or (5.22) exhibits decreasing returns to scale, i.e., given the total amounts of all three inputs $\left(L_t^A,\ K_t^A,\ F_t^A\right)$ an increase in all three factor shares:

$$\left(\frac{K_{it}}{K_t^A},\ \frac{L_{it}}{L_t^A},\ \frac{F_{it}}{F_t^A}\right)$$

by a factor, say k, leads to a rise in production of commodity i by less than k times. This is due to the restriction

*At the present stage of the work, such an updating mechanism has not been devised. Instead, the coefficients are held constant at their level of 1974 for all ex ante years.

†The amount of fertilizer needed for roughage production is assumed to be in fixed proportion to production of bovine and ovine animals, and is subtracted prior to the allocation of inputs by using previous years' bovine and ovine production; see also the discussion of inequality (5.28) below.

that the sum of the coefficients β_i, γ_i, and η_i in (5.21) and the sum of γ_i and β_i in (5.22) be less than one. However, considering all equations in (5.21) and (5.22) simultaneously, one finds that the whole production system exhibits constant returns to scale. This becomes apparent if the assumption is made that the allocation of inputs remains unchanged but the total quantity of each input is increased by a factor of k. Then output of each commodity will also be raised k times for the coefficients of all total input factors sum up to one (see the sum of δ_{it}, ε_{it} and ρ_i in (5.21) and of δ_{it} and ε_{it} in (5.22)).

Technical progress is incorporated into the system by allowing the coefficients of the prespecified inputs of labor and capital to change over time. In other words, technical progress is measured by the time variable t.

The index set (5.23) contains all commodities which are used for feeding purposes. The joint products of bovine and ovine animals are indexed in set (5.24) and those of other animals in (5.25).

Inequality constraint (5.26) ensures that not more labor is allocated than is totally available. The same purpose for capital stock is fulfilled by (5.27). According to (5.28), fertilizer allocation is restricted to total fertilizer availability (TF_t) minus the amount applied to roughage production. Fertilizer input for roughage is considered to be in fixed proportion to total production of bovine and ovine animals.

When farmers make their production and allocation decisions, the producer prices as well as the feed prices are unknown to them. It is assumed that they have naive expectations of producer prices. Expected feed prices are related to the expected producer prices by a given factor representing differences in nutritional value. Hence, when formulating their expectations regarding producer prices, they simultaneously arrive at the expected feed prices.

At the current modelling stage, no variable that reflects weather influence is incorporated. For some countries, however, it is apparent that the inclusion of such a variable would considerably improve the model performance. Accordingly, such an improvement will be undertaken at a later stage.

Before the estimation results are discussed, the methods used to obtain coefficients of feed requirements and joint production will be elaborated.

5.1.2.2. Coefficients for Feed Requirements and Joint Production.

The data for calculating feed requirement coefficients for each country were obtained from the supply utilization accounts. The feed supply as given in these accounts was allocated to the various animal categories. Beside the SUA-data, additional information on intake in terms of nutritional values was used for the calculation procedure.

In this subsection, only a brief overview of the method is given. For a more detailed description of all assumptions and the formulas, the reader is referred to Appendix A.

As a starting point, requirements of important feed components for each type of animal and for different countries judged typical of a larger set of countries were looked up in the literature. To give an example, it was determined how much grain equivalent would be needed per ton of pork production (inclusive the requirements for pigs used for reproduction) Table A1 in Appendix A shows those values. For some feed components and types of animals, minimum requirements were also set. These coefficients were then converted to make them coincide with the commodity aggregates of the supply module (see page 54). In Table A2 of Appendix A the values of these coefficients can be found. In a subsequent step, total feed consumption by the two livestock aggregates was obtained. These data then had to be made consistent with those data indicating total feed supply. The feed requirements coefficients used in the model were only calculated after this step.

The plausibility of this exercise was checked in two ways. First, a disaggregation of these coefficients into those for which information on nutritional requirements can be found allowed a comparison. Second, given the feed prices, the percentage of feed cost on the respective gross revenue was examined for each of the animal categories, even though this is admittedly a very crude measure.

It should be pointed out that the SUA-data do not contain information on roughage. Consequently, roughage requirement can not be considered explicitly in the model and total feed consumption of bovine and ovine animals lacks this feed item.

There are three aggregates which have joint products: the two livestock categories and protein feed (see the b-coefficients in the criterion function (5.20)). According to the way products have been aggregated for this allocation module, the commodity "other animals" has four joint products: the product "other animals" itself (meat of poultry, pork, eggs, and fish), fat, animal protein (fish meal), and animal fibre (skin, hair). Based on historical data, joint production coefficients were calculated for the latter three in terms of the former one.

For livestock commodity "bovine and ovine animals", aggregation resulted in five joint products; bovine and ovine meat, dairy products, fat, animal protein feed (meat meal), and animal fibre (skin, hair and wool). To determine these joint production coefficients, the following procedure was used: first, the commodities "bovine and ovine meat" and "dairy products" were added in terms of their protein content to the "aggregate of bovine and ovine production" (see description of index i on page 54). Then joint production coefficients were calculated for dairy products, fat, animal protein feed, and animal fibre in terms of this new aggregate.

The coefficient expressing units of dairy products per unit of the "aggregate of bovine and ovine production" varies substantially from country to country. In some countries economic conditions may have a greater impact on this coefficient than technical relations. Hence, the relation of milk to bovine meat production should be determined in the allocation model. The method used here can, however, be justified by the fact that in most countries dual-purpose cattle are dominant.

The joint production coefficient for oil per unit of protein feed of crop origin remains to be explained. This coefficient was calculated by using SUA data. Whereas the relation of oil to protein is fixed by technology for a single commodity within the aggregate--the same is indicated by the unchanging crushing ratio--it is not for an aggregated commodity as used in the model. Since the individual crops of the aggregate have different (but fixed) crushing ratios, a change in the composition of the aggregate brings about a change in this coefficient, too.

5.1.2.3. Results of Parameter Estimation.

The parameters of the set of production functions (5.21) and (5.22) are estimated. The statistical model employed in the estimation procedure is as follows:*

$$\tilde{Y}_{it} = \tau_i * \left(K_t^A\right)^{\epsilon_{it}} * \left(L_t^A\right)^{\delta_{it}} * \left(F_t^A\right)^{\rho_i} * \left(\frac{K_{it}}{K_t^A}\right)^{\gamma_i} * \left(\frac{L_{it}}{L_t^A}\right)^{\beta_i} * \left(\frac{F_{it}}{F_t^A}\right)^{\eta_i} + u_{it} \quad , \quad \text{for } i \in \text{crop product} \quad , \tag{5.29}$$

*For an explanation of the variables, see page 55.

and

$$\tilde{Y}_{it} = \tau_i * \left(K_t^A\right)^{\epsilon_{it}} * \left(L_t^A\right)^{\delta_{it}} * \left(\frac{K_{it}}{K_t^A}\right)^{\gamma_i} * \left(\frac{L_{it}}{L_t^A}\right)^{\beta_i}$$

$$+ u_{it} \quad , \qquad \text{for } i \in \text{animal product} \quad , \tag{5.30}$$

where it is assumed that:

$$E(u_{it}) = 0 \quad , \quad \forall\, i,t \quad , \tag{5.31}$$

$$E(u_{it}, u_{jt*}) = \begin{cases} \sigma_{ii} \quad , & \text{for } i=j \text{ and } t=t* \\ \\ 0 \quad , & \text{otherwise,} \end{cases} \tag{5.32}$$

u_{it}, for all i and t, are identical and independently distributed. (5.33)

Under these conditions, a minimum distance estimator which is used for the problem on hand is consistent (Jorgenson and Laffont 1974).

