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OUTLINE OF THE SOVAM

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FOREWORD

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

National food systems are highly interdependent, and yet the major policy options exist at the national level. Therefore, to explore these options, it is necessary both to develop policy models for national economies and to link them together by trade and capital transfers. 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.

The countries constituting the Council of Mutual Economic Assistance (CMEA) together are a major influence on the world market. An aggregate food and agriculture model of the CMEA, in which the CMEA is treated as one nation has been developed by the FAP, as part of the IIASA/FAP basic linked system.

In addition, development of detailed models for some of the major nations constituting the CMEA was undertaken. The development of the Soviet Agricultural Model (SOVAM) was started in late 1983 in collaboration with a number of institutions in the Soviet Union. These include the All-Union Research Institute of Cybernetics in Agriculture, the Computer Centre of the USSR Academy of Sciences, the All-Union Research Institute for Systems Studies, and the Central Economic Mathematical Institute.

This working paper is one of a series of working papers documenting the work that went into developing the various models of FAP. In this paper, V. Fedorov and V. Iakimets describe the outline of the SOVAM model.

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ABSTRACT

In this paper, the general structure, information flows and outline exchange and production modules of the SOVAM are described.

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Introduction

The main goal of the IIASA's Food and Agriculture Program is to create a set of national agricultural models interacted through the world market model as tool for understanding the influence of current and future national policy options upon the international food situation for the period of 15-20 years. During the period from 1977 until 1984, within the framework of this Program, and in collaboration with different national and international organizations, the linkage system and its methodological base were developed. Algorithms and software for national and international equilibrium computations were prepared and different country's agricultural policy models of various complexity were elaborated. (Parikh and Rabar (1981), Fischer and Frohberg (1980), Keyzer and Rebelo (1982), Csaki (1982)).

The Soviet Union is represented now in the FAP system through the CMEA countries model which has aggregated character (Csaki 1982). Unfortunately an independent model for the USSR agricultural sector doesn't exist in the current version of this model. Therefore we have two possibilities: to develop the Soviet model to be used in a stand-alone mode or to make a disaggregation of the current CMEA countries' model up to each country's submodels with a general agricultural policy module for the Community. We believe that the last proposal is the preferable one, however, in this paper we shall not discuss how it could be done.

This paper is devoted only to the problems of the Soviet model construction.

Development of the SOViet Agricultural Model (SOVAM) was started in the second half of 1983. The background, conceptual framework and some of the statistical data for the SOVAM are described in Iakimets (1984).

This paper is mainly concerned with the following aspects of the SOVAM:

- the structure of the model and its information flows;
- main stages of the SOVAM development;
- outline of exchange, consumption and production modules.

1. Main assumptions

To begin the description of the general structure and information flows of SOVAM, we briefly repeat the assumptions which were formulated in Iakimets 1984.

Assumption 1

Being descriptive in nature as many of the FAP models are, the SOVAM has to contain the normative elements to reflect the planned character of socialist agriculture development.

Assumption 2

Targeted levels, growth rates and structure of output of agricultural production are specified for the SOVAM exogenously.

Assumption 3

Alternatives to minimize deviations of real domestic agricultural output induced mainly by weather impact from target levels have to be considered explicitly and have to be determined endogenously.

Assumption 4

Annual target levels of internal consumption and its growth rates in agricultural and food commodities are specified exogenously.

Assumption 5

Versions for attainment of consumption targets in agricultural commodities have to be modelled explicitly. Comparisons of these versions and selection of the preferable one has to be envisaged endogenously.

Assumption 6

General volumes of some input resources (investments, labour, fertilizers, etc.) for the agricultural sector for the period under consideration are specified exogenously.

Assumption 7

Volumes of foreign trade in agricultural and food commodities both for import and export have to meet the lower and upper constraints given exogenously.

Assumption 8

Financial constraints for import and export in agricultural and food commodities are determined by an exogenously given foreign trade balance.

Assumption 9

Domestic producer and consumer prices for main agricultural and food commodities don't relate to their world market prices. Retail prices of most goods are stable for the period under consideration.

2. Stages of the SOVAM development

Taking into account the expediency of the step by step elaboration of the SOVAM it is reasonable now to characterize main planned stages of this model development. We discern the following 3 stages.

