NOT FOR QUOTATION
WITHOUT PERMISSION
OF THE AUTHOR

FIRST VERSION OF THE SOVAM

V. Iakimets
V. Kiselev

September 1985
WP-85-60

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

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, Computer Center of the USSR Academy of Sciences, 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. Iakimets and V. Kiselev describe a first version of the SOVAM.

Kirit S. Parikh
Program Leader
Food and Agriculture Program.

ACKNOWLEDGMENT

Authors would like to address their gratitude to Academician A. Nikonov and Academician V. Nazarenko for supporting the work and providing the data needed for it. Helpful discussions with Dr. F. Ereshko and Prof. O. Kossov were very important. Our thanks also to Dr. V. Lebedev who has made fruitful contributions to the SOVAM from the beginning. We are very grateful to Cynthia Enzlberger for typing and retyping this manuscript.

ABSTRACT

This paper contains the formalized description of the main modules for the first version of the SOVAM, including production and exchange modules and outline for the policy module.

CONTENTS

FIRST VERSION OF THE SOVAM

V. Iakimets, V. Kiselev

1. Introduction

During the development of the Soviet national agricultural policy model (SOVAM) it was necessary to provide for meeting the requirements of the BLS at the same time to keep the adequacy of the description of the economy, actually existing controls and methods for their implementation, mechanism for generating shares and growth rates of the agricultural development and principle features of Soviet foreign trade. This paper contains first of all the description of the main features and tendencies of further development of the Soviet agriculture. The formalized description of the first version of the SOVAM and its modules based on this analysis is the main objective of the paper.

Background and requirements for the SOVAM as well as its general structure, information flows and the outline of consumption, exchange and production modules were described in Iakimets, 1984; Fedorov and Iakimets 1985.

2. Directions for the further development of Soviet agriculture

In order to model correctly the growth rates and proportions of the development of the USSR agriculture for the period of 15-20 years it is necessary to take into account the historically established tendencies and their future changes under the influence of the centralized measures carried out for the last years. For the period 1979-1982 some decrease in agricultural growth rates was observed in the USSR mainly due to extremely unfavorable weather conditions and shortcomings in economic mechanism. The important transformations in the national agro-industrial complex directed to considerable improvement of its functioning were laid down by May (1982) Plenum of the Central Committee of the CPSU. The system of interrelated measures formulated within the USSR Food Program and in a number of following government resolutions showed its efficiency already for the two first years of realization (1983, 1984).

The following three wide directions for the further improvement of the efficiency of agroindustrial production under current implementation can be characterized:

2.1. Improvement of the economic mechanism

This direction relates to:

- strengthening the influence of economic incentives in agriculture due to establishment of direct dependence of labour payment on final results;
- enhancing non-financing by the State;
- broadening the rights of collective and state farms in relation to their internal economic activity, utilization of material and technical resources and finances;
- integration of management on the level of interacting economic systems (creation of regional agro-industrial amalgamation) and on the more higher level (creation of management bodies for the planning and coordination of activity on the first level and for the allocation resources and investments).

2.2. Implementation of structural changes in agriculture

This direction includes:

- improvement of the structure of land under grain cultivation;
- deepening specialization of production in different natural and climatic zones;
- increasing the efficiency of mineral fertilizers and other chemicals utilization by means of improvement of their compound and structure and rational application with organic fertilizers;
- development and technical support of technologies for crop cultivation settled to weather fluctuations.

2.3. Implementation of structural changes in branches of production adjacent to agriculture

This direction relates to:

- improvement of quality of material and technical resources and services for agriculture;
- improvement of conditions for transportation, storage and primary processing of agricultural commodities;
- broadening the road construction in rural districts.

These measures are undertaken for stabilization of higher output of agricultural production to provide self-sufficiency in foodstuffs and for necessary level of internal consumption independently of world market.

It is easy to see that taking into account the abovementioned facts, the productivity of agricultural crops cannot be modelled only on the basis of indirect extrapolation of trends (Figure 1) but should be calculated taking into consideration the present changes observed.

