THE CMEA AGRICULTURAL MODEL IN THE FAP/BLS SYSTEM

Csaba Csáki
Lászlo Zeóld

April 1986
WP-86-17

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

FOREWORD

Understanding the nature and dimensions of the world food problems and exploration of policies available to alleviate them has been the focal point of IIASA's Food and Agriculture Program (FAP) since it began in 1977.

Over the years FAP has, with the help of a network of collaborating institutions, developed and linked national policy models of twenty countries, which together account for nearly 80 percent of important agricultural attributes such as area, production, population, exports, imports and so on. The remaining countries are represented by 14 somewhat simpler models of groups of countries. This system of models, that we call the Basic Linked System (BLS) permits analysis of national and international policies in a global context.

The economies of the CMEA (Council of Mutual Economic Assistance) member countries play an important role on the world agricultural trade. The FAP of IIASA has invested substantial effort in the investigation of the agricultural system of the CMEA countries. The CMEA Agricultural Model was constructed as one of the models of the BLS. The model treats the European CMEA member countries, including the Soviet Union, as one aggregate. In fact, two versions of the CMEA Agricultural Model have been developed so far. In this paper Csaba Csáki and Lászlo Zeóld give a detailed description of the structure and mathematical background of the second version of the model (CMEA/2). The CMEA/1 model, as well as results of the investigations with the first FAP/CMEA model were presented earlier in two publications, see C. Csaki (1982) and (1985).

Kirit S. Parikh
Program Leader
Food and Agriculture Program.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to Günther Fischer for his contributions to the computer implementation of the model, to V. Iakimets, K. Parikh and F. Rabar for their comments on the model and to B. Hauser for typing the material.

CONTENTS

THE CMEA AGRICULTURAL MODEL IN THE FAP/BLS SYSTEM

Csaba Csáki and László Zeöld

1. GENERAL CHARACTERISTICS OF THE CMEA/2 MODEL

The Food and Agriculture Program of IIASA has been engaged in the development of a set of linkable national models for agricultural policy analysis since 1976, with the help of a network of collaborating institutions around the world. The purpose of the FAP is to study the effect on policy measures as taken by their own governments, by the governments of other countries and by international organizations which operate under specified international agreements. The basic elements of the FAP model system are the ***national policy*** models developed on the basis of a joint methodology. A special linkage methodology was developed in order to create the global food system. For further information on the structure of the FAP national models and the linkage methodology see M. Keyzer (1981).

The ***FAP global agricultural model system*** called the Basic Linked System (BLS); for further information about the BLS see G. Fischer and K. Frohberg (1980), consists of twenty one models linked together. Of these twenty one models, 18 refer to individual countries, two refer to the EC and the CMEA and one to the rest of the world. These models have been developed at IIASA in cooperation with scientists of the respective countries. The BLS describes the international trade at *10 sectors level*, namely, wheat, rice, coarse grain, bovine and ovine meats, dairy products, other animal products, protein feeds, other food, nonfood agriculture, and nonagriculture. However, some of the national models have a different sectoral detail.

Within the FAP, a specific modeling framework was developed to represent the centrally planned food and agriculture systems in the global investigations. This modeling approach

- incorporates the basic features of the CMEA member countries' economy
- offers opportunities to include the country specific features
- is detailed enough to be used as an experimental tool for actual planning and forecasting purposes

IIASA's modeling framework for centrally planned food and agriculture systems was first applied for the development of the Hungarian Agricultural Model (HAM), see (Csaki, 1981). The aggregated CMEA Agricultural Model has been constructed by using the experience gained with HAM and by the first version of the BLS country models. Actually two versions of the CMEA Agricultural Model have been developed.

CMEA/1 Model was built in 1980-81 with a detailed commodity coverage (22 food and agriculture commodities) consistent with the commodity classification of FAO's Agriculture Toward 2000 Project. The model is divided into two major parts; the first submodel describes the agricultural system of the Soviet Union and the second includes the smaller European CMEA countries, namely, Bulgaria, Czechoslovakia, the GDR, Hungary, Poland and Rumania. The two submodels have a completely identical structure and can be operated independently of each other. The CMEA/1 model has never been linked to the BLS, it has only been used in a stand-alone mode for mid- and long-range projections on limits and potentials of agricultural development in the CMEA countries. For a detailed account of CMEA/1 experiments, see C. Csaki (1982).

The CMEA/2 Model represents the CMEA region in the current version of the BLS. The model is designed along the same principles as the CMEA/1 model and also fully consistent with the other elements of the BLS. The commodity classification follows the one used in the BLS and the production model block is constructed by using the overall methodology and based on the same data base from FAO as other country models. Due to the specific features of the centrally planned food and agriculture systems of the CMEA, the model has several specific features as well. Figure 1 shows the structure of the CMEA/2 Model.