First Stage

The exchange and consumption modules are developed as an optimization model. The production module is described by a regression type model. The agricultural policy module isn't formalized either in the part related to exchange and consumption, or in the part of internal production development. (See Assumptions

6-9). The elements describing the internal agricultural policy are given exogenously. Exchange, consumption and production modules of the SOVAM do not contain feedbacks. The world market prices on agricultural commodities don't influence the internal agricultural output and its structure. It is also supposed that the allocation of resource inputs such as capital, fertilizers, labour etc. does not depend upon these prices and their allocation will change exogenously in accordance to historical data analysis and statistical forecasting (assumption 6).

Second Stage

Fluctuations in the weather and climatic changes will be taken into consideration. At this stage of the SOVAM development the statistical significance of these factors for internal agricultural output and trade flows will be studied. The structure of the production module and other modules as well as main assumptions and relations will be assumed to be similar to the first stage.

Third Stage

At this stage the main efforts will be directed to the construction of a more sophisticated version of the production module. Its core will be the optimization model which will reflect the dependence of agricultural output on national agricultural policy options and fluctuations of world market prices. It is supposed however that this model will be aggregative and will include mainly variables which are more or less explicitly connected with export or import of agricultural commodities. It will nevertheless be constructed in a way to study what kind of policies in the agricultural sector will allow a reduction in imports in the near future, while at the same time providing for admissible levels of internal consumption of agricultural and food commodities.

Naturally the model should take into account the main directions of the development of the USSR agro-industrial complex both in technology and economy. Special attention will be given to the study of the appropriate proportion between industries involved in agricultural and food production. Depending on availability of corresponding information, it is also supposed to take into consideration the regional structure of Soviet agriculture.

3. General structure and information flows

The SOVAM has to meet two sets of requirements. First of all these are requirements of the FAP Basic Linked System:

- prescribed list of aggregated agricultural commodities for exchange (see Table 1)
- one year time increment
- the country's export (import) for each commodity should be a function of world market prices which satisfies certain assumptions (continuity, homogeneity of degree zero)
- a national model should contain production, policy, exchange and consumption modules.

Specific national requirements are defined by assumptions 1-9 and can be summarized in the following way:

- centrally planned development
- existence of target levels for production and consumption and their growth rates according to the USSR Food Program (see Table 2 for human consumption)

Table 1. The FAP Commodity Lists

No.	Aggregated Commodity	Units of Measurement	No.	Disaggregated Commodity
1	wheat	10^3 tons	1	wheat
2	rice,milled	10^3 tons	2	rice,milled
3	coarse grains	10^3 tons	3	coarse grains
4	bovine and ovine meats	10^3 tons	4	bovine and ovine meats
5	dairy products	10^3 tons fresh milk equivalents	5	dairy products
6	other animal products	10^3 tons protein equivalents	8	pork
			9	poultry and eggs
			13	fish
7	protein feeds	10^3 tons protein equivalents	5	protein feeds
8	other foods	million US$ 1970	4	oils and fats
			6	sugar products
			11	vegetables
			12	fruits and nuts
			14	coffee
			15	cocoa, tea and their products alcoholic beverages
9	nonfood agriculture	millions US$ 1970	17	clothing fibers
10	nonagriculture		18	industrial crops

- the model should be based on official national statistical data.

It should be emphasized that the structure of the SOVAM has to be flexible and to allow a future improvement of each module independently. At present the model consists of 4 main modules (see Figure 1): production, consumption, policy and exchange. The information flows between these are shown on this scheme.

The SOVAM policy module has three interconnected blocks concern with policy decisions on production, consumption and foreign trade in agriculture and food commodities. The reasons for this were described in Iakimets 1984. According to the state long-term plans and guidelines for Soviet agriculture development within these three blocks targets, proportions and constraints have to be determined. For instance, decisions regarding the per capita consumption, proportions between various consumers in each commodity and growth rates of its consumption for the period under consideration will be specified.

Decisions concerning agricultural production include volumes and growth rates of each commodity, production and prescribed self-sufficiency ratio as targets, and availability of various input resources as constraints (labour, acreage, capital investments, capacities and so on) as well as prescribed proportions of their utilization for different commodities.