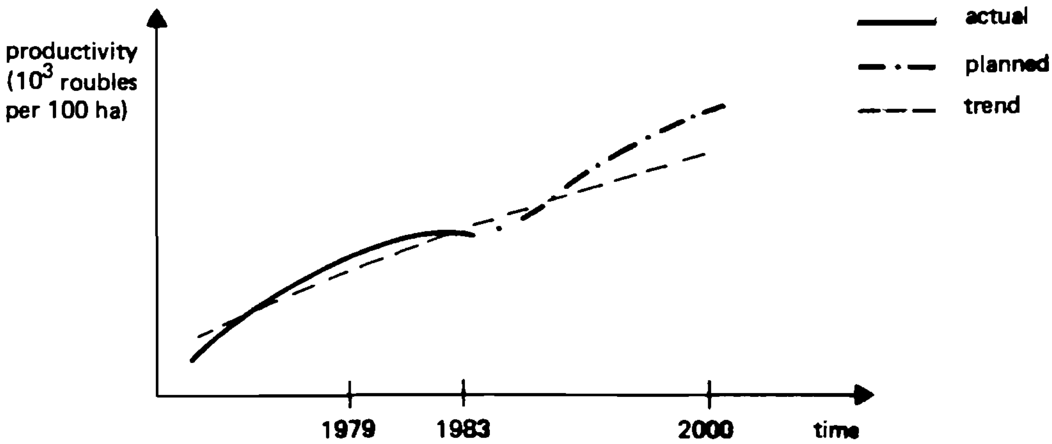

Figure 1. Productivity of agricultural crops.

These considerations have to be taken into account during the construction of the SOVAM.

3. Some peculiarities of macroeconomic modelling of the Soviet agricultural sector behaviour within the framework of the FAP system of models

As concerns to Soviet foreign trade of agricultural commodities this will be permanently developed mainly on the basis of assortment exchange and long-range bilateral agreements. It should be noted that practically it is impossible to take into account in the SOVAM because of accepted high level of aggregation (for example, for considerable turnover inside of such aggregated commodity as "other food" the total export-import balance can be equal to zero). The existing system of models catches only large-scale changes in trade of homogeneous commodities. Such changes in foreign trade flows can be evaluated for the Soviet Union only for grain and meat. However, in this case it is necessary also to take into account that USSR will seek to self-sufficiency of main agricultural products, to reduction of hard currency expenditures for purchases, and to lessening the dependence on external markets. It should be noted that availability of grain purchases by the Soviet Union during last years was caused by extremely unfavourable weather conditions in main grain producing regions.

1. Implementation of planned measures will allow not only to attain the necessary level of internal agricultural production but will provide for increasing the efficiency of production and capital investments utilization. It is the feature that to be reflected by national model. However, because there are not quantitative evaluations of efficiency production growth its implementation can be taken into consideration by some scenarios by means of adjustment of coefficients of elasticity of production functions. The more adequate way seems to be to see the speeded up growth of average crop productivity by years for the first 10 years period without considerable increase of investments.

The efficiency of utilization of early made investments and accumulated potential in this case will be also considered as more increased in comparison with beginning of 1980. Then the more strong relationship of agricultural productivity from mineral fertilizers applications and investments has to be used for the next period (in comparison with relationship found from correlation analysis). It is not expedient to use the labour and control variable for production modelling because the migration of labour between different branches of agriculture is a conservative process and does not depend on some control effects.

2. Within the framework of the SOVAM the following other ways of increasing production efficiency is logical to use (see Iakimets, 1984).

A. Changing the structure of acreage both for better utilization of bioclimatic potential of different regions and for better adaptation to requirements of population taking into account the tendencies of world market. It is expedient in this way to use as upper constraint for annual changes of acreage for several crops the value equaled approximately to 0.05 of acreage for previous year because of inertia of process of changing the existing specialization of regions.

B. Optimization of structure of allocation of annual increase of mineral fertilizers supply taking into account responses of different crops to fertilizers. This way will favour using the increase of fertilizers supply for elimination of bottlenecks in crop production.

C. Optimization of feed crops production by means of increasing roughage, succulent and green fodder, coarse grain production as well as increasing the protein feeds (such as cakes) production for improvement of livestock rations. In spite of approximation of this way description it's consideration will be useful for further elaboration of the model.