In the CMEA member countries agricultural policy and policy goals are determined by the fact that they are integral parts of the central plan for the whole national economy. The targets for production and consumption are fixed in the national plan and are realized by a coordinated system of--sectoral, industrial, agricultural, etc.,--regional, local and enterprise plans. Though the indirect policy instruments of price, market, tax, credit and interest policy are used to an increasing extent to realize targets, their role and the way in which they are implemented are rather different from those in market economies. First of all, one should point out the following characteristics:

- The agricultural and the domestic market of the CMEA countries are not directly related to the world market. Protection is implemented not by price and tax policy instruments, but mainly by administrative means, e.g., government foreign trade monopoly, central decisions on export and import of agricultural products.
- Decisions on the desired growth of personal consumption and investment allocation to agriculture are made within the framework of the five-year national plans.
- Domestic producer prices are not directly related to international prices, they are generally fixed for a given year and changed mainly to adjust to changing production expenses.
- Producing firms have no direct relation to the world market. Exports and imports are carried over by government foreign trade agencies.
- Availability of foreign currencies and labor flows are controlled by the central planners.
- Consumer prices are set based on central income and wage policy targets and they do not reflect the actual supply demand relations.

The CMEA/2 model in the BLS is constructed to reflect the above mentioned conditions. Thus,

- Domestic prices are not endogenized and are expressed in rubles.
- In the model the desired growth of the overall economy, a_1, the desired growth of consumption, a_2, and the desired share of food and agriculture in total investment funds, a_3, are taken exogenously with lower and upper bounds determining the desired path. Adjustment mechanism is also built in to keep these targets as much as possible.
- Lower and upper bounds are introduced in the production module to assure self-sufficiency requirements or limit production growth in certain commodities.
- Modeling of consumption is based on FAO trends, see "Agriculture Toward 2000" (FAO), estimations and targets on private consumption published in CMEA countries.