Table 2. Per capita annual consumption of foodstuffs (in kg)

	1950	1965	1970	1975	1980	1990* (planned targets)
Meat and meat products (including animal fats and byproducts)	26	41	38	57	58	70
Milk and dairy products (in terms of milk)	172	251	307	316	314	330-340
Eggs (pieces)	60	124	159	216	239	260-266
Fish and fish products	7	12.6	15.4	16.8	17.6	19
Vegetable oil	2.7	7.1	6.8	7.8	8.8	13.2
Potatoes	241	142	130	120	109	110**
Vegetables and melons	51	72	82	89	97	126-135
Fruits and berries	11	28	35	39	38	66-70
Breads and cereal products	172	156	149	141	138	135**
Sugar***		34.2	38.8	40.9	42.2	45.5

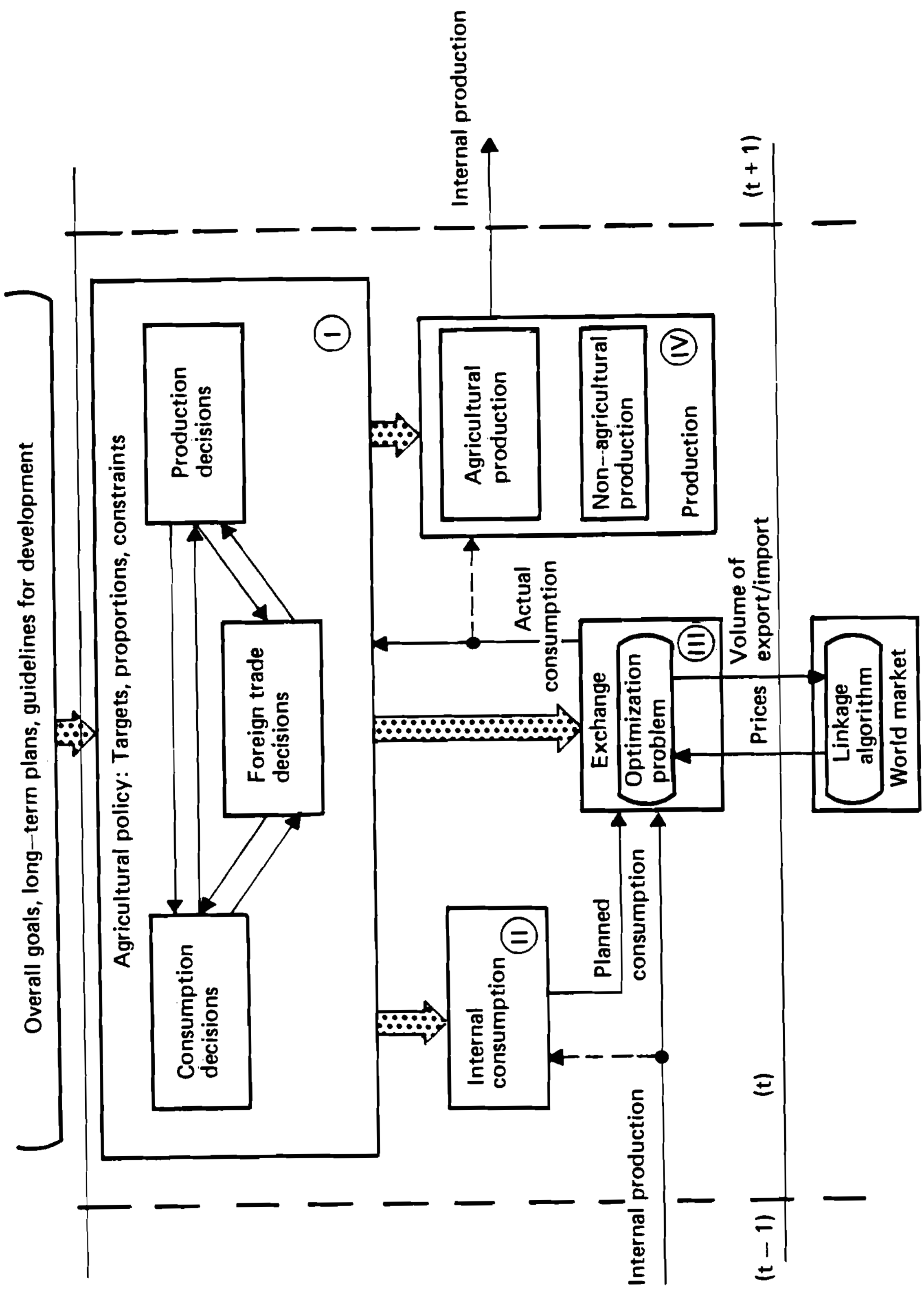
Source: N. A. Tikhonov, p. 180
* The USSR economy for the period 1922-1982, p. 73
** K. Bogolyubov, p. 113
*** The USSR economy in 1980, p. 405

Decisions concerning agricultural foreign trade determine the value of foreign trade turnover as a target and export revenue and import budget as constraints. Information on them have to be used in modules II, III and IV of the SOVAM (see double arrows on the scheme).