D. From the point of view of interaction of the SOVAM with the FAP system it is important to characterize the specifics of relationships of the Soviet Union with world market taking into consideration the orientation of the USSR on grain self-sufficiency. The world market was and will be in the future mainly the source for compensation of grain shortages in extremely unfavourable years. The volume of grain import will not be strongly dependent on prices of world market. More exactly the volumes of the USSR grain purchases will influence on those prices. Hence the more adequate to the reality will be the following concept for simulation of interaction of the SOVAM with world market model. Yield of agricultural crops will be determined as an average expected yield for achieved level of resources supply. At the same time the separate computer program will calculate correction factors simulating influence of weather fluctuations on grain output. Values of these factors as well as their time series for the period under consideration will reflect observed recurrence of unfavourable years and can be changed by means of scenarios. So basic calculated yield will monotone increase in accordance with trend and actual yield will be evaluated with the help of stochastic values. Such approach will allow to model the creation of stocks which will be replenished in favourable years and will be used in unfavourable ones. The volume of grain purchases on world market will be determined also taking into account internal demand, yield in dependence on weather conditions, stocks created in favourable years. At the same time the inverse influence of world market prices on the structure of purchases: in unfavourable years the volume of purchases can be more for low prices.

4. Formalized description of the main modules

Considerations given in previous sections determine the features of separate modules.

Annual levels of end consumption of separate commodities are generated on the basis of targets formulated in the USSR Food Program and these are considered as main targets. The required total annual volumes of internal consumption are calculated in the model taking into account in farms demand. The possible internal output is determined taking into consideration the internal capacity of economy and weather conditions. Difference between supply and demand is determined on the basis of these calculations and is used for determination of import volume. This value is used for linkage of the SOVAM with the BLS. At the same time the value of commodity deficit is used for analysis of the state economic strategy: whether to import the necessary volumes or to reduce consumption, or to increase investment in agriculture.

In the production module the maximally possible levels of consumption of separate goods close to given targets of consumption are dependent on various constraints (investments, fertilizers, acreage, etc.) and needed for this domestic output taking into account internal industrial consumption are determined. Crop outputs are determined dependent on acreage structure and projected yields which itself depend upon available resources and tendencies of development. Weather conditions and fertilizer distribution do not influence the acreage structure. However these have an effect on the volume of crop outputs. Such an influence is reflected by corresponding correction coefficient. As a result the conditionally actual crop output is determined which is used for distribution. In the case when this conditionally actual output is higher than projected internal consumption, the surpluses of commodities are directed to stocks. If not, then stocks are used to cover deficit. If the stocks available are not sufficient then the import of the commodity is requested.

Within the exchange module, the volumes of imports are calculated dependent on calculated deficit, world market prices and available hard currency. As a result, the corrected final consumptions of separate commodities are determined.

The policy module is intended for national accounting, calculation of values of general indicators and correction of corresponding policy parameters concerning production, consumption, investment policy, etc.

4.1. Consumption module

This module was described in Fedorov, Iakimets, 1985. The structure and volumes of each commodity planned consumption are calculated on the basis of fixed targets. Actual consumption will be calculated after results of production and exchange module simulation.

4.2. Production module

One important step for modeling agricultural production is the construction of adequate yield functions for various crops in relation to a number of production factors. Capital investments are one of such factors. However, investments have no direct influence on yield, but its influence is an indirect one through fixed capital stock. It is well known that crop yields are significantly dependent on the timeliness of carrying out the agrotechnological operations. Because many agricultural farms in the Soviet Union produce several commodities (5-10) then the general part of fixed capital stock influencing yields has to be considered for all these crops at the same time. The value of this part has of course a different impact on the yield of various crops. However it is difficult to single out the share of total fixed capital stock used for separate commodities. Therefore, it is reasonable:

(1) to consider the statistical relationship of yield of separate crops on the total fixed capital stock;

(2) to accept that future yield is dependent on the increment of fixed capital stock.

At the same time the yield of various crops is directly dependent on mineral fertilizer applied. In the USSR, the determined levels of saturation of yields from fertilizer application was achieved for rice and cotton and for some industrial crops. This level of application should be kept because the whole system of agrotechnology and machinery was adjusted to it. However, taking into account the differences between actual and normative efficiency of fertilizers for various crops, the optimal redistribution of incremental volume of produced fertilizers will be sought for during the simulation. It means that the value of the yield will depend on the increment of fertilizers used on the crops.

The other factor influencing the yield is technological progress in agriculture related for example to the selection of new varieties, production of new substances for plant protection, etc. Dynamics of the yield growth depends also on efficiency of economic incentives and mechanisms in agriculture. Both of these factors are poorly correlated with capital investments. However, to take into account its influence on yields, these can be treated as a function of time. Thus crop yield function $u_i(t)$ for i-th crop can be written as

$$u_i(t) = f_i\ (t,\ K_a(t),\ \Delta F_i(t)),$$

where $K_a(t)$ is the total fixed capital stock in agriculture and $\Delta F_i(t)$ is a commodity wise increment of fertilizers used.