For estimation, the parameters of equations (5.29) and (5.30) were transformed into another set of parameters, μ, which then actually was estimated. The transformation incorporates the constraints given in (5.21) and (5.22) and is as follows:

$$\varepsilon_{it} = \begin{cases} \mu_{3i} * \mu_{4i} * \mu_{1it} , & \text{if } i \in \text{crop product} , \\ \mu_{4i} * \mu_{1it} , & \text{if } i \in \text{animal product} , \end{cases} \tag{5.34}$$

$$\delta_{it} = \begin{cases} \mu_{4i} - \varepsilon_{it} , & \text{if } i \in \text{crop product} , \\ 1.0 - \varepsilon_{it} , & \text{if } i \in \text{animal product} , \end{cases} \tag{5.35}$$

$$\rho_i = \begin{cases} 1.0 - \varepsilon_{it} - \delta_{it} = 1.0 - \mu_{4i} , & \text{if } i \in \text{crop product} , \\ 0.0 , & \text{if } i \in \text{animal product} , \end{cases} \tag{5.36}$$

$$\gamma_i = \begin{cases} \mu_{5i} * \mu_{6i} * \mu_{7i} , & \text{if } i \in \text{crop product} , \\ \mu_{6i} * \mu_{7i} , & \text{if } i \in \text{animal product} , \end{cases} \tag{5.37}$$

$$\beta_i = \begin{cases} \mu_{6i} * \mu_{7i} * (1.0 - \mu_{5i}) , & \text{if } i \in \text{crop product} , \\ \mu_{7i} * (1.0 - \mu_{6i}) , & \text{if } i \in \text{animal product} , \end{cases} \tag{5.38}$$

$$\eta_i = \begin{cases} \mu_{7i} * (1.0 - \mu_{6i}) , & \text{if } i \in \text{crop product} , \\ 0.0 , & \text{if } i \in \text{animal product} , \end{cases} \tag{5.39}$$

and where μ_{1it} is time dependent in one of the following ways:

$$\mu_{1it} = 1.0 - \frac{\mu_{3i}}{1.0 + \mu_{2i}*t} , \tag{5.40}$$

$$\mu_{1it} = 1.0 - \frac{0.8}{1.0 + \mu_{2i}*t} , \tag{5.41}$$

$$\mu_{1it} = 1.0 + e^{-\mu_{2i}*t} . \tag{5.42}$$

Upper and lower bounds were set for the set of transformed parameters. These bounds are based on plausibility considerations. The variable t equals the year minus 1965.

Seven parameters had to be estimated for each crop production function and five for each animal production function. Data from 1966 to 1974 (inclusive) were used for estimating.

Not all of the exogenous variables of the production functions are known. The commodity-specific input levels (F_{it}, K_{it} and L_{it}) have not been observed. Therefore, this information had to be generated. This was done by solving the allocation model while estimating the parameters. After each iteration over the parameter set, the allocation model was solved for the parameter set obtained in the previous iteration. The solution of the allocation model resulted in commodity-specific input levels, which then were used together with the total input factors to perform a new iteration in the estimation process. This procedure was followed until the estimation routine converged.

As indicated earlier, the three model versions estimated differ only in the way in which μ_{1it} is made time dependent (see equations (5.40) to (5.42)). To discrimi..ate between these model versions, the following criteria were used:

- goodness of fit (expressed in the value of the sum of squared error terms)

- t-value of the estimated parameters

- resulting allocation of fixed inputs among the commodities
- resulting shadow prices of the prespecified inputs
- number of parameters at bound.

For selecting a model version, these criteria were evaluated in an informal way.

Indicators of these criteria--except for the resulting allocation--are summarized in Table 7. As can be seen in this table, the type III function (see equation 5.42) is most often used. Type II (see equation 5.41) has been estimated only for Ireland, for which the other two types did not work properly. Likewise, no result was obtained with function I (see equation (5.40)) for the United Kingdom.

The comparison of the values of the criterion function between countries is only possible for those countries for which the same number of commodities has been estimated.

Evaluating the acceptability of the estimated allocation of fixed inputs requires information on how such a reasonable allocation might look. Lack of information forced us to perform some calculations to obtain insight. Only a very brief description of the method used will be given here. A more detailed explanation can be found in Appendix B.

The starting point for this calculation was the average productivity of the input factor under consideration. Since it is assumed that inputs are allocated to equalize their

Table 7. Indicators for the "goodness" of the result of the allocation model.

Country #	Country Name	Type of function[1]	Number of Commodities	Number of Parameters Estimated	Number of Parameters At bound	Shadow price of[2] ... in 1970 Capital λ_K	Labor λ_L	Fertilizer λ_F	Index of commodities for which some of the t-values of the estimated parameters are rather low[3]	Value of criterion function[4]
9	Argentina	I	8	39	13	.0405	121.55	2.44	5	$1.267*10^{0}$
		III	8	46	6	.0405	122.45	2.45	3,4,5,6	$1.233*10^{0}$
10	Australia	I	8	41	11	.0383	611.90	0.69		$1.646*10^{0}$
		III*	8	43	9	.0875	468.96	0.58	5	$1.537*10^{0}$
15	Belgium	I	7	33	12	.0241	29.0617	82.38505	6	$1.075*10^{0}$
		III*	7	38	7	.0234	28.30874	81.85934		$1.074*10^{0}$
21	Brazil	I	8	36	16	.0216	100.93	17.63	2,6,7	$2.189*10^{0}$
		III*	8	36	16	.0210	110.40	21.69	2,4	$1.852*10^{0}$
33	Canada	I	8	36	9	.0270	.04373425	.1117683	4,5	$1.364*10^{0}$
		III*	8	36	7	.0271	.0440648	.1126572		$1.302*10^{0}$
54	Denmark	I	7	30	15	.0236	319.40	0.22		$4.306*10^{0}$
		III*	7	34	11	.0235	321.68	0.22	4,7	$4.126*10^{0}$
68	France	I	8	39	13	.0512	2796.3	5.24		$6.513*10^{-1}$
		III*	8	42	10	.1370	1056.4	1.40		$5.826*10^{-1}$
78	FRG	I*	7	37	8	.0224	180.17	3.46	4	$2.820*10^{-1}$
		III	7	37	8	.0228	180.98	2.27		$2.809*10^{-1}$
104	Ireland	II*	5	22	9	.0043	142.93	.0247533		$7.102*10^{-1}$
106	Italy	I	8	43	9	.0269	47.17649	178.7478	3,4	$3.193*10^{-2}$
		III*	8	44	8	.0305	18.00594	83.0843		$3.156*10^{-2}$
110	Japan	I	8	41	11	.0941	17993.9	1148.77		$1.912*10^{0}$
		III	8	45	7	.0820	15256.8	13377.8	2,6	$1.578*10^{0}$
114	Kenya	I	8	42	10	.0269	72.53	22.20		$1.038*10^{0}$
		III*	8	44	8	.0210	55.91	26.43	3,4	$9.245*10^{-1}$
150	Netherlands	I*	7	35	10	.0561	4451.2	1.55		$1.794*10^{0}$
		III	7	35	10	.0562	4451.2	1.56		$1.691*10^{0}$
156	New Zealand	I	7	35	10	.0325	609.58	28.44	4	$7.409*10^{-1}$
		III*	7	38	7	.0329	601.39	29.01	4,6	$6.801*10^{-1}$
159	Nigeria	I	8	40	12	0.0679	0.0058	82.909	3	$2.4340*10^{0}$
		III*	8	43	9	0.0927	0.0052	54.591	1,7	$1.9510*10^{0}$
229	U.K.	I								
		III*	7	40	5	.0503	.03190805	,01820117	2,6	$3.493*10^{-2}$
59	Egypt	I	8	34	18	0.0073	0.0205	0.3074		$3.5171*10^{-1}$
		III*	8	40	12	0.0113	0.0219	012023	5	$3.588*10^{-1}$
101	Indonesia	I*	7	33	12	7.4547	0.4609	51.132		$5.4067*10^{-1}$
		III	7	34	11	7.3330	0.4735	50.430	7	$6.728*10^{-1}$
138	Mexico	I	8	34	18	0.6125	0.1004	1.2230	7	$5.2825*10^{-1}$
		III*	8	36	16	0.5611	0.0878	1.2781	1	$5.145*10^{-1}$
165	Pakistan	I	8	35	17	0.1539	0.0255	0.6307	6	$3.7020*10^{-1}$
		III*	8	39	13	0.1530	0.0269	0.6306	6	$3.633*10^{-1}$
216	Thailand	I	7	32	13	0.3464	0.0249	6.0234	1,3,7	$1.1553*10^{0}$
		III*	7	32	13	0.3591	0.0241	6.2104	5,6	$1.1302*10^{0}$