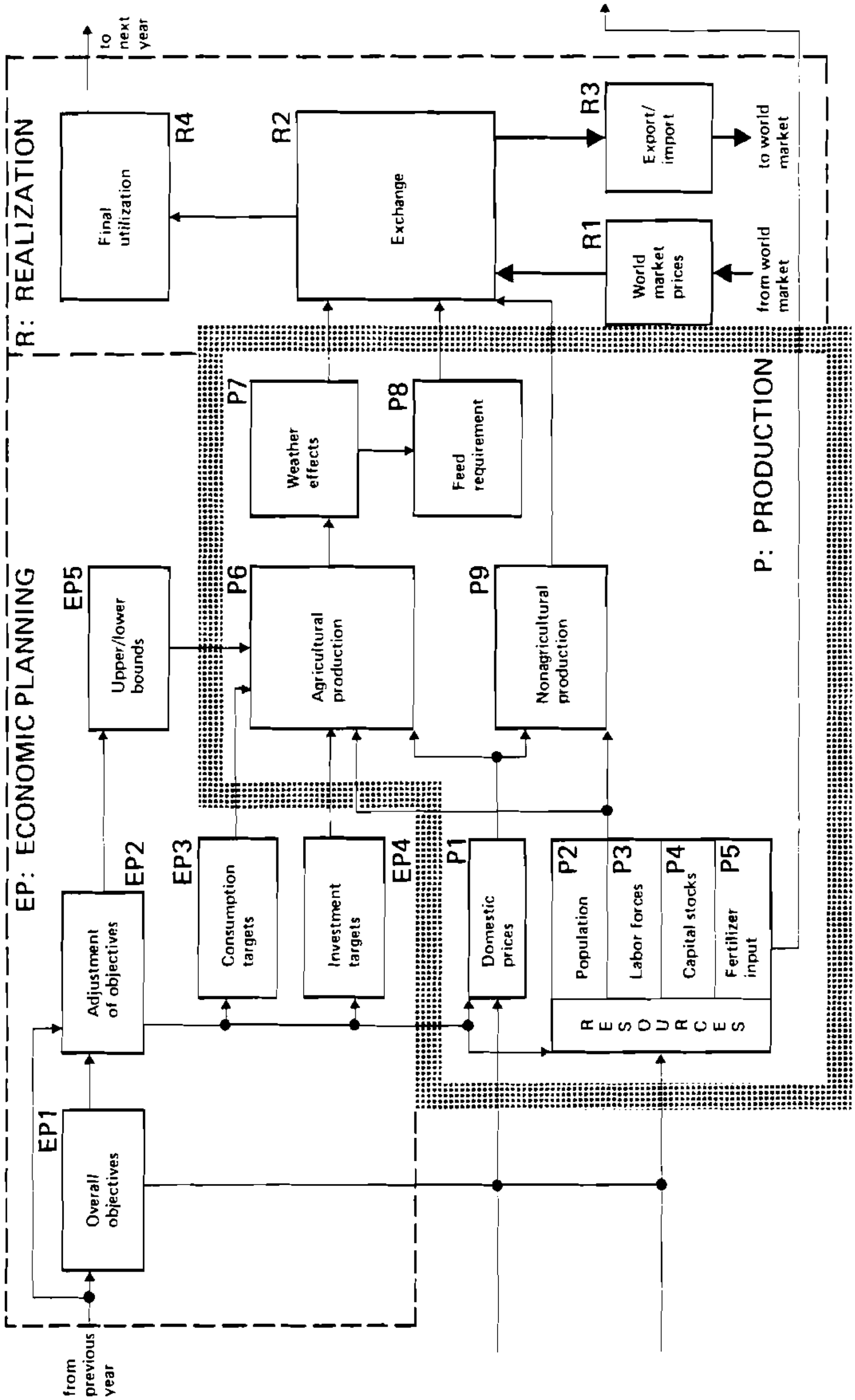


Figure 1: Overall Structure of the CMEA/2 Agricultural Model

- The exchange model built into the model expresses present practice and assumed preference ordering of areas where the adjustment to changes in the conditions of the world market takes place. In the present version the preference ordering of adjustment is stated as follows:
  - adjustment of stocks of the nonagricultural commodity;
  - stock adjustment of agricultural commodities;
  - modification of government expenditures;
  - modification of investment in the rest of the economy;
  - modification of investment in agriculture;
  - adjustment of private consumption of the nonagricultural product;
  - modification of food consumption
- The model can be run with various assumptions on domestic price policy. It is possible to use unchanged domestic prices for the whole run, while it can also be assumed that if a world market price changes strongly in a persistent way over a long period of time, this will result in changes of domestic prices of CMEA countries. A logistic function is used proposed by O. Gulbrandsen, where the transmission of the world market price change is very limited with small change and grows with large persistent changes. Other price policies might also be included in the model.

2. MATHEMATICAL DESCRIPTION

As Figure 1 shows three major submodels are differentiated within the model as follows:

EP: Economic Planning

P: Production

R: Realization

The *Economic Planning Submodel* reflects the decision making and economic control activities of the government. The overall targets guiding the operation of the whole system are set here. There are five modules within this submodel.

The *Production Submodel* relate agricultural and nonagricultural production. Resources and domestic prices are set also in this module. The random effects of weather upon crop production can also be taken into account. The submodel P is structured according to nine modules.

The *Realization Submodel* describes product utilization, demand and relations to the international market. There are four modules in this submodel. The model is dynamic, with a one year time increment. The basic methodology used is a simulation technique. Next the mathematical description of the model is presented according to the structure outlined above. The actual values of parameters used in the present version of the model are also listed.

2.1. Economic Planning Submodel

This submodel is devoted to introduction of government policy objectives.

2.1.1. Module EP/1: Overall objectives

The major government objectives are taken into consideration in an exogenous manner within the model. The three major exogenous parameters given for the system are as follows:

1. Desired growth of the *national income:*

$$a_1 \ (=0.05)$$

2. Desired growth of personal *consumption:* here lower and upper bounds are given for the annual growth rate of the total personal consumption

$$a_{2\,min} \ (=0)$$

and

$$a_{2\,max} \ (=0.1)$$

3. Desired share of agricultural *investment* in the total investment funds: here also lower and upper bounds are set:

$$a_{3\,min} \ (=0.1)$$

and less or equal to

$$a_{3\,max} \ (=0.3)$$

2.1.2. Module EP/2: Adjustment of Objectives

The major exogenous parameters are updated at the beginning of each simulated time increment.

1. *National Income*

The targeted national income is computed by

$$PNIC_t = NIC_{t-1}\,(1+a_1)$$

where NIC_{t-1}: the actual national income in the previous year.

2. *Personal Consumption*

The planned value of total personal consumption in year t is

$$PCONS_t = (1 + a_{2t})$$

where $CONS_{t-1}$: the actual value of total personal consumption in the previous year. The a_{2t} parameter is adjusted in the following way

$$sa_2 = \frac{NIC_t}{NIC_{t-1}} - 1$$

if: $sa_2 < s_{2\,min}$ then a_{2t} increases

$$a_{2t} = a_{2t-1} + 0.5(s_{2\,min} - sa_2)$$

$$(s_{2\,min} = 0.04)$$

if: $sa_2 > s_{2\,max}$, then a_{2t} decreases,

$$a_{2t} = a_{2t-1} - 0.5\,(sa_2 - s_{2\,max})$$

$$(s_{2\,max} = 0.09)$$

in all other cases

$$a_{2t} = a_{2t-1}$$

3. *Agricultural Investment Share*

Total investment target:

$$PINV_t = PNIC_t - PCONS_t$$

Agricultural investment target:

$$PINVA_t = a_{3t} * PINV_t$$

Nonagricultural investment target:

$$PINVN_t = (1 - a_{3t}) * PINV_t$$

The a_{3t} parameter is adjusted in the following way:

$$sa_3 = \frac{GNPA_t}{GNPA_{t-1}} - 1$$

where

GNPA is gross national product of the agricultural sector

if: $sa_3 < s_{3\,min,}$ then a_{3t} increases,

$$a_{3t} = a_{3t-1} + (s_{3\,min} - s_{a3})$$

$$(s_{3\,min} = 0.03)$$

if: $sa_3 > s_{3\,max}$, then a_{3t} decreases

$$a_{3t} = a_{3t-1} - (sa_3 - s_{3\,max})$$

$$(s_{3\,max} = 0.06)$$

in all other cases

$$a_{3t} = a_{3t-1}$$

4. *Stocks*

The desired stocks are set as a ratio to the previous year's actual personal consumption

$$DS_{i,t} = \Pi_i\, TC_{i,t-1} \qquad (i = 1, \cdots, 10)$$

where

$DS_{i,t}$: desired stock for the i-th commodity

$TC_{i,t-1}$: previous year actual consumption from the i-th commodity

Π_i : desired stock level

Table 1

i	Π_i	i	Π_i
1	0.1	6	0.1
2	0.1	7	0.1
3	0.1	8	0.1
4	0.1	9	0
5	0.1	10	0.025

2.1.3. Module EP/3 Consumption Targets

The targets for personal consumption are computed by using trend functions, which have been estimated on the basis of 1961-1974 data. The consumption target for commodity i is computed by

$$PTC_{i,t} = TC_{i,t-1} + C_{1i} * (1 - e^{-t/c_{2i}}) \quad (i = 1,\ldots,8)$$

Table 2 Parameters of Demand Trend Functions

i	C_{1i}	C_{2i}
1	-55.78	56.18
2	3.657	9.635
3	-11.44	9.837
4	13.32	12.1
5	526.	110.3
6	2.647	11.11
7	0.075	10.002
8	39.24	28.67

2.1.4. Module EP/4 Investment Targets

Targets for gross and agricultural investment are set by using the exogenous parameters explained under 2.1.1 and 2.1.2.

Target for gross investments:

$$PINV_t = PNIC_t - PCONS_t$$

Target for agricultural investments:

$$PINVA_t = a_{3t} * PINV_t$$

Target for agricultural investments:

$$PINVN_t = (1 - a_{3t}) * PINV_t$$

2.1.5. Module EP/5: Setting Upper and Lower Bounds

In the last module of EP Submodel lower and upper bounds are set for production. There are two approaches used in the model in this respect:

1) We assume that the maximal possible level of self-sufficiency in most of the products is a major government policy objective. The production lower and upper bounds are set accordingly. In this case ***production lower bounds*** are set for the 10 exchange commodities as follows:

$$pdlb_i = yb_i * slb_i \quad (i = 1,\ldots 9)$$

where

yb_i the previous year's production

slb_i: required minimum level of self sufficiency

Then, for

$i=1$, $pdlb_1 = \max\{pdlb_1, tpl_1 * (PTC_1 + FEED_1 + CINT_1)\}$

$i=4$, $pdlb_4 = \max\{pdlb_4, tpl_4 * (PTC_4 + FEED_4 + CINT_4)\}$

$i=5$, $pdlb_5 = \max\{pdlb_5, tpl_5 * (PTC_5 + FEED_5 + CINT_5)\}$

$i=7$, $pdlb_7 = \max\{pdlb_7, tpl_7 * (PTC_7 + FEED_7 + CINT_7)\}$

$i=8$, $pdlb_8 = (yb_8 - b_{78} * yb_7) * slb_8$

$pdlb_8 = \max\{pdlb_8, tpl_8^* (TC_8 + FEED_8 + CINT_8)\}$

where the allowed

tpl_i = parameters expressing lower level of self sufficiency

PTC_i = planned total consumption

TC_i = actual total consumption

$FEED_i$ = feed usage

$CINT_i$ = internal consumption

b_{78} = byproduct parameter

The *upper bounds for production* are set for the 10 exchange commodities as follows:

$$pdub_i = 1000 * yb_i \quad (i = 1,\ldots,9)$$

Then, for

$i = 2$, $pdub_2 = yb_2 * 1.025$

$pdub_2 = \min\{pdub_2, tpu_2 * (PTC_2 + FEED_2 + CINT_2)\}$

$i = 3$, $pdub_3 = tpu_3 * (TC_3 + FEED_3 + CINT_3)$

$i = 6$, $pdub_6 = yb_6 * \max\left(1.025, \frac{PTC_6}{TC_6}\right)$

$pdub_6 = \max\{pdub_6, 1.05 * (PTC_6 + CINT_6)\}$

where

tpu_i = parameter expressing the allowed upper level of self sufficiency.