According to this information the planned consumption for each commodity is calculated in the consumption modules. These results as well as data on each commodity's internal production in the previous period (t-1) and the information concerning targets, proportions and constraints for agricultural foreign trade, are delivered to the exchange module. Within this module the corresponding optimization problem is solved at every stage of the iterative procedure of determining the equilibrium world market. In other words the SOVAM *will* react through the exchange module on changing world prices and deliver the data about its export/import volumes to the global system. When equilibrium is approached, the value of consumption corresponding to the equilibrium point is calculated with the exchange module and transmitted to blocks I and IV to make decisions on targets, constraints and proportions in all three blocks of the policy module. These decisions are inputs of the production module which works out the production volumes for the next period.

It should be noted that within the SOVAM the special submodule for calculation of a number of other endogenous variables is envisaged (it is not shown in Figure 1). These will include several general indicators such as general domestic product, investments, volume of fertilizers etc., and several sectorwise parameters such as feed, human consumption, acreage, yields and so on.

Figure 1: The SOVAM general structure and information flows



4. Consumption and exchange module

Let I be the index set of aggregated agricultural crops commodities; $i \varepsilon I$; J is the index set of aggregated livestock commodities, $j \varepsilon J$, and $I \cup J = I_a$, $|I_a| = n-1$.

According to the previous section, the targets $d^*(t) = (d^*_1(T),\ldots,d^*_{n-1}(t))^T$ for human consumption of commodities in year t are given exogenously. Here "T" stands for transposition. It is clear that

$$d^*(t) = \nu(t) \cdot N(t) \tag{1}$$

where: N (t) is population in year t given by some scenarios, $\nu(t) = (\nu_1(t),\ldots,\nu_{n-1}(t))^T$ is the vector of the per capita annual consumption values of which for the period under consideration can be calculated for example with the help of linear approximation:

$$\nu(t) = \begin{cases} \nu(o) + \dfrac{\nu(T) - \nu(o)}{T}\, t & , \ t < T, \\ \nu(T) & , \ t \geq T, \end{cases} \tag{2}$$

Here values of T, $\nu(o)$ and $\nu(T)$ are taken from national statistics and targets determined in the USSR Food Program (see Table 2 for observed changes of real per capita consumption of main staple foodstuffs in the Soviet Union for the period 1950 to 1980 and targets for 1990). These targets for 1990 were determined on the basis of scientifically developed standards. Hence it is reasonable to use these target values to fix $\nu(T)$ for T = 1990. The value of $\nu(o)$ can be taken for example equal to $\nu(1980)$.

According to the first stage of the SOVAM development, we suppose to implement exchange module as the following optimization problem:

$$(\hat{z}^+(t), \hat{z}^-(t)) = \underset{z,^+z^-}{\mathrm{Argmin}} \{\omega_1(t)\,[d^*(t) - d(t)]^T A(t)\,[d^*(t) - d(t)] + \omega_2(t)[I(t) - E(t)]\} \tag{3}$$

subject to:

Balance of commodities utilization

$$d(t) = \sigma(t)\, y(t-1) + z^-(t) - z^+(t) - w(t) \tag{4}$$

Balance of feeds and livestock commodities

$$d^T(t)\, \beta^k(t) - w^T(t) \cdot \gamma^k = 0, \qquad k = 1,2. \tag{5}$$

Value of agricultural export

$$E(t) = p^T(t) \cdot z^+(t) \geq R^+(t) \tag{6}$$

Value of agricultural import

$$I(t) = p^T(t) \cdot z^-(t) \leq R^-(t) \tag{7}$$

Low and upper bounds for volumes of export

$$\underline{z}^+(t) \leq z^+(t) \leq \bar{z}^+(t) \tag{8}$$

Low and upper bounds for volumes of import

$$\underline{z}^-(t) \leq z^-(t) \leq \bar{z}^-(t) \tag{9}$$

Weights $\omega_1(t)$ and $\omega_2(t)$ are given exogenously. Matrix A (t) describes the significance of commodities and their replaceability.

The volumes of internal production of crop and livestock commodities y(t) are determined in the production module. Components of

$z^+(t)$ and $z^-(t)$ are volumes of export and import of agricultural commodities;

d (t) are the calculated volumes of human consumption of commodities;

E (t) is revenue from export of agricultural commodities;

I (t) is expenditures for import of agricultural commodities;

$R^+(t), R^-(t)$ are correspondingly constraints on hard currency used for export and import.

Components of $\underline{z}(t)$, $\bar{z}(t)$ are low and upper constraints on volumes of export and import of commodities, for describing for example long-term trade agreements.