Notes to Table 7:

1) The functions estimated are:

$$\tilde{Y}_{it} = \tau_i * \left(K_t^A\right)^{\varepsilon_{it}} * \left(L_t^A\right)^{\delta_{it}} * \left(F_t^A\right)^{\rho_i} * \left(\frac{K_{it}}{K_t^A}\right)^{\gamma_i} * \left(\frac{L_{it}}{L_t^A}\right)^{\beta_i} * \left(\frac{F_{it}}{F_t^A}\right)^{\eta_i}$$

with

$$\delta_{it} = \begin{cases} \mu_{4i} - \varepsilon_{it} & \text{if } i \in \text{ crop product} \\ 1.0 - \varepsilon_{it} & \text{if } i \in \text{ animal product} \end{cases}$$

$$\rho_i = \begin{cases} 1.0 - \varepsilon_{it} - \delta_{it} & \text{if } i \in \text{ crop product} \\ 0.0 & \text{if } i \in \text{ animal product} \end{cases}$$

$$\varepsilon_{it} = \begin{cases} \mu_{3i} * \mu_{4i} * \mu_{1it} & \text{if } i \in \text{ crop product} \\ \mu_{4i} * \mu_{1it} & \text{if } i \in \text{ animal product} \end{cases}$$

and with

Type I: $\mu_{1it} = 1.0 - \dfrac{\mu_{3i}}{1.0+\mu_{2i}*t}$

II: $\mu_{1it} = 1.0 - \dfrac{0.8}{1.0+\mu_{2i}*t}$

III: $\mu_{1it} = 1.0 + e^{-\mu_{2i} * t}$

where

$\tilde{Y}_{it}$ = production (net of seed and waste) of commodity i in year t

Notes to Table 7 continued:

K_t^A = total capital stock of agriculture in year t

L_t^A = total labor force of agriculture in year t

F_t^A = total fertilizer (nitrogen) in year t net of the quantity used for roughage production

K_{it} = capital stock utilized in production of commodity i in year t

L_{it} = labor utilized in production of commodity i in year t

F_{it} = fertilizer (nitrogen) applied for crop i in year t.

Those types of functions indicated by an asterisk are used in the model.

2) λ_K is expressed as a relative value (interest rate divided by 100), λ_L is measured in national currency per laborer, and λ_F in national currency per kilogram of fertilizer (nitrogen).

3) The index as used in the estimation routine is as follows:

i = 1 wheat

2 rice, milled

3 coarse grain

4 protein feed

5 other food products of crop origin

6 nonfood agricultural products

7 bovine and ovine meat and dairy products

8 other animals.

The t-value was judged to be "rather low" if it was below 0.7.

4) Sum of squared error terms. (Notice that these values are not strictly comparable between countries, due to the different numbers of commodities estimated).

respective marginal value product for all commodities, the average value product was scaled up or down as it is affected by different technologies used to produce the various commodities. These scaling factors are given in Table B1 in Appendix B.

To make the estimation somewhat more stable, the predetermined values of the input allocation for the year 1970 were included in the criterion function. In other words, for that year, the weighted squared deviation of the commodity-specific input levels obtained by the allocation model from the predetermined ones was minimized.

5.2. The Supply Module of the Nonagricultural Sector.

Production of the nonagricultural sector is aggregated to a single commodity. This aggregate consists not only of industrial products but also of services. It is assumed that this sector's production activities can be represented by a Cobb-Douglas function. Three determinants of production are included: labor force (measured in number of laborers), capital stock and technical progress. It is further assumed that capital stock is always fully utilized and there is no unemployment. The amount of those inputs employed in the nonagricultural sector is expressed as the difference between the total availability* for the whole economy and what the agricultural sector utilizes. Assuming linear homogeneity of the nonagricultural sector, the following model was estimated:

$$Y_t^{NA} = \phi_t * \left(K_t^{NA}\right)^{\theta_t} * \left(L_t^{NA}\right)^{1-\theta_t} + u_{Nt} \quad , \qquad (5.43)$$

where

Y_t^{NA} = nonagricultural production in year t

K_t^{NA} = capital stock of the nonagricultural sector in year t

L_t^{NA} = labor force in the nonagricultural sector in year t

*The determination of total availability of labor and capital is discussed in the previous section (see pages 36 and following).

u_{Nt} = error term which is identically, independently distributed

t = time variable; t-year minus 1965

with

$$E(u_{Nt}) = 0 \quad , \quad \forall t \quad ,$$

$$E(u_{Nt}, u_{Nt^*}) = \begin{cases} \sigma & \text{if } t = t^* \\ 0 & \text{if } t \neq t^* \end{cases} .$$

Incorporating technical progress in different ways led to the following five types of functions:

$$\phi_t = \alpha_{N3} \quad , \quad \theta_t = \alpha_{N1} * \left(1.0 - \frac{\alpha_{N1}}{1.0 + \alpha_{N2} * t}\right) \quad , \qquad (5.44)$$

$$\phi_t = \alpha_{N3} \quad , \quad \theta_t = \alpha_{N1} / \left(1.0 + e^{-\alpha_{N2} * t}\right) \quad , \qquad (5.45)$$

$$\phi_t = \alpha_{N3} + \alpha_{N2} * \ln t, \quad \theta_t = \alpha_{N1} \quad , \qquad (5.46)$$

$$\phi_t = \alpha_{N3} + \alpha_{N2} * t, \quad \theta_t = \alpha_{N1} \quad , \qquad (5.47)$$

$$\phi_t = \alpha_{N3} + e^{\alpha_{N2} * t} \quad , \quad \theta_t = \alpha_{N1} \quad . \qquad (5.48)$$

These specifications indicate two different types of technical progress. The first two measure technical progress as an increase in capital efficiency, the latter three have no effect on labor and capital. However, for all specifications, technical progress is exogeneous to the model. For most countries, either type (5.44) or (5.45) could successfully be estimated. These two specifications differ in the way the exponent θ increases towards the assymptote. Except for Brazil θ takes on values for all countries which lie between 0.20 and 0.37 (see Table 8). The θ-value for Brazil is 0.568, indicating a relatively high capital productivity.

Only for Nigeria could neither (5.44) nor (5.45) be successfully estimated. Best results were obtained with specification (5.47). The growth of the nonagricultural sector was very high in Nigeria during the period of consideration, which is why a linear trend for the multiplicative factor was used.

Table 8. Parameter values of production function for the non-agricultural sector.