All other variables are the same as for production lower bounds. It is assumed that self sufficiency requirement may vary in order to utilize comparative advantages via an extended magnitude of international trade. The lower bounds for production are set for the 10 exchange commodities as follows:

$$PDLB_i = slb_i * (TC_{i,t-1} + FEED_{i,t-1} + CINT_{i,t-1})$$

where

slb_i: required minimum level of self sufficiency for the i-th commodities

$TC_{i,t-1}$: actual private consumption from the i-th commodity in the previous year

$FEED_{i,t-1}$: feed usage from th i-th commodity in the previous year

$CINT_{i,t-1}$: internal consumption from the i-th commodity in the previous year.

By changing slb_i coefficients various desired self sufficiency levels can be considered. The ***production upper bounds*** are very large numbers expressing no actual upper limits upon production. This option has been used in the so called Free Trade for CMEA/BLS Run with $slb_i = 0.6$ for all the commodities.

Due to the present features of the Production Submodel when the 10-list commodities are aggregated into the 8-list production commodities in both cases the bounds set for the 10 commodity list have to be converted as follows:

ylb_1	=	$pdlb_1$
ylb_2	=	$pdlb_2$
ylb_3	=	$pdlb_3$
ylb_4	=	$pdlb_7$
ylb_5	=	$pdlb_8$
ylb_6	=	$pdlb_9$
ylb_7	=	$\max(pdlb_4 * 0.147/(1-b_{45}), pdlb_5 * 0.035/b_{45})$
ylb_8	=	$pdlb_6$
where		
b_{45}	=	0.756648

Similar procedure is used for the upper bounds

2.2. P/Production Submodel

The Production Submodel consists of 9 models. Five of them are used to set parameters for the modeling of agricultural and nonagricultural production. Four modules are devoted to supply modeling.

2.2.1. Module P1: Domestic Prices

In the Production Submodel first the domestic prices are adjusted for the given period. There are two switch-selectable methods to determine the domestic prices. First we determine prices corresponding to the 10-commodity list.

The ***first method*** is based on the assumption of fixed domestic prices by using the procedure as follows:

$PD_t(1)$	=	$PD_{t-1}(1)$	+	Δp_1
$PD_t(2)$	=	$PD_{t-1}(2)$	+	Δp_2
$PD_t(3)$	=	$PD_{t-1}(3)$	+	Δp_3
$PD_t(4)$	=	p_{41}	+	$p_{42}*PW_{t-1}(4)$
$PD_t(5)$	=	p_{51}	+	$p_{52}*PW_{t-1}(5)$
$PD_t(6)$	=	p_{61}	+	$p_{62}*PW_{t-1}(6)$
$PD_t(7)$	=	p_{71}	+	$p_{72}*PW_{t-1}(7)$
$PD_t(8)$	=	$PD_{t-1}(8)$	+	Δp_8
$PD_t(9)$	=	$PD_{t-1}(9)$	+	Δp_9
$PD_t(10)$	=	$PD_{t-1}(10)$	+	$(3 \cdot PW_{t-1}(10) - PW_{t-2}(10) - PW_{t-3}(10) - PW_{t-4}(10))/6$

and

$PDT_t(i) = PD_t(i) \quad (i = 1,\ldots,10)$

The *second method* has been recommended by O. Gulbrandsen. In this case world market price changes are transferred into domestic price system by using a logistic function after the year of 1980:

$PDT_t(i) \quad = PD_t(i) \; (i = 1,\ldots,10)$, if year less or equal 1980.

$PW80(i) \quad = PW_t(i)/PW_t(10) \; (i = 1,\ldots,10)$, if year equal 1980.

If year greater than 1980, then

$dpw_i \quad = (PW(i) / (PW(10) - PW80(i)) / PW80(i)$

$adpw_i \quad = \min(1, abs(dpw_i))$

$r_i \quad = \rho_1 / (1 + e^{-adpw_i}) - \rho_2$

$PDT_t(i) \quad = PD_t(i) * (1 + dpw_i * r_i) \quad (i=1,\ldots10)$

Due to the specific commodity classification (only 8 commodities) of agricultural supply module (P/6), switch-selectable methods are used to determine the expected producer prices from domestic prices set by the above mentioned two methods.

