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SOVSIM: A Model of The Soviet Economy

A Research Paper

ER 79-10001
February 1979

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Director for Public Affairs
Central Intelligence Agency
Washington D.C.,20505
(703) 351-7676

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Preface

Econometric models have become conventional tools for analyzing Western economies during the past decade. They provide a convenient mechanism for looking at the interactions of many factors simultaneously and for studying the potential impacts of policies and economic events on the path the economy is expected to follow.

The use of models in the study of centrally planned economies (CPEs) has lagged behind Western applications, however. Western models are essentially descriptions of the structure and sources of demand, which in turn determine the levels of production, employment, and prices. Little of the understanding of the economic structure gained from Western modeling research can be transferred to the description of supply-oriented CPEs, where resources are more or less fully employed and use is determined by both availabilities and relative priorities.

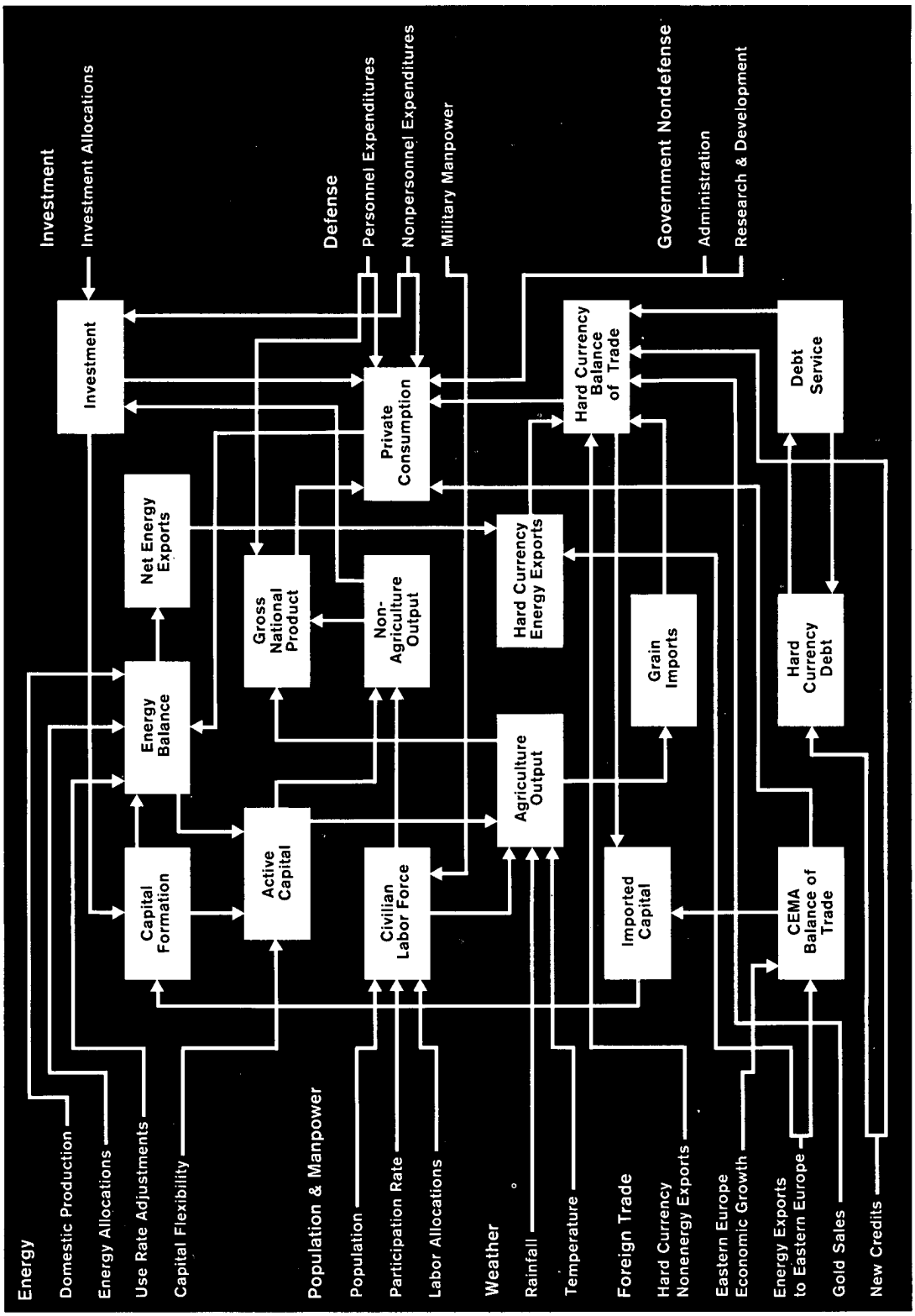
SOVSIM is the outgrowth of a continuing effort to develop a model of the Soviet economy. The structure of SOVSIM reflects the fundamental production focus of a CPE. Capacity of the capital goods industries determines investment, which in turn establishes the pattern of growth in the stock of productive capital. Demographically determined employment together with the capital stock set the achievable level of production. This output is then divided among competing uses based on availabilities and relative priorities, with private consumption generally taken as the residual claimant.

The primary purpose of SOVSIM is to support studies of growth prospects for the Soviet economy, especially the influence that certain constraints on the supply side could have on these prospects over the next decade. Consequently, the structure of the model is designed to accommodate analysis of the impact of policy shifts and contingent events in areas like labor supply, energy, investment, and foreign trade.

This paper describes the present version of SOVSIM. The first section discusses the structure of the model in general and schematic terms. The second section reviews the performance properties of the model in historical simulations, and the third looks at the model as a short-run forecasting tool. The fourth section illustrates the use of the model in impact analysis of Soviet growth prospects to 1985, and the final section gives a preliminary assessment of our research. We have also included appendixes detailing the model's structure and listing all of the variables.

Figure 1

General Flow Diagram of the Soviet Economic Model



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SOVSIM: A Model of The Soviet Economy

A General Overview of SOVSIM

SOVSIM is an annual model consisting of 207 equations connecting a like number of endogenous variables with 67 exogenous variables. Thirty-five of the equations involve econometric estimates of parameters; 90 of them use nonstatistical procedures to estimate structural parameters and 82 are accounting identities.