#	Country Name	Number of equation in text 1)	Value of α_{N1} (t-values in parentheses)[2]	α_{N2}	α_{N3}	Value of criterion function (SSQ)	Value of θ_{70}	$\theta_{70} - \theta_{66}$
9	Argentina	5.44	0.5794 (2.58)	0.05688 (0.90)	6.107 (14.2)	0.00113	.31804	0.09561
10	Australia	5.44	0.3136 (9.88)	0.1479 (1.41)	2.934 (41.7)	0.00077	.25706	0.04348
14	Belgium-Luxembourg	5.45	0.4338 (2.37)	0.1152 (1.64)	151.8 (3.93)	0.00071	.27767	0.10084
21	Brazil	5.45	0.95	0.07941 (12.6)	4.831 (71.26)	0.00294	.56808	0.14401
33	Canada	5.45	0.6874 (0.64)	0.0289 (0.53)	3.231 (0.57)	0.00164	.3683	0.03953
54	Denmark	5.44	0.3251 (0.03153)	0.2122 (0.2195)	23.33 (1.012)	0.002322	.27380	0.05086
68	France	5.44	0.5382 (5.07)	0.0496 (1.67)	15.510 (26.6)	0.00059	.30610	0.05570
78	F.R.G.	5.44	0.3902 (6.40)	0.1494 (0.95)	9.771 (23.0)	0.00442	.30303	0.06751
104	Ireland	5.44	0.3802 (4.99)	.7954 (.59)	.7366 (4.13)	0.00212	.35118	0.06280
106	Italy	5.45	0.3834 (36.7)	.3609 (2.27)	1294.0 (21.6)	0.00076	.33095	0.07340
110	Japan	5.45	0.3605 (11.2)	.5369 (4.01)	680.3 (11.0)	0.00570	.33746	0.13014
114	Kenya	5.44	0.3074 (1.47)	.07721 (.16)	7.737 (9.20)	0.00179	.23922	0.03196
138	Mexico	5.44	0.4736	.04147	25.41	0.00073	.28782	0.05203
150	Netherlands	5.44	0.3798 (15.6)	.1560 (22.1)	9.771 (59.6)	0.00067	.29876	0.06378
156	New Zealand	5.44	0.2202 (4.39)	.3425 (0.21)	2.585 (5.17)	0.00963	.20233	0.02434
159	Nigeria	5.47	0.8000	.02754 (4.52)	.1754 (6.33)	0.14838	.8000	
229	U.K.	5.45	.4320 (.07)	.04554 (.05)	.9849 (.14)	0.00071	.24050	0.03874
59	Egypt	5.45	0.7792 (.4577)	0.7651 (.4098)	.3575 (1.329)	0.00652	.46322	.11418
101	Indonesia	5.48	.7872 (2.44)	.06380 (16.48)	90.79 (7.06)	0.00299	.7872	
165	Pakistan	5.47	.4981 (.80)	.08579 (1.56)	1.960 (1.08)	0.00619	.4981	
216	Thailand	5.44	0.6486 (11.55)	.1264 (2.13)	15.27 (17.19)	0.00185	.39083	.17667

[1] See page 72.

[2] If no t-value is given, the parameter is on a bound.

5.3. Coupling of Supply and Demand Modules

After supply has been determined, some intermediate steps are necessary before both equilibrium demand and prices can be calculated. Likewise, after equilibrium has been reached, some additional calculations are required before the supply module can be solved for the next year. The former task consists mainly of calculating the vector of endowments, whereas in the latter, income for each income class has to be determined and some price splitting has to be performed in order to establish prices which are in agreement with the commodity specification in the supply module.

5.3.1. The Vector of Net Endowments.

By assumption, endowment of an agricultural commodity is defined as gross production minus those quantities needed for reproduction (seed, hatching eggs) and waste. Endowment of nonagricultural goods is considered to be gross production. These definitions hold for those countries for which only one income class is included.* In the case of two income classes, these definitions are slightly modified. Income class one, which coincides with the agricultural sector, has as endowments the agricultural commodities as defined above and feed processing as endowment of the

*For developed countries, population is not divided into different income classes, since demand for food is not considerably affected by income differences. In developing countries larger differences in demand by various income groups are assumed. Hence, for those countries, two income classes are distinguished: income group 1 represents the rural population (agriculture sector) and group 2 the urban population (nonagriculture sector).

nonagricultural commodity. Endowments of income class two, the nonagricultural sector, are zero for all agricultural commodities, and are equal to gross production minus processing of feed for the nonagricultural commodity.

The method of handling feed processing in all models assumes that this activity takes place in agriculture. In reality, however, only part of it is performed by agriculture. But the lack of more information forced us to follow this line.

Intermediate consumption is not subtracted from gross production, but included as committed demand in the demand model. Similarly, feed is also put into the demand module, by augmenting the expenditure shares of human consumption, which are annually updated for those quantities. The method used for correction is described in section 6.

Including intermediate consumption as committed demand and feed as part of the expenditure share in the model implies that the former is not income-responsive, but the latter is. Including feed in this way also ensures that a numerical solution of the exchange model is obtained.

5.3.2. Calculation of Income and Price Splitting

After equilibrium has been reached, income, which is taken to be GDP, is calculated. There are two reasons for this. First, calculating GDP annually for the whole economy and each sector (i.e., each income class), is a good indicator of the model's performance. Second, as was described above, GDP is used in some input functions as an independent variable, and is needed for simulating another year.

The GDP of each sector is calculated according to the following formula:

$$GDP_t^A = \sum_{i=1}^{10} p_{it}^e * YMA_{it} - p_{10,t}^e * CINT_{10,t} - p_{10,t}^e$$

$$* \sum_{i=1}^{9} t_i * YMA_{it} + \left[\left(p_t^{NA} * p_{F,70}\right) - p_{Ft}\right] * TF_t \quad , \tag{5.49}$$

and

$$GDP_t^{NA} = YMNA_{10t} * p_{10,t}^e - \sum_{i=1}^{9} p_{it}^e * CINT_{it}$$

$$- \left[\left(p_t^{NA} * p_{F,70}\right) - p_{Ft}\right] * TF_t \quad , \tag{5.50}$$

where

GDP_t^A = GDP of agriculture in year t

GDP_t^{NA} = GDP of nonagriculture in year t

YMA_{it} = agricultural sector's endowments of good i in year t

p_{it}^e = equilibrium price of (processed) commodity i in year t

t_i = units of commodity 10 required for processing a unit of commodity i

$CINT_{it}$ = intermediate consumption of commodity i in year t

p_t^{NA} = price index of nonagriculture in year t

p_{Ft} = fertilizer price in year t (assumed to be p times a factor*)

TF_t = total fertilizer use in year t

$YMNA_{it}$ = nonagricultural sector's endowment of good i in year t

The first term on the right side of equation (5.49) is gross income of agriculture. Then, the values of intermediate consumption of agriculture and of processing of agricultural goods are subtracted. The last term is a correction term for differences in fertilizer prices and the price index of the nonagricultural commodity. Net income of the nonagriculture sector is its gross income minus the value of its intermediate consumption and the correction term for the fertilizer price.

It was mentioned earlier that the level of commodity aggregation for the supply module is more refined than that for the demand module (16 versus 9 agricultural commodities). However, the producer needs price information for all commodities considered at this level, in order to make appropriate production decisions. Hence, some of the price

*This factor was calculated given historical data:

$$\text{factor} = \frac{\text{value of total fertilizer input in t}}{\text{quantity of nitrogen in t} * p_t^{NA}}$$

signals obtained from the equilibrium calculation have to be split.*

Table 9. Commodities for which prices have to be split

Demand module	Allocation module	
	Disaggregated commodities considered:	
Aggregated commodity	independent	substitutes
protein feed		protein feed of plant origin meat meal fish meal
other food	nonoil-nonfat part of other food oil and fat part of other food	
		oil of other food fat of bovine animals fat of other animals
nonfood		nonfood of plant origin fibre of bovine animals fibre of other animals

In Table 9, the prices which have to be split are listed. The prices of commodities 7 and 9 are split into three different prices. It is assumed that both these commodities consist basically of substitutes. The price of commodity 8 (other food) has, in a first step, to be split into

*It should be stressed that price splitting is necessary only for decision making on production and does not have any direct impact on equilibrium prices or on income. These disaggregated prices are further used (as all the other prices) in the price expectation model to derive expected prices.

the nonoil-nonfat part of other food and into its oil part. These two subaggregates are assumed to be independent commodities. The latter must then be further split into three oil and fat disaggregates. They are assumed to be substitutes, too. Here we distinguish independent commodities from substitutes, because for each category a different price-splitting procedure is used.