As an example of the simple version of a yield function, the linear relationship such as

$$u_i(t) = u_{0i} + a_{1i} \cdot t + a_{2i} \cdot K_a(t) + a_{3i} \cdot \Delta F_i(t)$$

can be used.

Using the correlation models linear and nonlinear trends for separate crops were found.

Thus for rice the nonlinear trend was accepted as an appropriate one. At the same time for other grain crops the extrapolation of the yield growth was made on the basis of the linear trends mainly due to the fact that the opportunity for this growth was not yet exhausted.

The influence of separate factors on yield was estimated on the basis of the historical data, results of calculation by correlation models and with the help of expert estimates.* As an example, we can give the following estimated yield function for wheat:

$$u_1(t) = 1.68 + 0.0056 \cdot t + 0.002 \cdot K_a(t) + 3.5 \cdot \Delta F_1(t)$$

For rice the average yield according to trend for last years equals 4.1 ton per ha. Therefore we supposed that the further growth of it will be due to the agrotechnological improvement and the selection of new varieties or in other words it will be a function of time:

$$u_2(t) = 4.1 + 0.0079 \cdot t$$

The values of coefficients in these equations were statistically estimated. For all other crops we have also correspondingly estimated yield functions. With respect to livestock production the output is strongly dependent on feed available. In order to increase the utilization of the biological potential of the productivity of animals, improvement in feed mix should be made. This is the most important area, because other problems such as buildings for livestock, have in general been solved.

Taking into account the specifics of Soviet agricultural production and trade, the list of commodities considered were extended to 18, including:

(1) wheat	(2) rice
(3) coarse grain	(4) green feed
(5) protein feed	(6) vegetable oil
(7) sugarbeet	(8) vegetables
(9) potato	(10) fruits
(11) fibre crops	(12) bovine and ovine
(13) pork	(14) poultry meat
(15) dairy	(16) eggs
(17) wool	(18) non-agricultural commodity

For the exchange module of the SOVAM these commodities are aggregated to the BLS 10 commodity list.

The 18 commodities extended list is nevertheless also quite a high level of aggregation and the detailed controls in order to reflect the appropriate economic strategy of the State concerning the structural changes of the agricultural production, dependent on the level of deficit for separate commodities, are difficult to determined. Therefore we choose as the main controls such variables as:

(1) increment of fertilizer application for each crop,

(2) quantity of feed used for the production of each livestock commodity, and

* Thus, the contribution of mineral fertilizers to the yield growth was made using the data from Mesyats V.K., Planovoe Khozyaystwo, Vol. 4, 1983.

(3) crop acreage.

The acreages cannot be changed quickly because the changes of fixed capital stocks, farms' specialization should be followed to it. Therefore, the corresponding constraints on annually changing acreage ($\approx$ 0.5%) were used. Such small admissible deviations reflect the cautious approach to the results of optimization calculations mainly due to the fact that for aggregated commodities the average yield does not correspond to the actual efficiency of the crop. The constant constraint of total acreage was used because it was supposed that for the period under consideration their qualitative improvement on the basis of amelioration would be more important than area expansion.

All these preconditions were used to implement the production module as the optimization problem with the following economic content.

To find the commodity-wise final consumption (maximally close to targets), crop acreages, crop output, mineral fertilizer distribution, feed utilization and import subject to constraints on total acreage, total amount of fertilizers delivered to agriculture and trade balance and, taking into account balances of rational utilization of produced output, and balances of meeting the complete requirements of livestock with feeds according to standards under given output of livestock commodities. Let us give a formalized description of the production model.

Let us denote I index set of crop commodities ($i \in I$) and J - index set of livestock commodities ($j \in J$), $I \cup J = I_a$, $|I_a| = n-1$, $n = 18$.

The following data are used in this module:

Exogenously calculated

- $d^*_i(t)$ human consumption targets for crop commodities in year t;
- $d^*_j(t)$ the same for livestock commodities;;
- $A(t)$ the total acreage;
- $x_i(0)$ the acreage of i-th crop at the beginning of the period under consideration;
- a, ω_i, ω_j specifically determined weights.