The general structure of the Soviet model is shown in figure 1. Since SOVSIM is basically supply driven, most of the model is devoted to describing resource availabilities and production relationships. This includes the effects of (a) investment on capital formation, (b) labor and capital on output, and (c) energy on capital utilization and foreign trade. A much smaller portion of the model is devoted to estimating the components of demand other than investment.

Model Variables

All projections from the model are conditioned by assumptions regarding six groups of external or exogenous variables:

- *Energy.* These variables include projected gross outputs of fuels and electric power, the energy allocation policy, and the capital flexibilities for each producing sector.

- *Population and Manpower.* Projections of the able-bodied population and the number of pensioners are inputs to the model. Participation rates and employment rates, as well as the distribution of employment by sector, must also be established using outside information or by assumption.

- *Weather.* Weather conditions are defined by indexes of precipitation and temperature.

- *Foreign Trade.* Nonfuel exports to the West depend primarily on external economic conditions and are an input to the model. Energy exports to Eastern Europe are considered a function of both political and economic factors and are therefore set outside the model. Gold sales, arms sales, and new credit drawings also fall in this category.

- *Investment.* The allocation of available investment resources among competing uses is set by policy decision.

- *Government Spending.* This group includes the level of personnel and the growth rate in nonpersonnel expenditures for defense, and the shares of administration and research and development in gross national product.

The model can be used to project seven groups of economic variables—the model's endogenous variables:

- *Production.* Outputs of 13 producing sectors are computed in terms of value added and then are summed to obtain GNP.

- *Consumption.* Separate calculations are made for four categories of public consumption: administration and R&D, which are scaled as fixed shares of GNP; nonpersonnel defense expenditures, which are computed from an exogenous growth rate; and personnel defense expenditures, which are the product of assumed manpower and imputed wage rates. Private consumption is determined as the residual claimant on output after deductions are made for public consumption, investment, and foreign trade.

- *Investment.* The model computes investment in each of the 13 producing sectors plus housing and capital repair.

- *Capital Formation.* New additions to the stock of productive capital, retirements, and the gross stock of productive capital are estimated for each producing sector.

- *Energy.* Nominal requirements and actual deliveries of fuels and electric power are computed for each producing sector. Utilization rates of capital and hence the effective or active capital stock are also estimated.

• *Employment.* This group includes the civilian labor force and the level of employment in each sector.

• *Trade.* Exports and imports are calculated separately for trade with Communist, hard currency, and other countries. Debt, debt service, grain imports, and net exports of fuels are for hard currency also estimated within the model.

Model Structure in Condensed Form

The structure of SOVSIM has been condensed into a set of 19 equations to facilitate discussion of the functional relationships among model variables (see figure 2). The variables and parameters appearing in these equations are also defined in figure 2. This way of reviewing the model focuses on the primary endogenous linkages; the full specifications of the model equations are given in appendix A. The model variables are listed in appendix B:

• *Production.* There are constant-returns-to-scale Cobb-Douglas production functions for each nonenergy producing sector (equation 1). Value added in the energy sectors is scaled from gross output, which is exogenous for these sectors. GNP is obtained by summing value added in the 13 producing sectors (equation 2).

• *Consumption.* Government expenditures (equation 3) include exogenous defense spending and an endogenous component scaled from the level of GNP. Private consumption (equation 4) is calculated as the residual claimant of GNP.

• *Investment.* The supply of capital goods available for domestic investment is the residual of deliveries of machinery and construction output to final demand, after deductions are made for deliveries to defense, exports, consumption, and capital repair (equation 5). Equation 6 distributes new fixed investment to each producing sector and housing with shares set outside the model.

• *Capital Formation.* Net additions to the productive capital stock are estimated from past investment and assumed depreciation rates (equation 7). Identity equations then link capital stock to the previous year's capital stock and net capital formation (equation 8).

• *Employment.* The labor force is estimated from the able-bodied population and participation rates (equation 9). Total employment (equation 10) depends on the labor force and employment rates, and sector employment levels (equation 11) follow from the total employment and labor allocation shares.

• *Energy.* Equation 12 estimates nominal demands for oil, gas, coal, and electric power in each consuming sector from the capital stock and energy-use coefficients tied to the capital stock of the given sector. Actual deliveries (equation 13) are determined by a combination of nominal requirements and assumed allocation policy. Equation 14 calculates domestic energy residuals by subtracting domestic deliveries from gross domestic output. Depending on its sign, the residual indicates either a capacity for net exports or a need for net imports. Equation 15 calculates the fraction of sector energy requirements, in terms of standard fuel units, actually met by deliveries. Together with an elasticity of active capital with respect to energy input, this fraction determines the rate of capital utilization and thus the active capital stock in each sector (equation 16). Any shortfall in meeting nominal domestic requirements for energy leads to a reduction in capital utilization. The degree of reduction for a given shortfall varies by sector depending on the value of the capital elasticity and the relative contribution of the type of energy in short supply to the particular sector's energy consumption.

• *Foreign Trade.* Net exports of fuels to hard currency countries (equation 17) are the difference between the domestic energy residuals and exogenous net exports to Communist and other countries. Net exports of fuels to hard currency countries, along with other variables that represent sources of hard currency, feed into a calculation of the hard currency import capacity (equation 18), which in turn drives imports from hard currency countries (equation 19). If these imports fall below a specified floor, domestic energy use is reduced by reducing e_{ij} and energy exports are increased (or energy imports are reduced) until sufficient import capacity exists to meet the import minimum.

Energy

12. $E_{i,j} = K_i \times d_{i,j}$
13. $\bar{E}_{i,j} = E_{i,j} \times e_{i,j}$
14. $R_j = Q_j - \sum_i \bar{E}_{i,j} - \bar{E}_{fd,j}$
15. $D_i = (\sum_j \bar{E}_{i,j} \times h_j) / (\sum_j E_{i,j} \times h_j)$
16. $\bar{K}_i = K_i \times (1 - g_i \times (1 - D_i))$

Foreign Trade

17. $EH_j = R_j - EC_j$
18. $MH_c = \sum_j EH_j + T$
19. $MH = f(MH_c, \overline{MH})$

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N_i	Employment in sector i
POP	Able-bodied population
Q_j	Gross output of energy type j
R_j	Residual of domestic production of energy type j after deduction for domestic deliveries
R_k	Capital repair
T	Net earnings of hard currency (other than through trade in fuels) and net credit drawings
X_i	Value added in sector i
X_k	Value added in machinery and construction sectors

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ect to

:rgy type j

p	Participation rate
r_i	Depreciation rate of capital in sector i
t	Share of output devoted to administration and research and development.