Coefficients $\beta^k(t)$ determine the amount of k-th substance needed to produce 1 unit of livestock commodity (k = 1 is related to feed units and k = 2 to protein) and coefficients γ^k shows the value of k-th substance in 1 unit of crop commodities.

The components of $\sigma(t)$ are shares of internal outputs used for human consumption.

Vector w(t) describes the consumption of the crop by livestock population. Therefore it has non zero components mainly for crop commodities.

Including of w(t) into the balance equation is very important for the determination of import values for crop commodities. In this version of the SOVAM exchange module, these values will be given exogenously according to different scenarios. There exists a number of proposals for the improvement of feed production in the Soviet Union. The description of some of these proposals one can find in Iakimets (1984), section 3.5. The abovementioned scenarios will correlate with them. There are two ways of constructing scenarios for w(t): by exogenously calculating the time series of w(t) corresponding to selected proposals for the whole period under consideration or by the following equation:

$$w(t) = c(t)\,[\sigma(t) \cdot y(t-1) + z^-(t) - z^+(t)] \tag{10}$$

and values of c(t) given exogenously are shares of crop commodities used to feed livestock.

The component of the vector $\hat{d}(t) = d(\hat{z}^+(t), \hat{z}^-(t))$ can be called "attainable consumptions". The above used optimality criterion is the simpliest one.

Strictly speaking the choice of the optimality criteria should be defined by decision makers. For instance taking into account assumption 3 one can use the following criterion:

$$\min_d F(d)$$

where

$$F(d) = \begin{cases} \max\limits_i \Delta_i(t) & ,\text{if } \Delta_i(t) \geq d_i^*(t) - d_i(t) \geq 0 \ ,i = 1,2,\ldots.n-1, \\ I(t) - E(t) & ,\text{if } \Delta_i(t) = 0. \end{cases}$$

5. Outline of the production module

In this section the short description of the agriculture production module is given. The two principally different approaches are considered. The first one is based on the assumption that international trade does not influence the structure of Soviet agriculture production. The second one assumes the existence of feedbacks between exchange and production modules. These feedbacks drastically increase the complexity of the model (both methodologically and technically). Presumably the latter approach will be used only in the final stage of the modelling.

The preliminary statistical analysis does not confirm the existence of any significant correlation between export-import data and data describing the structure of agriculture sector.

In what follows below only the first approach will be considered and its implementation on the basis of statistical approximation. Usually statistical methods can be appropriately used when some kind of "stability" is observed in data on the development of the object under investigation. In our case this stability really is confirmed both by statistical data and by analysis of structural development of the agricultural sector. At present for the production module the mixed regression-autoregression models are used:

$$y_t = F(\vartheta,t) + \Gamma y_{t-1} + \varepsilon_t , \tag{11}$$

where y_t is a vector the components of which correspond to volumes of production of different commodities, the vector $F(\vartheta, t)$ is a set of given functions, ϑ and Γ are matrices containing unknown parameters, t is time, the vectors ε_t describes the random errors.

Usually $F(\vartheta,t)$ approximates long-term trends, the second summond reflects the fluctuations with significant deterministic components, ε_t accumulates the random weather fluctuations and some nonsignificant factors, which for instance can not be approximated in a deterministic way because of lack of information.

It should be pointed out that vector y_t can contain a number component which corresponds to the same product. It happens when one needs to work with an autoregression of the second or higher order.

At present the random errors are suggested to be independent with zero means:

$$E\,[\varepsilon_t] = 0, \quad E[\varepsilon_t\, \varepsilon_{t'}^{T}] = \delta_{tt'}\, D \tag{12}$$

where $\delta_{tt'}$ is Kronecker's symbol and D is variance-convariance matrix.

The nonagriculture sector is modelled here independently of (11) with the help of traditional Cobb-Douglas function:

$$\ln y_{nt} = \varphi(t) + \vartheta_1 K(t) + \vartheta_2 L(t) + e_t, \tag{13}$$

where y_{nt} is the volume of nonagricultural production (only one product!) K(t) is capital, L(t) is labor force, $\varphi(t)$ reflects the technical progress, and e_t is a random value with zero mean and $E(e_t, e_{t'}) = \sigma^2\, \delta_{tt'}$. The main reason for the isolating of y_{nt} is the conjunction of the SOVAM with the FAP system of models.

The description of the SOVAM production module as an optimization model will be given in the next paper.

6. Summary

The general structure, information flows, outline of exchange and consumption module as well as production for the first stage of the SOVAM development were described in this paper. The next paper will contain the more detailed description of both modules and first results of estimation of corresponding functions parameters.

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