Standards given exogenously

- $\beta_j^k(t)$ amount of k-th substance to produce 1 unit of j-th livestock commodity ($k = 1$ feed units, $k = 2$ protein)
- $\lambda_{ij}(t)$ maximum admissible share of i-th feed in livestock ration to produce j-th commodity.
- σ_i marginally possible percentage of annual change of acreage for i-th crop;
- $\Delta F(t)$ increase of mineral fertilizers supply;
- q_i crop yield increment due to additional fertilizer supply;
- ε_i^k nutrients content of i-th feed ($k = 1$ feed unit, $k = 2$ protein)
- δ_i, δ_j shares of internal output considered in balances.
- b_{j+1} and γ_{j+1} parameters determining shares of meat output and trade.

The model has the following control and intermediate variables:

- $d_i(t)$, $d_j(t)$ calculated actual human consumption of crop and livestock commodities;

- $z_i(t)$, $z_j(t)$ import of these commodities;
- $y_i(t)$,$y_j(t)$ output of these commodities;
- $w_i(t)$ volume of utilization of i-th crop commodity for feed;
- $\Delta F_i(t)$ increment of fertilizers application for i-th crop;
- $x_i(t)$ acreage for i-th crop

Within one year period of calculation (t) the problem is to find such values of control variables

$x_i(t)$, $w_i(t)$, $\Delta F_i(t)$, $z_i(t)$, $z_j(t)$

to minimize

$$[a \cdot \sum_i \omega_i (d_i^*(t) - d_i(t))^2 + (1 - a) \cdot \sum_j \omega_j (d_j^*(t) - d_j(t))^2] \qquad (1)$$

subject to:

A. Crop production

$$y_i(t) = x_i(t) \cdot u_i(t) \cdot \zeta_i(t) \qquad (2)$$

output of i-th crop, where

$$u_i(t) = \varphi_i(K_a(t), \Delta F_i(t))$$

yield production function for each crop written for example as

$$u_i(t) = u_{0i} + a_{1i} \cdot t + a_{2i} \cdot K_a(t) + a_{3i} \cdot \Delta F_i(t) \qquad (3)$$

The value of agricultural capital stocks is calculated in the policy module as follows:

$$K_a(t) = (1 - D_a(t-1)) \cdot K_a(t-1) + I_a(t-1), \qquad (4)$$

where $I_a(t-1)$ are investments into agricultural capital stocks and $D_a(t-1)$ is depreciation rate.

To reflect an impact of weather fluctuations on crops output the coefficient $\xi_i(t)$ is introduced. This coefficient shows the excess ($\xi_i(t)>1$) or the drop ($\xi_i(t) < 1$) of the expected crop output in comparison to theoretical one, calculated according to (3). Values of this coefficient for various crops can be elaborated on the basis of the analysis of historical meteorological data for the last 20-30 years showing the impact of weather fluctuations on crop yield and the correlation of outputs for different crops. The expected crop output therefore is

$$y_i(t) = \xi_i(t) \cdot y_i^T(t), \qquad (5)$$

where:

$$y_i^T(t) = u_i \cdot x_i(t)$$

is the theoretical crop output.

$$\sum_i \Delta F_i(t) \leq \Delta F(t) \qquad (6)$$

constraint on utilization of total fertilizers increase.

$$\sum_i x_i(t) = A(t) \quad \text{balance of acreages} \qquad (7)$$

$$(1 - \sigma_i)\, x_i(t-1) \leq x_i(t) \leq (1 + \sigma_i)\, x_i(t-1) \qquad (8)$$

constraint on change of structure of acreage.

B. Feed balances and livestock output.

$$\sum_j \beta_j^k \cdot y_j(t) - \sum_i \varepsilon_i^k w_i(t) = 0 \qquad (9)$$

balance of total feed utilization in feed units (k = 1) and in protein (k = 2).

$$\sum_j \lambda_{ij} \cdot \beta_j^k \cdot y_j(t) \geq \varepsilon_i^k \cdot w_i(t) \qquad (10)$$

balances of each type of feeds in feed units (k=1) and in protein (k=2).

$$y_j(t) - b_{j+1} \cdot y_{j+1}(t) \geq B_j \qquad \text{for } j = 12,13 \qquad (11)$$

structural constraints on domestic meat output.

C. Commodities utilization balances.

$$\delta_i \cdot y_i(t) = d_i(t) + w_i(t) - z_i(t) \qquad (12)$$

for crop commodities

$$\delta_j \cdot y_j(t) = d_j(t) - z_j(t) \qquad (13)$$

for livestock commodities.