Figure 2
Condensed Model Structure

A. Equations

Production

1. $X_i = f(\bar{K}_i, N_i)$
2. $GNP = \sum_i X_i$

Consumption

3. $G = t \times GNP + DF$
4. $C = GNP - I - G - (Ex - M)$

Investment

5. $I = a \times X_k - C_k - G_k - Ex_k - R_k$
6. $I_i = b_i \times I$

Capital Formation

7. $KF_i = f(I_i, I(-1)_i, r_i)$
8. $K_i = K_i(-1) + KF_i(-1)$

Employment

9. $LF = p \times POP$
10. $N = er \times LF$
11. $N_i = c_i \times N$

Energy

12. $E_{i,j} = K_i \times d_{i,j}$
13. $\bar{E}_{i,j} = E_{i,j} \times e_{i,j}$
14. $R_j = Q_j - \sum_i \bar{E}_{i,j} - \bar{E}_{fd,j}$
15. $D_i = (\sum_j \bar{E}_{i,j} \times h_j) / (\sum_j E_{i,j} \times h_j)$
16. $\bar{K}_i = K_i \times (1 - g_i \times (1 - D_i))$

Foreign Trade

17. $EH_j = R_j - EC_j$
18. $MH_c = \sum_j EH_j + T$
19. $MH = f(MH_c, \overline{MH})$

B. Variables

C	Private consumption	G	Government expenditures	N_i	Employment in sector i
C_k	Expenditures on consumer durables	G_k	Defense expenditures on capital goods	POP	Able-bodied population
D_i	Deliveries of fuels and power to sector i as a percent of nominal requirements	GNP	Gross national product	Q_j	Gross output of energy type j
DF	Defense spending	I	Total investment	R_j	Residual of domestic production of energy type j after deduction for domestic deliveries
E_{ij}	Nominal requirements of energy type j in sector i	I_i	Investment in sector i	R_k	Capital repair
$\bar{E}_{ij}$	Deliveries of energy type j to sector i	K_i	Nominal capital stock in sector i	T	Net earnings of hard currency (other than through trade in fuels) and net credit drawings
$\bar{E}_{fdj}$	Deliveries of energy type j to final demand	$\bar{K}_i$	Active capital stock in sector i	X_i	Value added in sector i
EC_j	Net exports of energy type j to Communist and other countries	KF_i	Net capital formation in sector i	X_k	Value added in machinery and construction sectors
EH_j	Net exports of energy type j to hard currency countries	LF	Civilian labor force		
Ex	Exports	M	Imports		
Ex_k	Machinery exports	MH	Imports from hard currency countries		
		$\overline{MH}$	Minimum imports from hard currency countries		
		MH_c	Hard currency import capacity		
		N	Total employment		

C. Parameters

a	Ratio of deliveries to final demand of machinery and construction to value added in these sectors	e_{ij}	Deliveries of energy type j to sector i as a percent of nominal requirements	p	Participation rate
b_i	Share of total investment going to sector i	er	Employment rate	r_i	Depreciation rate of capital in sector i
c_i	Share of total employment in sector i	g_i	Elasticity of active capital with respect to input of energy in sector i	t	Share of output devoted to administration and research and development.
d_{ij}	Input of energy type j per unit of capital in sector i	h_j	Units of standard fuel per unit of energy type j		

Data Sources

The empirical relations in SOVSIM were estimated using a data base covering 1960-77. While some data series covering the 1950s were available, the 1960-77 period was the longest for which a consistent data set could be compiled. Data sources included official statistical publications of the USSR, national income accounts estimated by the Office of Economic Research (OER), and input-output tables reconstructed by the Foreign Demographic Analysis Division (FDAD) of the US Department of Commerce.

Output in the *Production Block* was described by sector-of-origin valued-added indexes of Soviet GNP accounts developed by OER. The corresponding OER estimates of GNP end-use accounts were the primary basis for estimating the *Consumption Block*.

Data for total investment, new fixed investment, net additions to livestock and capital repair in the *Investment Block* came from OER end-use accounts for GNP. In addition, various issues of the official Soviet economic handbook—*Narodnoye Khozyastvo SSSR (Narkhoz)*—were the source of the sector investment used to establish sector shares in new fixed investments. Capital stock data for the *Capital Formation Block* came from OER indexes of the fixed capital stock of the USSR. Estimates of imported capital were compiled by Green and Levine [1] and depreciation rates were estimated by Green.[2]

The *Energy Block* uses a combination of time series and intersectoral transactions data. Production figures for fuels and power were taken from the *Narkhoz*, and the amount of fuels in foreign trade from the official Soviet foreign trade handbook. Sector shares in the allocation of fuels and power available for domestic use were estimated for 1972 from a preliminary reconstruction of the 1972 Soviet input-output table in producers' prices. These figures for 1972, along with estimates of apparent consumption (gross production minus net exports) and sector capital stock for all years, were used to estimate changes in the allocation pattern over time.

[1] See Donald W. Green and Herbert S. Levine, "Soviet Machinery Imports," *Survey*, Spring 1977-78, p. 114.

[2] See Donald W. Green, "Capital Formation in the USSR, 1959-74," *Review of Economics and Statistics*, February 1978, p. 40.

Data for the *Employment Block* came primarily from FDAD projections and compilations.[3] The official Soviet foreign trade handbook was the major source of trade data for the *Foreign Trade Block* and OER estimates were used for hard currency debt and drawdowns of credit.

Model Comparisons

As a model of a centrally planned economy, SOVSIM bears little resemblance to conventional econometric models of Western economies. The impressive econometric research effort in the West has focused on giving empirical content to an essentially Keynesian view of Western macroeconomies. This means giving great attention to the determination of the structure and level of effective demand and little concern for real constraints on growth.

Obviously, the latter issue—real constraints on growth—is the core of any analysis of Soviet growth prospects. This requires giving much greater attention to descriptions of production and resource availability than to competing uses for the output produced. This was true of the earliest efforts by Niwa [4] to construct a very small model of the Soviet economy and continues with both SOVSIM and the SOVMOD series of large-scale econometric models developed by the combined efforts of SRI International and the Wharton Econometric Forecasting Associates (SRI-WEFA). [5]

Both SOVSIM and SOVMOD are driven by a series of sector production functions. Each uses Cobb-Douglas specifications rather than more complex forms because the statistical basis for rejecting the simpler form is, at best, weak at the sectoral level. In other areas, though, the specifications differ in critical ways.