Price splitting of an aggregate consisting of substitutes is done under the assumption that the shares of the disaggregates on the total value of the aggregate, s_{jit}, are given exogenously. The individual prices can then be calculated as follows:

$$p_{jit} = p^D_{jt} * \left(\sum_{k \in J} Q_{jkt}\right) * \frac{s_{jit}}{Q_{jit}} , \qquad (5.51)$$

where

p_{jit} = price of disaggregated commodity i of aggregate j in year t

p^D_{jt} = desired (target) price* of aggregate j in year t

s_{jit} = share of disaggregated commodity i of agrregate j in year t on total value of aggregate j in year t;

$$\text{i.e., } s_{jit} = \frac{p_{jit}Q_{jit}}{\sum_{k \in J} p_{jkt}Q_{jkt}}$$

*The desired (target) price is assumed to be set by policymakers.

Q_{jit} = quantity of disaggregated commodity i of aggregate j in year t

J = index set of aggregate j.

The split price in year t, p_{jit}, is equal to the target value of the aggregate times the value share of the disaggregate divided by its quantity. The target value is taken instead of the actual one because farmers take the desired prices as set by the government into account when they make decisions on what price level to expect.

It should be noted that this is just one of many possible assumptions. Its advantage is that for constant s_{jit} over time the relative change in price of a disaggregated commodity depends on the change of the quantity of the same commodity relative to the change of the others of that aggregate. This can be worded in another way: the direct price effect is always negative. Whether the price of the disaggregate moves in the same or in the opposite direction as that of the aggregate, however, also depends on how strong the cross price effect is. Only if the quantities of the other substitutes change more than those of this disaggregate will the direct effect be offset.

This can be explained as follows in mathematical notation. Let dp_{jit} be the price change from one year to another. The relative price change of the disaggregate in t is defined as:

$$\frac{dp_{ji,t+1}}{p_{jit}} = \frac{p_{ji,t+1}}{p_{jit}} - 1 \quad , \quad \text{which is for constant } s_{jit} \text{ ,} \quad \forall i$$

$$= \frac{Q_{jit} * \sum_{k \in J} p_{jkt} * Q_{jkt}}{Q_{ji,t+1} * \sum_{k \in J} (p_{jk,t+1} * Q_{jk,t+1})} \quad . \tag{5.52}$$

Hence, only if

$$\frac{\sum_{k \in J} p_{jk,t+1} * Q_{jkt}}{\sum_{k \in J} p_{jkt} * Q_{jkt}} > \frac{Q_{ji,t+1}}{Q_{jit}} \quad , \tag{5.53}$$

i.e., only if the value of the aggregate in t+1 increased more than the quantity of the disaggregate in the same year relative to its amount in the previous year, will the price change of the disaggregate be positive.

The value shares, s_{jit}, can be observed from the past. For ex-ante runs, they will be exogenously determined as a function of time. The estimate of the share of the disaggregate i in year t, $\hat{s}_{jit}$, has to be normalized to sum up to one, i.e.,

$$s_{jit} = \frac{\hat{s}_{jit}}{\sum_{k \in J} \hat{s}_{jkt}} \quad . \tag{5.54}$$

Price splitting for the aggregate other food, which is assumed to consist of independent subaggregates, is done under the hypothesis that the prices of the subaggregates remain in fixed proportion. This implies that prices of all subaggregates move in the same direction as the aggregate price, regardless of their respective quantities. The following formula is used:

$$p_{jit} = \frac{\sum_{k \in J} Q_{kit}}{\sum_{k \in J} (Q_{kit} * r_{kit})} * r_{jit} * p^{D}_{jt} \quad , \qquad (5.55)$$

where

r_{jit} = the ratio of the disaggregated price i of aggregate j in year t to the aggregated price j in the same year; i.e.,

$$r_{jit} = \frac{p_{jit}}{p^{D}_{jt}} \quad ,$$

and the other symbols are defined as above (see equation (5.51)).

The price of an independent disaggregate is equal to the ratio of total quantity of aggregate j to its weighted total quantity times the price ratio and multiplied by the desired price of the aggregate. The latter is used for reasons similar to those mentioned above. The price of "oil and fat of other food" is then further disaggregated in the way described above for substitutes.

6. DEMAND MODULE

Demand for each commodity is represented by retail expenditure shares. This simplified approach was selected because of time and manpower constraints.

In an extensive literature search, shares of private expenditures were collected. The two most widely used sources were the ILO publication on household income and expenditure statistics (ILO 1974), and various reviews of food consumption surveys published by the FAO (FAO 1977 and 1971). In selecting the data, much care was taken to obtain values for similar time periods and household classifications. However, differences in this respect were unavoidable. This is true especially for those countries for which two income classes are considered.

The expenditure shares taken from the literature cover only private consumption. To make them suitable for our purpose, the expenditure shares of commodities 1 to 9 were multiplied by the fraction of expenditure for private consumption to GDP (total GDP or GDP by income class as the case may be). This implies that the nonagricultural part of GDP is all accounted for by demand for the nonagriculture commodity (commodity 10). In other words, an extended expenditure share system is used. Expenditure share of commodity 10 is the difference between one and the sum of all other shares. The multiplication described above leaves some food quantities unaccounted for, since hospitals, army, etc., are not included in the household surveys. But lack of data did not leave us any alternative.

The food expenditure share of commodity protein feed, e_7^R, was calculated for all countries and income classes by the following formula, since no other information could be found:

$$e_7^R = \frac{\text{food of protein feed * producer price}}{0.7 * \text{GDP}} \quad . \qquad (6.1)$$

This calculation was necessary since the literature did not reveal any information on this item. Formula (6.1) implies that farmers receive 70 percent of consumer expenditure on this commodity.

Since for commodity 9 (nonfood agricultural products) most of the retail expenditure is spent for processing, distribution and marketing, summarized as processing hereafter, only the farmgate expenditure is taken as "retail" expenditure. All the processing outlays for this commodity are assumed to be included in expenditure for the nonagriculture commodity. Commodity 9 was handled in this way because of the high amount of processing needed.

Numerous other adjustments had to be made in order to obtain retail expenditure shares for the commodity classification on hand. They are too large in number to all be mentioned here. Only one will be cited as an example. The FAO statistics include the item "meals eaten away from home" This expenditure had to be split up into the respective commodities. Since no additional information could be found, it was equally distributed among the food commodities.

In a next step, the retail expenditure shares, e_i^R, $\forall i$,

= 1,...,9, were compared to the value shares farmers receive for their raw product, e_i^F, $\forall i$.* This was done for the years 1966 to 1974 using the following formula to set farmers' value shares:

$$e_i^F = \frac{\text{food of commodity i times its producer price}}{\text{GDP}} \quad , \qquad (6.2)$$

The ratio of farmers' expenditure share to total retail expenditure share in 1970 is used as a test for the reliability of the latter. When this ratio fell outside a reasonable range, retail expenditure shares were adjusted to make the ratio for 1970 plausible.

For the next adjustments to be made these retail expenditures are assumed to hold for the years 1966 to 1974.