In case of the first method (Fixed Prices)	In case of the second method (Domestic Price Adjustment)
$P(1)=PD(1)$	$P(1)=PDT(1)$
$P(2)=PD(2)$	$P(2)=PDT(2)$
$P(3)=PD(3)^{\Pi_1} * \left[P(1) * \frac{PW(3)}{PW(1)}\right]^{\Pi_2}$	$P(3)=PDT(3)$
$P(4)=\Pi_4$	$P(4)=\Pi_4 * PDT(7)/PD(7)$
$P(5)=\Pi_5$	$P(5)=\Pi_5 * PDT(8)/PD(8)$
$P(6)=\Pi_6$	$P(6)=\Pi_6 * PDT(9)/PD(9)$
$P(7)=\Pi_7$	$P(7)=\Pi_7 * (YS(4) * PDT(4)+YS(5) * PDT(5))/ (YS(4) * PD(4) + YS(5) * PD(5))$
$P(8)=\Pi_8$	$P(8)=\Pi_8 * PDT(6)/PD(6)$

2.2.2. Module P/2: Population Resources

The total population is computed by

$$POP_t = POP_{t-1} * grpop_t \qquad (POP_{1970} = 345710)$$
$$grpop_t = gr_2 + gr_3 * t \qquad (gr_2 = 1.00953)$$
$$(gr_3 = -0.000097)$$

2.2.3. Module P/3 Labor Forces

The total labor force is a fraction of the total population shared by the participation rate:

$$L_t^T = POP_t * part_t$$
$$part_t = gr_4 \qquad (gr_4 = 0.502157)$$

The agricultural labor force is:

$$L_t^A = \alpha_{L1} * \left[\frac{NICA_{t-1}}{NICN_{t-1}}\right]^{\alpha_{L2}} * L_t^T$$

and

$$L_t^A \geq L_t^{A1} = \alpha_{L3} * L_{t-1}^A$$

where

$(\alpha_{L1} = 1.001)$

$(\alpha_{L2} = 0.02813)$

$(\alpha_{L3} = 0.965)$

The labor force of the nonagricultural sector L_t^{NA} is determined as follows:

$$L_t^{NA} = L_t^T - L_t^A$$

where

t	= time variable, (1971 = 1)
POP_t	= population in year t [1000 persons] (1970: 345710)
L_t^T	= total labor force in year t [1000 persons] (1970: _)
L_t^A	= agricultural labor force in year t [1000 persons] (1970: 48755)
L_t^{Al}	= lower bound on agricultural labor force in year t [1000 persons] (1970: _)
L_t^{NA}	= labor force of nonagricultural sector in year t [1000 persons] (1970: _)
$NICA_t$	= net national income of agriculture in year t
$NICN_t$	= net national income of nonagricultural sector in year t

2.2.4. Module P/4: Capital Stock in Agriculture

$$CSA_t = CSA_{t-1} + \left[INVA_{t-1} + DEPA_{t-1}\right] / PD_t^n - DEPA_{t-1}$$

$$DEPA_t = \beta_1 * CSA_t$$

The variables and their initial values in year 1970:

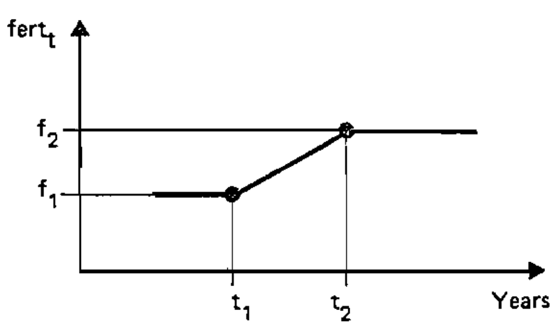
n.c	= UDSSR Ruble 1970
CSA_t	= capital stock employed in agriculture in year t [mill.n.c] (1970: 205921)
$INVA_t$	= agricultural investment in year t [mill.n.c]
$DEPA_t$	= depreciation value in agriculture in year t [mill.n.c]
PD_t^n	= domestic price of nonagricultural commodity in year t $\left[\dfrac{\text{mill.n.c}}{\text{millUS\$70}}\right]$
β_1	= 0.035: The (constant) depreciation rate in agriculture

2.2.5. Module P/5: Fertilizer Input

Total fertilizer input is calculated according to the following function:

$$TF_t = TF_0 * fert_t^{(t+1)}$$

$fert_t$ is a time dependent function in the following form:



The total amount of available fertilizer is modified by roughage production.

$$TFP_t = \left[1 - \frac{PYS_{t-1}(7) * YS_{t-1}(7) * v3(7)}{\sum_{i=1}^{7} PYS_{t-1}(i) * YS_{t-1}(i) * v3(i)} \right] * TF_t$$

The meaning of the variables and their initial values in year 1970:

- TF_t = total amount of fertilizer in year t [1000 m.t. nitrogen equivalent] (1970: TF = 7746)
- TFP_t = total amount of fertilizer (without roughage production in year t [1000 m.t. nitrogen equivalent] (1970: _)
- YS_t = produced amounts of commodities in year t. (In natural measurement, see commodity lists)

The meaning of the parameter:

- $fert_t$ = the (time dependent) growth rate of the fertilizer usage

The meaning of the coefficients and their input values:

- t_1 = the first breakpoint of the fertilizer function (=1970)
- t_2 = the second breakpoint of the fertilizer function (=2000)
- f_1 = minimum value of the growth rate of the fertilizer usage (=1.035)
- f_2 = maximum value of the growth rate of the fertilizer usage (=1.035)

2.2.6. Module P/6: Agricultural Production

The agricultural production module follows the earlier methodology of the BLS country models using a nonlinear programming model, where linear constraints are applied with a nonlinear objective function. Among the factors of the production capital, labor and fertilizer and considered.

The agricultural production model can be written for any year t as follows.

$$\max_{K_i, L_i, F_i} \sum_{i=1}^{mall} P_i \cdot YS_i$$

subject to:

$$YS_i = \alpha_i \left(\frac{K_i}{TK} \right)^{\beta_i} \left(\frac{L_i}{TL} \right)^{\gamma_i} \left(\frac{F_i}{TP} \right)^{\varepsilon_i} \quad (i \leq mc)$$

$$YS_i = \alpha_i \left(\frac{K_i}{TK} \right)^{\beta_i} \left(\frac{L_i}{TL} \right)^{\gamma_i} \quad (mc < i \leq mall)$$

$$YLB_i = YS_i \leq YUB_i \quad (i=1,\dots,mall)$$

$$\sum_{i=1}^{mall} K_i \leq TK$$

$$\sum_{i=1}^{mall} L_i \leq TL$$

$$\sum_{i=1}^{mc} F_i \leq TF$$

All variables and parameters also depend on the time but for simplicity we omit the "t" index.

The meaning of the *variables* are as follows:

Input variables

P_i = net revenue of commodity i

YLB_i = lower bounds on production

YUB_i = upper bounds on production

TK = agricultural capital stock

TL = agricultural labor force

TF = fertilizer input (except roughage)

Output variables

YS_i = net output (including feed)

K_i = capital allocated to commodity i

L_i = labor allocated to commodity i

F_i = fertilizer allocated to commodity i

The meaning of the *parameters* are as follows:

$$\left.\begin{array}{l}\alpha_i = \\ \beta_i = \\ \gamma_i = \\ \varepsilon_i = \end{array}\right\} \quad \text{Parameters of the Cobb-Douglas type production function}$$

mc = number of "crops" in the commodity list

mall = number of commodities

The module P/6 works on the basis of 8 commodities as was mentioned earlier, while the whole model is based on 10 commodities.

The commodity lists in the CMEA model system are as follows:

10 Commodity List (Realization)

1.	Wheat
2.	Rice, milled
3.	Coarse grain
4.	Bovine and ovine meat
5.	Dairy products
6.	Other animals
7.	Protein food (of crop origin)
8.	Other food
9.	Nonfood agriculture
10.	Nonagriculture

8 Commodity List (Agricultural Production)

1. Wheat
2. Rice, milled
3. Coarse grain
4. Protein feed
5. Other food
6. Nonfood agriculture
7. Bovine and ovine
8. Other animals

2.2.7. Module P/7: Weather Effects

In the basic version of the model no weather effects upon crop production are considered. However, the actual production computed by module P/6 for wheat (commodity 1) and for coarse grain (commodity 3) can be independently perturbed by a random weather effect using the following distribution:

Table 3. Weather Random Effects on Crops

Probability	% of change of total production
0.05	-20
0.075	-10
0.1	-5
0.55	0
0.1	+5
0.075	+10
0.05	+20

2.2.8. Module P/9* Non-Agricultural Production

The nonagricultural production, YB_n is calculated by the following function:

$$YB_{n,t} = pn_3 * CSN_t^{\varepsilon_t} \left[L_t^{NA}\right]^{1-\varepsilon_t}$$

and

$$\varepsilon_t = pn_1 * \left[1 - \frac{0.2}{1 + pn_2 * t}\right]$$

*Module P/8 does not exist in this version. This module is numbered P/9 to be consistent with earlier versions of the model.

where

pn_1 (= 0.728)

pn_2 (= 0.4183)

pn_3 (= 0.5461) are estimated parameters

CSN_t: capital stock employed in nonagriculture in year t (1970 = 1527677)

L_t^{NA}: labor force of nonagricultural sector in year t (1970 = 122164)

2.3. R: Realization

2.3.1. Module R/1: World Market Prices

The 10-commodity world market prices are taken from the international exchange module of the BLS and influence domestic prices according to module P/1.