[3] See Stephen Rapawy, *Estimates and Projections of the Labor Force and Civilian Employment in the USSR: 1950-1990*, Foreign Economic Report No. 10, September 1976.

[4] Haruki Niwa, "An Econometric Analysis and Forecast of Soviet Economic Growth" in P. J. Wiles, *The Prediction of Communist Economic Performance* (Cambridge, 1977).

[5] The original model is given in Donald W. Green and Christopher I. Higgins, *SOVMOD I: A Macroeconometric Model of the Soviet Union* (Academic Press, 1977). Later versions of SOVMOD have been described in working papers published by SRI-WEFA.

Most of these specification differences reflect a difference in the fundamental analytical objectives and assumptions underlying the development of the models. The SRI-WEFA research has assumed that any regularities in the decisions of planners that could be isolated from historical data were a preferred basis for projecting Soviet growth prospects. Consequently in certain parts of SOVMOD, important roles are played by estimated trade-offs between alternate patterns of resource use, based on indexes of planners' behavior. The SOVSIM research has focused, instead, on the roles that resource constraints play in shaping the pattern of Soviet growth and has assumed that past trade-off responses of the planners are not necessarily the preferred basis for judging the future. As a result, the specification of SOVSIM generally has less behavioral content but more effectively takes resource availabilities into account in projecting Soviet growth.

These differences are especially pronounced in four areas:

• *Investment.* SOVSIM constrains current new fixed investment to equal the available output of the machinery and construction sectors and allocates it among sectors by share trends, or shares determined exogenously. The SRI-WEFA approach looks at investment from a behavioral perspective that tries to link realized investment with resource competition with defense, but does not limit realized investment to the investment that could be carried out with the resources available.

• *Energy.* SOVSIM was developed to examine the effects of shifts in resource supplies, especially energy resources, on growth potential. The SOVSIM specification, therefore, gives explicit consideration to sector demands for energy and links energy supplies to both domestic production and foreign trade possibilities. This integration of energy into the model is missing in SOVMOD.

• *Foreign Trade.* Soviet imports from the West depend on Soviet hard currency import capacity, which in turn is limited by Western credits and hard currency export earnings. The SOVSIM specification, by explicitly linking Western imports to import capacity, import capacity to fuel exports, and fuel exports to a set of overall fuel balances, more fully integrates trade into Soviet growth analysis.

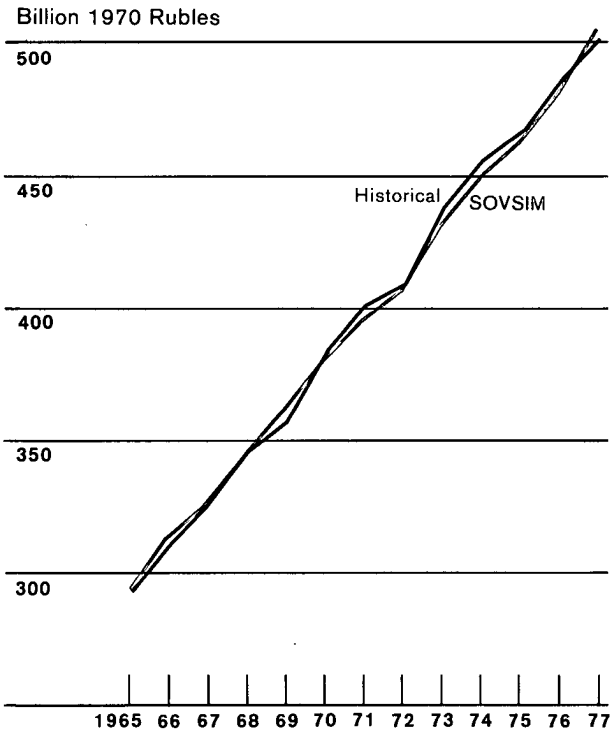
• *Employment.* The SOVSIM specification of employment is essentially an accounting framework based on outside projections of population, participation rates, and sector employment shares. The SRI-WEFA specification is a much more ambitious attempt to estimate the influences on urban-rural migration and the impact this process has on overall employment. It fails, however, to impose realistic upper bounds on Soviet participation rates, which are already the highest in the industrialized world. Under certain conditions, this can lead to an upward bias in long-term growth analysis.

SOVSIM is then much more eclectic than conventional econometric models, even of the Soviet Union. It tries to deal with the real constraints on Soviet growth while reflecting the rather underdeveloped theoretical understanding of the process of central planning and the behavior of the planners who shape it.

Historical Error Analysis, 1965-77

One measure of the performance of an econometric model is its ability to reproduce the historical (observed) growth pattern of key variables. This test, however, assumes knowledge of some data—such as nonfuel exports to the West, weather indexes, and defense spending—not available in making a forecast. Moreover, future structural changes could alter underlying functional relationships. Historical error analysis should therefore be considered only in conjunction with other tests in establishing the usefulness of SOVSIM in the analysis of Soviet growth potential.

SOVSIM: Simulation of GNP **Figure 3**



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General Tracking Record

The historical and simulated paths of GNP growth in 1965-77 are compared in figure 3. The model projections follow the historical record very closely, never deviating by more than 1.5 percent from the official figures. A more demanding comparison is that between actual and projected growth rates (table 1).

The projected growth rates are reasonably close to historical figures—the correlation coefficient between them is 0.54—and the direction of year-to-year changes is correctly projected in 10 out of 12 cases.

Private consumption and new fixed investment are shown in figures 4 and 5. Both figures again show a close match, but the simulation errors in a given year are in opposite directions. This reflects the model's specification of private consumption as the residual claimant on GNP. Since GNP is simulated with little error, when investment is overestimated, consumption as the residual use of GNP must be underestimated and vice versa. Nonetheless, the projection error in neither variable seems to be biased since the projections are not consistently above or below actual values.