D. Agricultural trade

$$\sum_i p_i(t-1) \cdot z_i(t) + \sum_j p_j(t-1) \cdot z_j(t) \leq R(t) \qquad (14)$$

constraint on hard currency utilization with $R(t)$ given exogenously and prices $p_i(t-1)$ and $p_j(t-1)$ taken from the BLS results of equilibrium simulation for the previous period.

$$z_j(t) \geq \gamma_{j+1} \cdot z_{j+1}(t) \qquad j = 12,13 \qquad (15)$$

structural constraint on trade of meat commodities.

Given model contains the nonlinearity because of (2). It can be solved by exogenous determination of discrete levels of the yield $u_i^q(t)$ coordinated with the required amounts of resources $K_a(t)$ and $\Delta F_i^q(t)$. Therefore the crop yield for the level q has a fixed value. Thus for the type of function as in (3):

$$u_i^q(t) = u_{0i} + a_{1i} \cdot t + a_{2i} \cdot K_a(t) + a_{3i} \cdot \Delta F_i^q(t).$$

Hence equation (2) can be rewritten as

$$y_i(t) = \sum_q x_i^q(t) \cdot u_i^q(t) \qquad (2a)$$

where $x_i^q(t)$ is acreage for i-th crop with q-th level of yield and corresponding levels of resources.

Because of possible deviations of values of calculated final consumption ($d_i(t)$ and $d_j(t)$) on targets ($d_i^*(t)$ and $d_j^*(t)$) the surplus of deficit of it is determined

$$\Delta d_i(t) = d_i^*(t) - d_i(t) \qquad (16)$$

$$\Delta d_j(t) = d_j^*(t) - d_j(t) \qquad (17)$$

The calculated values of outputs $y_i(t)$ and $y_j(t)$ are compared with exogenously given low bounds of it ($\underline{y_i}(t)$ and $\underline{y_j}(t)$). As a result the deficit or surplus of outputs is also determined:

$$\Delta y_i(t) = \underline{y}_i(t) - y_i(t) \tag{18}$$

$$\Delta y_j(t) = \underline{y}_j(t) - y_j(t) \tag{19}$$

It means that all balances used within the production model have to be changed.

If the calculated outputs are higher than these low bounds, then the surpluses will be used to eliminate consumption deficits (16) and to increase the stocks. If not then targets of consumption will be covered by stocks if these are enough or by additional imports if not.

Let us denote:

$s_i^0(t)$, $s_j^0(t)$ stocks of commodities at the beginning of year t,

$s_i^+(t)$, $s_j^+(t)$ replenishment of stocks,

$s_i^-(t)$, $s_j^-(t)$ depletion of stocks,

$\Psi_i(t)$, $\Psi_j(t)$ final deficit of commodity after complete meeting of consumption targets.

Then the equations for changes of stocks are

$$s_i^0(t) = s_i^0(t-1) + s_i^+(t-1) - s_i^-(t-1) \tag{20}$$

$$s_j^0(t) = s_j^0(t-1) + s_j^+(t-1) - s_j^-(t-1) \tag{21}$$

and final deficits are calculated as follows

$$\Psi_i(t) = \Delta y_i(t) - \Delta d_i(t) \tag{22}$$

$$\Psi_j(t) = \Delta y_j(t) - \Delta d_j(t) \tag{23}$$

If $\Psi_i(t)$, or $\Psi_j(t)$ are positive (surplus of outputs) then the stocks will be replenished:

$$s_i^+(t) = \Psi_i(t) \tag{24}$$

$$s_j^+(t) = \Psi_j(t) \tag{25}$$

If these are negative, then deficit of consumption will be covered by stocks when these are available:

$$\Psi_i(t) = s_i^-(t) = 0 \quad , \qquad s_i^-(t) \le s_i^0(t) \tag{26}$$

$$\Psi_j(t) = s_j^-(t) = 0 \quad , \qquad s_j^-(t) \le s_j^0(t) \tag{27}$$

If the stocks do not cover the deficit, then request for import is determined:

$$\hat{z}_i(t) = \Psi_i(t) + s_i^-(t) \quad , \qquad s_i^-(t) = s_i^0(t) \tag{28}$$

$$\hat{z}_j(t) = \Psi_j(t) + s_j^-(t) \quad , \qquad s_j^-(t) = s_j^0(t) \tag{29}$$

When these new values of imports are rewritten for the BLS commodities list the model is ready for exchange through world market.