As indicated earlier, feed requirements for total animal production are part of demand. Hence, the retail expenditure shares --only those of the agricultural sector if there are two income classes--have to be adjusted. This is done in the following way:

$$\tilde{e}_{ijt}^R = \begin{cases} \dfrac{\left(e_{ij}^R * m_{jt} + FC_{it}\right)}{\tilde{m}_{jt}} & \text{if } j = \text{agriculture}, \quad \forall i,t \\[2ex] e_{ij}^R & \text{if } j = \text{nonagriculture}, \forall i,t \end{cases} , \qquad (6.3)$$

with

*For countries with two income classes, expenditure shares of the total population were taken for comparison.

$$\tilde{m}_{jt} = \begin{cases} m_{jt} + \sum_i FC_{it} & \text{if } j = \text{agriculture}, \quad \forall t \\ m_{jt} & \text{if } j = \text{nonagriculture}, \forall t \end{cases}, \tag{6.4}$$

where

$\tilde{e}^R_{ijt}$ = for feed consumption adjusted expenditure share of commodity i and income class j in year t

m_{jt} = income (GDP) of income class j in year t

FC_{it} = (expected) feed cost of feed item i in year t, $\tilde{p}_{it} * Feed_{it}$, (note $FC_{9,t} = FC_{10,t} = 0$ for all t).

The expenditure shares $\tilde{e}_{ijt}$ are further used for calculating the physical processing quantity of commodity i. These coefficients are employed for the transmission from "retail" level (in the demand module) to farmgate level (in the supply module).* This is done by introducing a matrix of (annually) fixed coefficients for the conversion, i.e.,

(6.6) $$x = T * z \tag{6.5}$$

where

x = vector of processed commodities (l * 1)

z = vector of unprocessed commodities (n * 1)

*Here we assume that the outcome of the supply module has already been transformed so that the commodity aggregation coincides with the trading commodity list.

T = transmission matrix $(1 * n)$.

The element t_{ij} of T indicates the amount of farmgate commodity j used per unit of retail commodity i. For the simplified model, the following structure of T is assumed:

$$t_{ij} \begin{cases} = 1 \quad , & \text{if } i = j \\ \geq 0 \quad , & \text{if } j = n \quad , \quad \forall i \quad . \\ = 0 & \text{otherwise} \end{cases} \tag{6.6}$$

Moreover, T is considered to be a square matrix $(l=n=10)$* and the coefficient $t_{i,10}$† represents the amount of processing (commodity 10) per unit of commodity i at farmgate level, i.e., whenever some quantity of (farmgate) commodity i, z_i, is consumed, some of commodity 10, say z_i^p, is simultaneously demanded for processing. This is indicated by the following relation:

$$x_i = (1 + t_i) * z_i = z_i + z_i^p \quad , \qquad \text{for all commodities and years} \quad . \tag{6.7}$$

By assumption, t_9 is zero, since processing of nonfood agriculture is considered to be included in commodity 10. Starting with the identity:

$$\sum_{j=1}^{NC} \tilde{e}_{ijt}^R * \tilde{m}_{jt} = \left(p_{it}^F + t_i * p_{10,t}\right) * z_{it} \quad , \tag{6.8}$$

*This assumes that the 16 supply commodities are already aggregated to the 10 commodity classification.
†Thereafter, the index 10 will be dropped since it does not convey any additional information.

where

p^F_{it} = the farmgate level price of commodity i in year t

NC = the number of income classes and

all other variables are as explained earlier,

the processing margin t_i can be calculated according to the following formula:

$$t_i = \frac{\sum_{j=1}^{NC} \tilde{e}_{ijt} * \tilde{m}_{jt}}{z_{it} * p_{10,t}} - \frac{p^F_{it}}{p_{10,t}} \quad , \quad \text{for } t = 1970 \quad . \tag{6.9}$$

The calculation was done for the year 1970. The coefficients obtained are used for the following years as well. It is assumed that the physical processing margin, t_i, does not differ between income classes.

The retail expenditure shares discussed above are assumed to hold for 1970. For all other years they are annually updated using either one of the following two equations:

$$\bar{e}^R_{ij,t+1} = \frac{\alpha_{ij}\left(\frac{m_{jt}}{m_{0jt}}\right)^{v_i}}{\sum_{k=1}^{10} \alpha_{kj}\left(\frac{m_{jt}}{m_{0jt}}\right)^{v_k}} \quad , \tag{6.10}$$

$$\bar{e}^R_{ij,t+1} = \frac{\alpha_{ij} * \left(\frac{m_{jt}}{m_{0jt}}\right)^{v_i} * \left(\frac{p_{it}}{p_{10,t}}\right)^{w_i}}{\sum_{k=1}^{10} \alpha_{kj} * \left(\frac{m_{jt}}{m_{0jt}}\right)^{v_k} * \left(\frac{p_{kt}}{p_{10,t}}\right)^{w_k}} , \qquad (6.11)$$

with

$$m_{jt} = \frac{\sum_{i=1}^{10} p_{i,70} * X_{ijt}}{POP_{jt}} ,$$

$$m_{0jt} = \frac{\sum_{i=1}^{10} p_{i,70} * X_{ij,70}}{POP_{j,70}} ,$$

$$\alpha_{ij} = e^R_{ij,70} ,$$

where

$p_{i,70}$ = retail price of commodity i in year 70

X_{ijt} = demand for commodity i by income class j in year t

POP_{jt} = population of income class j in year t

$\bar{e}^R_{ij,70}$ = retail expenditure share of income class j for commodity i in year 1970.

According to updating scheme (6.10) the retail expenditure shares in year t+1 are changed by the ratio of real expenditure in year t to that in 1970 raised to an exponent and then multiplied by the retail expenditure share of the same commodity in 1970. The denominator normalizes these values to make them add up to one. There is no general rule as to which of the expenditure shares will increase and which will decrease according to a change in real expenditure from one year to another. However, the larger the value of v_i relative to all other v_j's is, the more likely it is that the expenditure share of the i-th commodity becomes larger in the following year. Updating scheme (6.11) differs from (6.10) in that it also takes relative prices into account.

The parameters of the two updating schemes were estimated. Since there is no time series for retail expenditure shares available, it had to be generated. This was done by adding annually the expenditure share for processing to the food expenditure share at the farmgate level. The formula according to which the time series of retail expenditure for this estimation was calculated, is:

$$e^*_{it} = \left(p^F_{it} * x_{it} + t_i * p_{10,t}\right)/GDP_t \quad , \qquad (6.12)$$

where

e^*_{it} = calculated retail expenditure share of commodity i in year t

p^F_{it} = farmgate price of commodity in year t

x_{it} = human consumption of commodity i in year t

t_i = the physical quantity of commodity 10 needed for processing per unit of commodity i

GDP_t = gross domestic product in year t.

In a final adjustment step these annually updated retail expenditure shares, $\bar{e}^R_{ijt}$, are corrected for the nutritional value of food consumption. The intake in terms of calories is taken as an indicator of the nutritional value of food consumption. Annually, a target value was set according to which the food expenditure shares are adjusted. If the food expenditure shares as obtained in the updating scheme indicate a deviation of expected calorie consumption from this target value they are adjusted to reach this value. The expected intake is calculated by using desired retail prices. The annual target value itself is a function of per capita income asymptotically approaching a level of 3500 calories per capita per day (except for countries which exceed this level in the base year 1970).

The retail expenditure shares are adjusted four times altogether before they are used. One of those adjustment processes, however, is to include feed consumption in those retail shares. Intermediate consumption items are included as committed demand in the exchange module.

APPENDIX A: DESCRIPTION OF CALCULATION OF FEED REQUIREMENTS

The supply utilization accounts contain information on total feed consumption for each feedstuff (except roughage). They do not, however, indicate its allocation to the various animals. Hence, the formidable task of distributing these feed consumption data to the two animal categories considered in the model, i.e. 'bovine and ovine animals' and 'other animals', had to be carried out as realistically as possible.

As a starting point, assumptions were made on the physiological requirements of the aggregate 'other animals'. Two sets of countries were distinguished for this purpose. One set comprises all those countries which use advanced technologies in livestock production: Australia, Canada, the EC-countries, Japan and New Zealand. All other countries modelled were grouped into set two. Since for the group-one countries some additional detailed information was available, these requirements were specified for each feedstuff.* For the set-two countries, however, the requirements could best be specified in terms of grain equivalents and protein feed. The amount of feed consumed by fish in fish farms was considered to be only marginal and hence neglectable. Table A1 indicates the assumptions made with respect to feed requirements. The figures in this table are then aggregated to requirements of (i) grain and 'other food' and (ii) protein.† The result of this aggregation can be found in Table A2.