Table 1

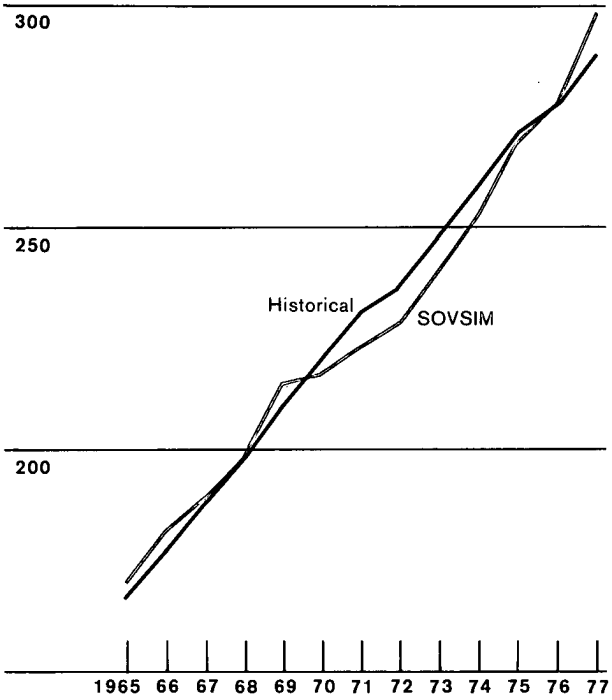
USSR: Comparison of Actual and Projected GNP Growth

	Actual [1]	Projected
1965	6.8	7.6
1966	6.4	7.0
1967	5.2	4.0
1968	6.1	5.8
1969	3.0	4.9
1970	7.7	5.2
1971	4.5	3.9
1972	1.9	2.7
1973	7.2	6.3
1974	4.1	9.1
1975	2.2	2.8
1976	4.0	4.0
1977	3.6	5.1

[1] OER estimates.

The value of net exports of oil, gas, and coal to hard currency trading partners is a key foreign trade variable calculated in the model. Since these exports are estimated as residuals in the fuels balance equations, while gross production of fuels and exports to other countries are exogenous, the ability of the model to track hard currency fuel exports depends on the ability to project domestic use of fuels. Figure 6 shows that the model accurately tracks the value of hard currency fuel exports, including the rapid acceleration that occurred after 1973. This indicates the general validity of the underlying energy balance computations in the model.

SOVSIM: Simulation of Private Consumption **Figure 4**



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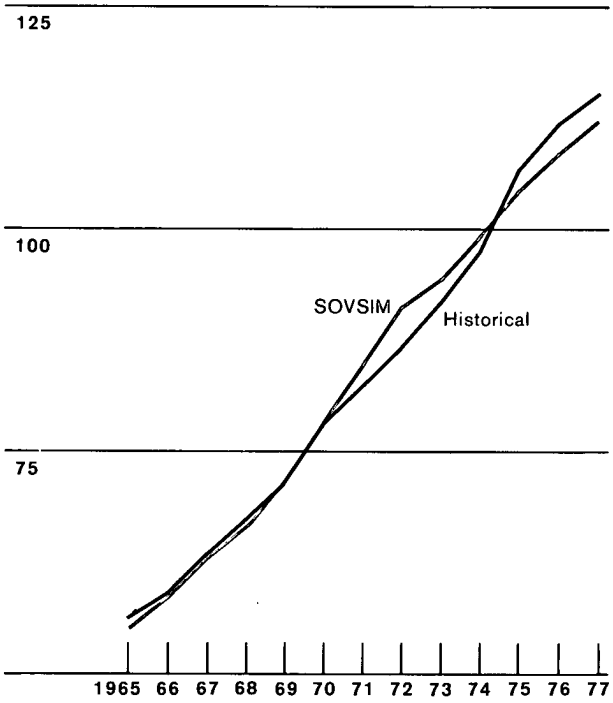
SOVSIM: Simulation of New Fixed Investment **Figure 5**



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The dominant variable feeding into the calculation of net exports of fuels to hard currency countries is net exports of oil. The results depicted in figure 7 show that the changing Soviet capacity to export oil to the West was captured by the model, although the historical shift was sharper than the simulations indicated. Nonetheless, there is no particular bias in the projection errors over the full period.

Average Errors for Key Variables

The model's ability to replicate history can be best measured by computing average simulation errors for 1965-77. No single error index can describe the predictive power of the model reliably. Three conventional indexes, however, taken together give a rounded picture of how well the model projections match the historical data:

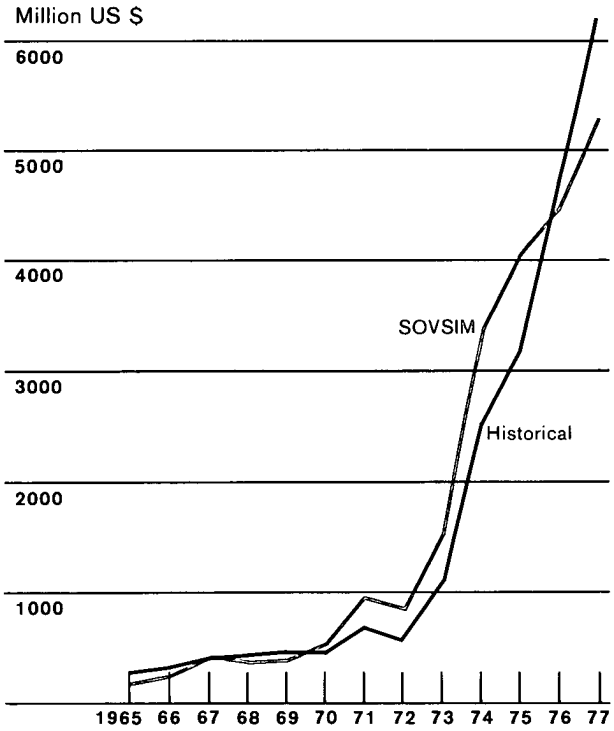
- *Mean Percentage Error (MPE)* [6]—The MPE will be smaller to the degree that annual or individual errors are of opposite signs and therefore offsetting.

- *Mean Absolute Percentage Error (MAPE)* [7]—This error index is useful because it counts individual errors without regard to their signs and therefore does not allow for offsetting effects. If the absolute value of the MPE is close to the MAPE value and annual percentage errors are generally of similar size, annual errors tend to be of the same sign, perhaps signifying some built-in model bias.