4.3. The Exchange Module

After aggregating expected imports for the SOVAM detailed list of commodities are calculated using the prices of the previous year to the imports for the BLS list within the exchange module through the linkage procedure, the new values of imports are sought for using the data on hard currency available for this.

As mentioned earlier, in Soviet agricultural trade annual values of import and export are determined mainly on the basis of bilateral and multilateral agreements about the assortment exchange or by payment with industrial goods for such agricultural commodities as tropical fruits, tea, coffee, cocoa, etc., to improve and diversify the structure of ration for people. In respect to main staple foods, the attainment of self-sufficiency is planned in the nearest future and the world market will be used for compensation of the drop in domestic output induced by unfavourable weather conditions.

Within this module, the imports are determined by requested imports $\hat{z}_i(t)$, $\hat{z}_j(t)$, calculated in the production module, available hard currency $R(t)$, and equilibrium market prices of the year under simulation $p_i(t)$, $p_j(t)$.

In the exchange module the problem such as the following one is supposed to be solved:

Find values of imports $\bar{z}_i(t)$, $\bar{z}_j(t)$ to minimize

$$\sum_i \rho_i(\hat{z}_i(t) - \bar{z}_i(t))^2 + \sum_j \rho_j(\hat{z}_j(t) - \bar{z}_j(t))^2 \quad (30)$$

subject to

$$\sum_i p_i(t) \cdot \bar{z}_i(t) + \sum_j p_j(t) \cdot \bar{z}_j(t) \leq R(t) \quad (31)$$

4.4. Outline of the Policy Module

This module allows to analyse the solution of previous problem and tendencies of national economic development in order to adjust determined control parameters. Decision making has to be made from the point of view of the whole economy interests. Therefore this module is aimed to evaluate the influence of agricultural development on the national economy. In particular it has to be done from the point of view of comparison of agricultural growth rate with nonagriculture one for various allocation of investments.

$$I(t) = I_a(t) + I_n(t) \quad (32)$$

allocation of investments.

$$K_n(t) = K_n(t-1)\,(1 - D_n(t-1)) + I_n(t-1) \quad (33)$$

increase of capital stocks in nonagriculture (the same for agriculture).

$$IN_a(t) = \sum_i \pi_i(t)\, y_i(t) + \sum_j \pi_j(t) \cdot y_j(t) \quad (34)$$

national income in agriculture.

$$INN(t) = a_0(t)\, K_n(t)^{a_1} \cdot L_n(t)^{1-a_1} \quad (35)$$

national income in nonagriculture with labour forces $L_n(t)$ given exogenously.

$$INN(t) = (1 + \Delta(t))\, INN(t-1) \quad (36)$$

condition for non decreasing of national income in agriculture.

$$IN(t) = INA(t) + INN(t) \quad (37)$$

total national income.

$$I(t) = IN(t-1) \cdot \alpha \quad (38)$$

investment in the whole economy.

Some additional notations introduced in this section include:

$\pi_{i(j)}(t)$ is increase of national income due to one unit of i-th (j-th) agricultural commodity production; and Δ is the growth rate of national income in nonagriculture.

The determination of values of $\pi_i(t)$ and $\pi_j(t)$ was the difficult problem. Application of the regression analysis techniques to construct equation connecting agricultural national income with changing outputs of different commodities did not yield the appropriate result.

Therefore the attempt was made to estimate the gross agricultural output (G (t)) on the basis of average national wholesale prices $(\bar{p}_i(t), \bar{p}_j(t))$ and then to use it to find correlation relationship with agricultural national income. Results of estimations based on data for the period 1970-1980 yield the following equation:

$$IN_a(t) = 42 + 0.22 \cdot G(t) \tag{39}$$

Finally

$$IN_a(t) = 42 + 0.22 \left(\sum_i \bar{p}_i(t) \cdot y_i(t) + \sum_j \bar{p}_j(t) \cdot y_j(t)\right) \tag{40}$$

5. Conclusion

In this paper the first version of the SOVAM was described to give general ideas about its structure, commodity lists and separate modules.

References

Iakimets, V. (1984). Background and Requirements for the SOVAM: Soviet Agricultural Model, IIASA, Laxenburg.

Fedorov, V., and V. Iakimets (1985). Outline of the SOVAM, IIASA, Laxenburg, (forthcoming).