We now turn to the calculation of feed requirements of grains and of 'other food' per unit of each of the two animal aggregates.

For the calculations the following relation must hold:

$$a_{g,6,t} = \sum_{i \in I} a_{i,6,t} + a^{*}_{8,6,t} , \quad \forall t , \tag{A1}$$

with I = {1(wheat), 2(rice), 3(coarse grain)}

where

*This information was obtained from feed statistics of the EC member countries.
†The term 'other food' is used hereafter for 'other food of crop origin' according to the commodity classification for the supply module and should not be confused with the one defined for exchange (see Table 2).

Table A1

The figures shown below indicate the feed requirements of animals belonging to category 6 per unit protein equivalents. The rest of feed of each commodity group goes to 'bovine and ovine' animals.

Index of feed component	Pork	Poultry	Pork	Poultry
	Ton feed per ton meat (or eggs)		Ton feed per ton protein equivalent[1)]	Ton feed per ton protein equivalent[3)]
	Country set I[5)]			
1	.7	.9	7.865	7.692
2	-	-	-	-
3	2.9	2.1	32.584	17.49
5	.3	-	3.371[4)]	-
7	.8	1.1	2.571[2)]	2.689[2)]
8	.42	.01	4.719	.085
	Country set II[6)]			
1	-	-	-	-
2	-	-	-	-
3	4.0	3.5	44.944	29.914
5	-	-	-	-
7	1.3	1.3	4.177[2)]	3.178[2)]
8	-	-	-	-

1) 0.089 ton protein per ton meat

2) .286 protein equivalent for protein feed

3) .117 ton protein per ton poultry (meat and eggs)

4) 0.035 protein equivalent in milk

5) Australia, Canada, EC-countries, Japan, New Zealand

6) all other countries modelled

Table A2

Values of coefficients a_{g6} and a_{p6} [5)]

coefficient	country group I[1)] pork	country group I[1)] poultry	country group II[2)] pork	country group II[2)] poultry
a_{g6} [3)]	41.40	25.67	44.95	29.92
a_{p6} [4)]	3.49	2.69	4.18	3.18
$\tilde{a}_{g6}^{min}$	11.8 [6)]	21.4 [7)]	11.8	21.4

1) country group I: EC-countries, Canada, Australia, New Zealand

2) country group II: rest of countries

3) ton of grain equivalents per ton of protein equivalents of pork (0.089 ton protein per ton pork) or of poultry (.117 ton protein per ton poultry, meat and eggs)

4) ton of protein equivalents of feed per ton of protein equivalents of pork or of poultry

5) see data given in the tables in the Appendix. It is assumed that 1 ton of feed of commodity 8 is equivalent to .2 ton of feed of grain equivalents

6) based on .7 kg grain per day of fattening (150 days for fattening) = 1.05 ton grain per ton pork

7) based on 2.5 ton grain as minimum per ton of meat and eggs of poultry

$a_{g,6,t}$ = total feed requirement of grains and 'other food' per unit of 'other animals' in year t (measured in grain equivalents)

$a_{i,6,t}$ = requirement of feed component i per unit of 'other animals' in year t (measured in grain equivalents)

$a^*_{8,6,t}$ = requirement of feed component 'other food' per unit of livestock category 'other animals' (measured in grain equivalents).

For the conversion of the requirement of the feed component 'other food' into grain equivalents it was assumed that potatoes are the main feed item within the aggregate 'other food'. The substitution rate of potatoes for grain was based on the energy content. A conversion factor $C_{g,6}$ was calculated in the following way:

$$C_{g,6} = .2 * \text{weighting factor} \tag{A2}$$

where

.2 = substitution rate

and

$$\text{weighting factor} = \frac{1000}{69}$$

= tons of potatoes per thousand volume (1970 US $) of the aggregate 'other food'.

The coefficient $a_{g,6,t}$ was obtained according to the following equation:

$$a_{g,6,t} = \frac{\left(a_{g,6}^{pork} * \tilde{y}_{pork,t} + a_{g,6}^{poultry} * \tilde{y}_{poultry\ and\ egg,t}\right)}{\tilde{y}_{pork,t} + \tilde{y}_{pountry\ and\ egg,t} + \tilde{y}_{fish,t}} \quad , \qquad \forall t \qquad (A3)$$

where

$a_{g,6}^{k}$ = feed requirements of grains and 'other food' per unit of animal k, for k = pork, poultry. These values can be found in Table A2.

$\tilde{y}_{it}$ = net production of animal i in year t, for i = pork, poultry and eggs, fish.

We then calculated the requirement of feed grain only (in tons) per ton of 'other animals' and assumed that a minimum of grain has to be fed to this animal category.

$$\tilde{a}_{g,6,t} = \max\{a_{g,6,t} - c_{g,6} * \frac{Feed_{8,t}}{\tilde{y}_{6,t}} \ , \ \tilde{a}_{g,6}^{min}\} \quad , \qquad (A4)$$

where

$\tilde{a}_{g,6,t}$ = requirement coefficient of grain (excluding the feed component)

$Feed_{8,t}$ = total feed consumption of 'other food' in year t

$\tilde{y}_{6,t}$ = net production of 'other animals' in year t

$\tilde{a}^{min}_{g,6}$ = minimum grain requirement per unit of 'other animals'. These values are given in Table A2.

and

$a_{g,6,t}$ as explained above.

In equation (A4) it is assumed that, if not all feed consumption of 'other food' is used up by 'other animals', it will be fed to 'bovine and ovine animals'. This occurs when the minimum grain requirement, $\tilde{a}^{min}_{g6}$, becomes binding (see also equation (A7)).

Using the relation

$$r_t = \min\left\{\frac{\tilde{a}_{g,6,t} * \tilde{y}_{6,t}}{\sum_{i=1}^{3} \text{Feed}_{it}} \; , \; 1\right\} \; , \qquad \text{(A5)}$$

i.e. the relative amount of grain which has to be fed to 'other animals', we can calculate the feed requirements of grain per unit of 'other animals', $a_{i,6,t}$,

$$a_{i,6,t} = r_t * \frac{\text{Feed}_{it}}{\tilde{y}_{6,t}} \; , \quad \text{for } i = 1,2,3 \; ; \quad \forall t \qquad \text{(A6)}$$

and of 'other food' per unit of 'other animals', $a_{8,6,t}$,

$$a_{8,6,t} = \min\left\{\frac{\text{Feed}_{8,t}}{\tilde{y}_{6,t}} \; , \; \left(\tilde{a}^{min}_{g,6} - a_{g,6,t} + c_{g,6}\right) * \frac{\text{Feed}_{8,t}}{\tilde{y}_{6,t}} * \frac{1}{c_{g6}}\right\} \; ,$$

$$\text{for } \forall t \; . \qquad \text{(A7)}$$

Notice that from (A4) and (A5) we obtain

$$\tilde{a}_{g,6,t} = \sum_{i \in I} a_{i,6,t} \quad . \tag{A8}$$

Having obtained the requirements of grain and 'other food' per unit of 'other animals' we get the same coefficients per unit of 'bovine and ovine animals', $a_{i,17,t}$, in the following way:

$$a_{i,17,t} = \frac{\mathrm{Feed}_{it} - a_{i,6,t} * \tilde{y}_{6,t}}{\tilde{y}_{17,t}} \quad , \qquad \text{for } i \in I \quad ,$$

$$i = 8 \quad ; \qquad \forall t \quad , \tag{A9}$$

where

$\tilde{y}_{17,t}$ = net production of 'bovine and ovine animals' in year t

and all other variables are as explained above.