[6] $$\text{MPE} = \frac{1}{N} \sum_t \frac{(\text{Estimated} - \text{Actual}) \times 100}{\text{Actual}}$$

[7] $$\text{MAPE} = \frac{1}{N} \sum_t \frac{|\text{Estimated} - \text{Actual}| \times 100}{\text{Actual}}$$

SOVSIM: Simulation of Net Exports of Fuel for Hard Currency **Figure 6**



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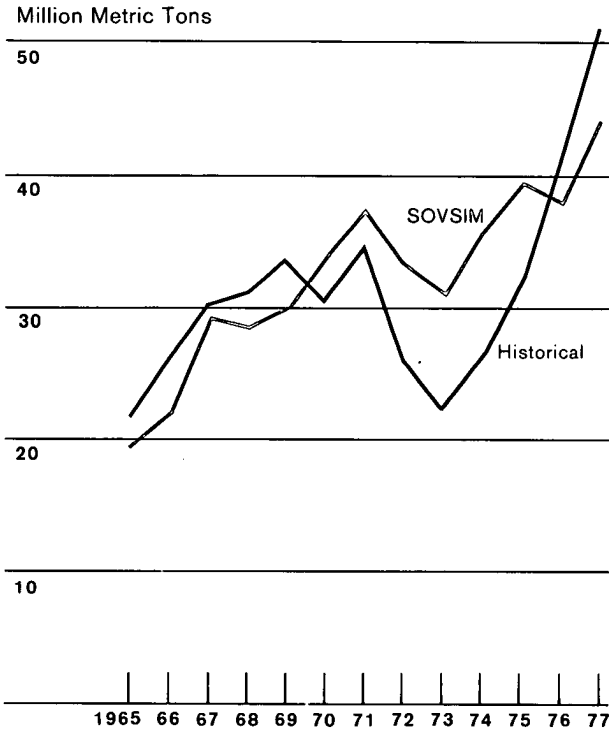
SOVSIM: Simulation of Hard Currency Net Exports of Oil **Figure 7**



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• *Root-Mean-Squared Percentage Error (RMSE)* [8]— The RMSE like the MAPE, ignores the signs of individual errors. However, an individual error receives more weight in calculation of this index according to the square of its size. This index has preferred statistical properties but can easily become distorted. One or two historical figures lying far from the values projected by the model can cause large RMSE values.

The average simulation errors for key production, end-use, and foreign trade variables are summarized in table 2. The main characteristic of the production and end-use variables themselves is that they all show a strong time trend. With the exception of agricultural output, they are not especially volatile, but they tend to grow fairly steadily from year to year. The statistical equations used in projecting the output variables generally exhibit extremely good fits. Consequently, average simulation errors tend to be small for this group of variables. Of the 12 production and end-use variables listed in table 2, seven have RMSEs of less than 3 percent and only one has an error larger than 5 percent.

The trade variables are fundamentally more volatile than the production and end-use variables. Part of the explanation for this is that trade depends on conditions outside the control of Soviet policymakers. Furthermore, those aspects of trade subject to control can change dramatically from one year to another as Soviet trade policies vary.

[8] $$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{t}\left[\frac{(\text{Estimated}-\text{Actual})\times 100}{\text{Actual}}\right]^2}$$

Table 2 Percent

Average Simulation Errors of Key Variables, 1965-77

	Mean Error	Mean Absolute Error	Root-Mean-Squared Error
Gross National Product	−0.1	0.8	1.0
Total Consumption	−0.3	2.0	2.3
Total New Fixed Investment	0.2	2.0	2.4
Actual Agriculture Output	−0.5	3.6	4.3
Consumer Goods Output	−0.2	2.5	3.1
Industrial Materials Output	−1.8	2.3	2.7
Other Industry Output	−0.6	1.5	1.7
Chemicals Output	5.5	8.0	9.0
Construction Output	−0.6	1.5	1.8
Machinery Output	1.8	3.2	3.6
Transport and Communications Output	−3.1	3.3	3.5
Trade and Services Output	0.9	1.3	1.4
Hard Currency Balance of Trade	−13.1	61.4	74.4
Nonoil, Nongrain Imports	−4.4	12.0	18.7
Hard Currency Net Exports of Fuel	9.1	20.0	28.0
Communist Balance of Trade	−156.9	165.8	316.6
Communist Nonenergy Exports	0.2	3.4	5.9
Communist Nonfuel Imports	0.0	3.7	6.8
Balance of Trade With World	−143.5	158.8	392.8
Hard Currency Net Exports of Oil	6.1	16.6	20.0
Hard Currency Net Exports of Coal	17.7	69.4	78.3
Hard Currency Net Exports of Gas	103.9	217.5	301.1

Table 2 shows that average simulation errors for the trade variables tend to be considerably larger than those for the production and end-use variables. Nonetheless, exports of oil and total fuels to the West, nongrain imports from the West, and Communist exports and imports are tracked fairly well over the historical period—their average errors are generally less than 20 percent. The trade balances show larger errors because they are calculated as residuals of balance relations in which the residual is much smaller in absolute terms than the variables involved in the calculation. As a consequence, small percentage errors in these variables can result in large percentage errors in the balance residuals. Just as in Western economies, prediction of Soviet trade balances probably will remain one of the areas of projection most prone to error. Comparison of the RMSEs and MAPEs for the balance variables also shows that aberrations in one or two years are a major source of distortion in the RMSE index.

The relatively large average-percentage error in projected gas exports primarily reflects the small absolute errors in estimating gas exports in the early years of the simulation period when they were practically negligible. Although less pronounced, a similar situation exists in the case of coal exports. In both cases, simulation errors in the later years were substantially below the average.

A Short Run Forecasting Experiment

Historical simulations can give an unrealistic impression of the strengths or weakness of an econometric model. They presume the existence of some data—for both exogenous variables and structural parameters—that would not actually be available when using the model to look into the future. They also place in a favorable light model specifications that are peculiar to the historical period but that are not necessarily the preferred way of viewing more general, long-term trends.

As a second test of SOVSIM, we have constructed a short run forecasting experiment free of these defects. We use data for 1960-75 to forecast Soviet economic growth in 1976 and 1977, using projections of the

exogenous variables for 1976-77 based on growth rates of preceding years. Comparison of the simulation results for 1976 and 1977 with actual values for the endogenous variables suggests the order of magnitude of forecasting errors one might expect in using SOVSIM as a short run forecasting tool. It also highlights the parts of the model in which accuracy of exogenous data is crucial to forecasting performance and tests the general stability of the underlying structural specifications.