2.3.2. Module R/2: Exchange

Module R/2 is a crucial part of the whole model, where the final level of private and government consumption as well as stocks satisfying balance of trade equilibrium conditions are determined. It is very important to underline that the reaction mechanism of domestic demands to new world market conditions (prices) is described here.

In this module the so-called noncommitted demands, which can be the subjects of further adjustment, are determined. The noncommitted demand for a specific commodity consists of various elements; therefore, let q_{ih} express the hth type of demand for commodity i. To reach a solution first we define a target level of the hth demand for commodity $i(q_{ih}^{(t)})$ and introduce a vector λ which indicates the extent to which the targets are realized. Obviously the realization levels are constrained between two bounds:

$$\lambda^* \le \lambda \le \lambda^{**}$$

Let us assume that y is the vector of supply after the deduction of committed expenditures $p_i^{w(t)}$ is the world market price of commodity i, and k is the preliminary fixed balance of foreign trade.

The solution of module R/2 is equal to the determination of the values of vector λ which satisfy

$$p^w Q \lambda = p^w y + k$$

with

$$\lambda^* \le \lambda \le \lambda^{**}$$

and where Q is a matrix of noncommitted demands.

During the solution procedure a strict preference ordering of various types of demands is followed:

1. ds_{10}
2. ds_{1-9}
3. PINVN
4. PINVA

5. PTC_{10}
6. PTC_{1-9}
7. $CINT_{1-9}$

In the event of changes in the world market prices a new λ vector has to be calculated. If no solution can be obtained, the λ^* and λ^{**} vectors have to be adjusted so that a solution can be reached. The calculation of vector λ is easily programmed. It is worthwhile to consider unity as an initial value of λ_i. It is obvious that in the event that the target is realized, $\lambda_i=1$, and always $\lambda_i^* < 1$ and $\lambda_i^{**} \geq 1$.

The target values of noncommitted demands are determined as follows.

- As far as stocks are considered, so-called optimal stocks are taken as target values. These optimal stocks are computed by: $ds_i = 0.1*PTC_i$ $(i=1,...9)$ and $ds_{10} = 0.025*PTC_n$.
- As the target value of direct government investments in food and agriculture the value of PINVA (planned investments in food and agriculture), as determined in module EP/2 is used. The target value of INVN (planned investment of the rest of the economy) calculated based on the value of PINVA determined in module EP/2.
- The targets on consumption $PTC_i^{(t)}$ are computed in EP/3 module
- As targets on private consumption, the values of $TC_i^{(t)}$ related to consumer price for the given year and endowments calculated in module EP/3 determined by the nonlinear demand system are used.

λ^* and λ^{**} express the extent of allowed deviation from target levels. For the various elements of Q different λ^* and λ^{**} values are given, expressing the government objectives and policies in demand of adjustment. Vector λ is determined using the algorithm mentioned above and the final values of variables included in matrix Q can be calculated. On the basis of the elements of the Q matrix the export-import vector is calculated:

$$EI_i^{(t)} = \sum_j q^{ij(t)} - y_i^{(t)}$$

if

$$EI_i^{(t)} \leq 0 \quad \text{then } I_i^{(t)} = -EI_i^{(t)} \quad \text{and } E_i^{(t)} = 0$$

if

$$EI_i^{(t)} \geq 0 \quad \text{then } E_i^{(t)} = EI_i^{(t)} \quad \text{and } I_i^{(t)} = 0$$

if

$$EI_i^{(t)} = 0 \quad \text{then } E_i^{(t)} = 0 \quad \text{and } I_i^{(t)} = 0$$

The final values of government investment $INVA^t$ and $INVN^t$ are also calculated. Based on the latter information the investment program of the given year is finalized.

REFERENCES

Csaki, C. (1981). A National Policy Model for the Hungarian Food and Agriculture Sector. RR-81-23: International Institute for Applied Systems Analysis, Laxenburg, Austria.

Csaki, C. (1982). Long-Term Prospects for Agricultural Development in the European CMEA Countries, Including the Soviet Union. RR-82-25: International Institute for Applied Systems Analysis, Laxenburg, Austria.

Csaki, C. (1985). *System Simulation and Systems Analysis in Agriculture.* Elsevier, Holland.

Food and Agriculture Organization (FAO). (1981). Agriculture Toward 2000. Rome, Italy.

Fischer, G., and K. Frohberg (1981). Simplified National Models: The Condensed Version of the Food and Agriculture Model System of the International Institute for Applied Systems Analysis. WP-80-56: IIASA, Laxenburg, Austria.

Keyzer, M. (1981). The International Linkage of Open Exchange Economies. Doctoral Dissertation. Free University, Amsterdam, 1981.