The calculations of feed requirements of protein feed per unit of each of the two animal categories is performed according to the following formulas.

The basic relation which should hold for the requirement of protein feed per unit of 'other animals' is

$$a_{p,6,t} = \sum_{i \in J} a_{i,6,t} \quad , \qquad \forall t \quad , \tag{A10}$$

with

$J = \{5(\text{milk}),\ 7(\text{protein feed of crop origin}),\ 13\ (\text{meat meal}),\ 14(\text{fish meal})\}$

where

$a_{p,6,t}$ = feed requirement of protein feed per unit of 'other animals' in year t

$a_{i,6,t}$ = requirement of feed component i per unit of 'other animals' in year t.

The coefficient $a_{p,6,t}$ was obtained according to

$$a_{p,6,t} = \frac{\left(a_{p,6}^{pork} * \tilde{y}_{pork,t} + a_{p,6}^{poultry} * \tilde{y}_{pountry\ and\ eggs,t}\right)}{\tilde{y}_{pork,t} + \tilde{y}_{pountry\ and\ eggs,t} + \tilde{y}_{fish,t}} \quad , \quad \forall t \ . \qquad (A11)$$

It is assumed that both meat meal and fish meal are fed only to 'other animals'.

$$a_{i,6,t} = \frac{Feed_{it}}{\tilde{y}_{6,t}} \quad , \quad \text{for } i = 13,14 \quad , \quad \forall\ t \ . \qquad (A12)$$

It is further assumed that 50% of total protein requirement of 'other animals' is fed in the form of animal protein. In other words, milk is used to close the gap if necessary.

$$\tilde{a}_{5,6,t} = \max\{\frac{1}{d}(0.5 * a_{p,6,t} - a_{13,6,t} - a_{14,6,t}) , 0\} , \quad \text{(A13)}$$

where d is the protein content of milk, which is set to 0.035.

We make the additional assumption that at most 80% and at least 20% of total milk consumption for feeding purposes is taken in by 'other animals'. This leads to a feed requirement of milk per unit of 'other animals', $a_{5,6,t}$, according to the following formula:

$$a_{5,6,t} = \max\left\{\bar{a}_{5,6,t} , \frac{.2 * \text{Feed}_{5,t}}{\tilde{y}_{6,t}}\right\} , \quad \forall t , \quad \text{(A14)}$$

where

$$\bar{a}_{5,6,t} = \min\left\{\tilde{a}_{5,6,t} , \frac{.8 * \text{Feed}_{5,t}}{\tilde{y}_{6,t}}\right\} , \quad \forall t .$$

According to the above formulas the remaining feed requirement coefficient--that for protein feed of crop origin--per unit of 'other animals', $a_{7,6,t}$, can be calculated.

$$a_{7,6,t} = \min\left\{h_t , \frac{.8 * \text{Feed}_{7,t}}{\tilde{y}_{6,t}}\right\} , \quad \forall t , \quad \text{(A15)}$$

where

$$h_t = \max\{a_{p,6,t} - a_{13,6,t} - a_{14,6,t} - d * a_{5,6,t} , 0\} , \quad \forall t .$$

h_t represents the amount of protein feed of crop origin per unit of 'other animals' needed to fulfill the total protein feed requirement. However, the assumption is added that protein feed. This is reflected in equation (A15).

Protein feed requirements per unit of 'bovine and ovine animals', $a_{i,17,t}$, are obtained as follows:

$$a_{i,17,t} = \frac{\mathrm{Feed}_{it} - a_{i,6,t} * \tilde{y}_{6,t}}{\tilde{y}_{17,t}} , \quad \text{for } i = 5,7 , \quad \forall t . \qquad \text{(A16)}$$

APPENDIX B: DESCRIPTION OF HOW COMMODITY-SPECIFIC INPUT LEVELS WERE CALCULATED FOR A COMPARISON WITH THE RESULT OF THE ALLOCATION MODEL

The calculation is based on the assumption that the prespecified total inputs are allocated in such a way that their respective marginal value product for all commodities is equalized. However, this information was not available. Therefore, the average value product was used as a starting point. These figures were then modified to reflect as closely as possible the marginal value product. The modifications take differences in the technology used for each commodity production into account and are based on a subjective evaluation.

In a more formal way, the procedure used was derived as follows:

Define: $W_{it} = p^F_{it} * \tilde{Y}_{it}$

where

p^F_{it} = the producer price of commodity i in year t

$\tilde{Y}_{it}$ = the net production (gross production minus seed use) of commodity i in year t

$$TW_t = \sum_{i=1}^{n} p^F_{it} * \tilde{Y}_{it} \quad , \qquad \text{(B2)}$$

where

n = number of commodities considered

TW_t = total gross revenue in year t

Then we get

$$I_{it} = b^I_{it} * W_{it} * \frac{TI_t}{TW_t} \quad , \qquad \text{(B3)}$$

where

I_{it} = input of factor I into commodity i in year t

b^I_{it} = scaling factor for input type I and commodity i in year t

TI_t = total input of factor I available in year t

We have the condition $\sum_i b^T_{it} * w_{it} = TW_t$.

Hence

$$b^I_{it} = \frac{TW_t}{\sum_{k=1}^{n} c^I_k w_{kt}} * c^I_i \quad , \tag{B4}$$

where

c^I_i = relative allocation factors.

This leads to the following formula

$$I_{it} = \frac{c^I_i * TI_t}{\sum_{k=1}^{n} c^I_k * w_{kt}} \quad , \tag{B5}$$

which was used for the calculation. The c^I_i-values are given in Table B1.

Table B1. c_i^I-values (relative allocation of input factors)

country set	commodity index[1)]	I = labor	I = capital	I = fertilizer
A[2)]	i = 1	.39	.99	2.52
	2	.50	1.20	2.50
	3	.51	1.25	2.31
	4	1.59	1.27	1.00
	6	.38	.62	-
	7	.38	.95	2.94
	8	1.08	.82	1.10
	9	4.00	.20	.47
B	i = 1	.39	1.00	2.50
	2	.50	1.20	2.50
	3	.51	1.30	3.00
	4	1.20	1.40	.60
	6	.38	.70	-
	7	.34	.90	.50
	8	.90	1.00	1.50
	9	4.00	.30	.60
C	i = 1	.39	1.00	2.52
	2	.70	1.30	2.50
	3	.51	1.20	2.00
	4	1.20	0.90	.70
	6	.45	0.50	-
	7	.45	0.70	.50
	8	1.00	0.70	1.00
	9	2.00	0.20	.47

Footnotes to Table B1

[1] A description of the index set is given on page 54.

[2] set A: Belgium-Luxembourg
Denmark
France
FRG
Ireland
Italy
Japan
Netherlands
UK

set B: Argentina
Australia
Brazil
Canada
New Zealand

set C: Kenya
Mexico
Nigeria
Pakistan
Indonesia
Thailand
Egypt

REFERENCES

FAO. Review of Food Consumption Surveys. 1977. Rome.

FAO. Review of Food Consumption Surveys. 1970. Vol. 1A and 1B. Rome.

Fischer, G., and U. Sichra. 1980. Aggregation of FAO Supply Utilization Accounts. Laxenburg, Austria: International Institute for Applied Systems Analysis. Forthcoming.

ILO. Household Income and Expenditure Statistics No. 2, 1960-1972. Geneva. 1974.

Jorgenson, D.W., and J.-H. Laffont. 1974. Efficient Estimation of Nonlinear Simultaneous Equations with Additive Error Terms. Annals of Economic and Social Measurement Vol. 3-4, p. 314, 1974.

Keyzer, M. 1977. Linking National Models of Food and Agriculture: An Introduction. RM-77-02. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Keyzer, M. 1980. An Outline of IIASA's Food and Agriculture Model. WP-80-9. Laxenburg, Austria: International Institute for Applied Systems Analysis.