As part of the analysis, the net forecast error was partitioned into (a) an error reflecting the approximate nature of the model's structure as a description of the Soviet economy and (b) an error reflecting the approximate nature of the exogenous variables that were extrapolated based on their 1960-75 values. All endogenous variables were first forecast for 1976 and 1977 using parameters estimated from the full historical data through 1977 and actual observations of exogenous variables also through 1977. Comparing forecasts based on full historical information (through 1977) with actual observations for the endogenous variables in 1976 and 1977 gives the "model error," the forecasting error due solely to the model's approximate specification. The "net error," the difference between actual observations and forecasts using only data through 1975, reflects both exogenous data error and "model error." Therefore, the "data error" can be estimated as the difference between the "net error" and the "model error." In general, if the "model error" and the "data error" have the same signs, they reinforce each other. If not, they partially offset each other.

Results for 1976

For 1976, the projections of the model (table 3) were more accurate for the production and end-use variables than for the trade variables, but this is to be expected for reasons already discussed. Most of the errors are in the range of 1 to 3 percent. In the group of production and end-use variables, only value added in chemicals exhibits a net error greater than 3 percent in the experimental forecast. The estimate falls short of the actual figure because of roughly equal negative errors due to model specification and data error. The branch output forecasts show no consistent bias; the net error in 1976 GNP is only 0.1 percent. For 1976, neither the error due to model deficiencies nor the error due to data errors consistently dominates as the source of forecasting error.

Results for 1977

A comparison of net percentage errors for 1976 and 1977 (tables 3 and 4) indicates that the projections of the simulated forecast tend to be further off the mark in 1977. The difference is most pronounced for the trade variables. Six of the 12 production and end-use variables have greater net percentage errors in 1977 than in 1976 compared with seven out of the 11 trade variables. Moreover, the differences in net percentage errors between the two years are much greater for the trade variables than for the production and end-use variables. In 1977 the model error is generally lower than the data error (both measured in absolute values) for the trade variables. This means that forecasts of external events affecting trade are a more severe constraint than model structure on the ability of the model to make accurate projections more than a year ahead.

Nonetheless, even for forecasts two years beyond the 1960-75 period covered by the data base used in this experiment, net errors were generally only about 1 percentage point worse for production and end-use variables and around 10 to 15 percentage points worse for most trade variables than the one-year forecast errors. The 1977 results also vividly show that a model will never be able to predict the kind of dramatic turnaround in Soviet trade balances that occurred in that year. As the error decomposition indicates, this failure in 1976-77 is essentially a reflection of trade variable sensitivity to shifts in behavior that are not anticipated in either the underlying model parameters estimated for 1960-75 or the crude extrapolations of exogenous data also based only on preceding years.

SOVSIM Impact Analysis, 1978-85

All SOVSIM projections depend on assumptions regarding the exogenous variables and key coefficients in the model. These variables and coefficients define the internal and external economic, political, and technological environments. Domestic and foreign policies or economically significant events can be described by combinations of these variables and coefficients. The reaction of SOVSIM to hypothetical policy changes or

Table 3

SOVSIM Forecasts of Key Variables for 1976

	Level		% Error	% Error Due To:	
	Simulated	Actual		Model	Data
	Billion 1970 Rubles				
Gross National Product	483.4	482.9	0.1	−0.5	0.6
Total Consumption	273.9	277.9	−1.4	0.2	−1.6
Total New Fixed Investment	108.6	111.7	−2.7	−2.5	−0.2
Actual Agriculture Output	69.6	68.7	1.3	1.1	0.2
Consumer Goods Output	62.3	61.2	1.8	−0.5	2.3
Industrial Materials Output	25.6	25.9	−1.3	−3.1	4.4
Other Industry Output	8.0	8.1	−0.4	−1.5	1.1
Chemicals Output	12.2	12.9	−5.7	−3.3	−2.4
Construction Output	33.9	33.9	−0.2	−1.7	1.5
Machinery Output	62.1	63.7	−2.6	−0.7	−1.9
Transport and Communications Output	46.9	45.6	3.0	0.4	2.6
Trade and Services Output	72.2	73.1	−1.2	−0.7	−0.5
	Million US $				
Hard Currency Balance of Trade	−5,106.0	−5,516.0	−7.4	−18.7	11.3
Nonoil, Nongrain Imports	11,416.0	12,051.0	−5.3	−13.4	8.1
Hard Currency Net Exports of Fuel	4,708.0	4,683.0	0.5	−7.2	7.7
Communist Balance of Trade	1,014.0	1,787.0	−43.3	−17.1	−26.2
Communist Nonenergy Exports	14,969.0	16,114.0	−7.1	−5.1	−2.0
Communist Nonfuel Imports	19,642.0	19,652.0	−0.1	−2.7	2.6
Balance of Trade With World	−4,119.0	−3,797.0	8.5	−19.2	27.7
	Million Metric Tons				
Hard Currency Net Exports of Oil	36.7	41.2	−11.0	−10.9	−0.1
Hard Currency Net Exports of Coal	11.1	8.8	26.8	−3.0	29.8
	Billion Cubic Meters				
Hard Currency Net Exports of Gas	11.9	11.5	3.7	29.4	−25.7

Table 4

SOVSIM Forecasts of Key Variables for 1977

	Level		% Error	% Error Due To:	
	Simulated	Actual		Model	Data
	Billion 1970 Rubles				
Gross National Product	504.3	500.2	0.8	1.0	−0.2
Total Consumption	284.5	289.2	−1.6	3.2	−4.8
Total New Fixed Investment	114.1	115.0	−0.8	−2.3	1.5
Actual Agriculture Output	70.6	70.4	0.3	8.6	−8.3
Consumer Goods Output	64.8	63.3	2.4	−0.5	2.9
Industrial Materials Output	26.7	26.4	1.4	−1.0	2.4
Other Industry Output	8.2	8.2	0.3	−0.8	1.1
Chemicals Output	12.9	13.6	−5.3	−3.3	−2.0
Construction Output	35.3	34.7	1.6	−0.9	2.5
Machinery Output	66.1	67.5	−2.1	−0.6	−1.5
Transport and Communications Output	50.5	47.4	6.5	2.8	3.7
Trade and Services Output	74.6	76.1	−1.9	−2.0	0.1
	Million US $				
Hard Currency Balance of Trade	−5,354.0	−2,431	120.2	9.7	110.5
Nonoil, Nongrain Imports	13,291.0	10,229.0	29.9	−3.4	33.3
Hard Currency Net Exports of Fuel	6,260.0	6,180.0	−1.3	−17.9	19.2
Communist Balance of Trade	1,174.0	2,718.0	−56.8	−38.9	−17.9
Communist Nonenergy Exports	16,733.0	16,950.0	−1.3	0.2	−1.5
Communist Nonfuel Imports	22,739.0	20,368.0	11.6	5.3	6.3
Balance of Trade with World	−4,255.0	93.8	−4,636.0	−1,337.0	−3,259.0
	Million Metric Tons				
Hard Currency Net Exports of Oil	40.3	50.7	−20.5	−16.2	−4.3
Hard Currency Net Exports of Coal	9.5	9.2	3.6	−93.8	97.4
	Billion Cubic Meters				
Hard Currency Net Exports of Gas	13.8	14.8	−7.2	14.9	−22.1

external events described by shifts in particular variables and parameters can be extremely useful in evaluating the path of the economy's adjustment to such changes as well as in validating the model itself. Such projections are called conditional forecasts.

Baseline Case

The potential impact of particular events or policy changes is conventionally assessed by comparing two model projections, a reference case and a case incorporating the given changes in terms of shifts in parameters or exogenous variables.

As a reference case, we developed a baseline projection of Soviet growth in 1978-85 that assumes a continuation of present Soviet policies and no change in the trends of critical variables like participation rates and weather:

- *Exports of Fuels.* Net exports of oil, coal, and gas for hard currency are the residual from domestic production after domestic deliveries and net exports to Communist countries are covered. Net exports of oil to Communist countries increase to 95 million metric tons in 1980 and stay at this level through 1985.

- *Other Hard Currency Trade.* Hard currency exports of commodities other than fuels grow at 9 percent a year in real terms, and new drawdowns of medium- and long-term credits increase at a real rate of 5 percent a year. Both rates are consistent with recent trends. A floor was placed on the value of hard currency imports other than oil and grain; their share of GNP in any year was not allowed to fall below one-half the 1977 figure.

- *Allocation of Fuel Supplies.* Sectors producing fuels and power, and public and private consumption are given priority when oil deliveries are insufficient to meet the demands of all sectors. They are always allocated 100 percent of their nominal oil demand.

- *Production of Fuels.* Oil production peaks at 590 million metric tons in 1980 and falls to 500 million metric tons in 1985. This is at the high end of the production range we have estimated.[9] Gas output grows at 6 percent a year and coal production at 2 percent.

- *Defense Spending.* The real value of Soviet defense expenditures rises at an annual rate of 4 percent—consistent with the trend over the last decade.

- *Population and Employment.* Total population grows at 1 percent a year, but growth in the able-bodied population slows dramatically through 1985 because of demographic factors. Agriculture's share of the labor force falls from 24 percent in 1978 to 20 percent in 1985, while participation rates essentially remain at their current high levels.

In the baseline case, these assumptions lead to a Soviet oil shortage in the 1980s and a deceleration in Soviet growth rates. The average annual rate of GNP growth falls to 2.5 percent in 1981-85, more than 1 percentage point below the average annual growth in 1976-80. The Soviets would export oil to the West until 1981, after which they would become net importers of Western oil. Soviet net oil exports to the world would remain positive through 1985, however, because of our assumption that exports to Eastern Europe and other Communist countries continue at a level of 95 million metric tons in 1981-85.

Impacts of Three Hypothetical Shifts

To illustrate how SOVSIM can be used to make conditional forecasts, we have resimulated the model over the 1978-85 period after changing—one at a time—three of the assumptions underlying the baseline solution:

- Labor force participation rates rise by 1985 by 1 percentage point for the able-bodied population and by 2 percentage points for pensioners. The increase in participation rates implies that the Soviets make greater use of incentives and manpower regulations than assumed in the baseline to improve the tight labor situation over the next decade.

- Western economic growth is slower than the baseline case assumes for the next decade, and therefore nonfuel exports to hard currency countries grow at only one-half the assumed baseline rate.

[9] *Prospects for Soviet Oil Production,* April 1977.

• Oil exports to Eastern Europe fall from 95 million metric tons in 1980 to 45 million metric tons in 1985, as the Soviets attempt to relieve economic pressures associated with oil shortfalls in the early 1980s.

The more aggressive manpower policy would have an immediate positive effect on GNP that would cumulate over the period (table 5), eventually adding a little less than 1 percentage point to GNP by 1985. The gains in private consumption would amount to about half the gains in GNP—implying a stable share for consumption in final demand. The small increase in oil exports possible in the early years comes from the excess of new domestic production over new domestic demand resulting from the extra labor. The extra hard currency imports are simply a reflection of the extra hard currency earnings resulting from these oil exports. The improved labor situation would have little impact on the hard currency and oil problems projected for 1982-85. As table 5 shows, hard currency imports in those years would not change from their baseline levels, which are the minimum allowed under the baseline conditions. The extra GNP during 1982-85 comes from two sources—primarily the increased labor supply and to a much smaller extent added energy production from domestic sources.

Slower Western growth would cut hard currency imports immediately because of the lower-than-baseline Soviet import capacity. The early effects of trade on GNP are passed through very slowly because of the small role that imported capital goods play in the total Soviet economy. The large negative impact in the later years is predominantly due to a reduced ability to finance oil imports from the West, which is reflected in lower capital utilization rates. Imports would be restricted to almost 20 million metric tons below baseline levels in 1985 because of the need to devote increasingly scarce hard currency to keep other imports from the West at least at minimum levels. With other oil trade fixed, this means higher Soviet net oil exports by the same amount. These shifts in trade would improve the Soviet trade balance and simultaneously reduce the level of private consumption compared with baseline levels. Consequently, consumption as the residual end use would absorb a larger share of the projected GNP fall—about two-thirds—than the projected 50-percent share in the GNP increase in the previous case where trade balances were essentially stable between the baseline and resimulation.

In the last case, it was assumed that Soviet oil exports to Eastern Europe would fall only after pressures on oil supplies began to mount in the early 1980s. The potential impact of this policy shift is substantial—it would add more than 1 percent to GNP by 1985—because it would directly ease oil shortages, projected in the baseline for the later years. The emergence of oil shortages would be delayed, as the hard currency import constraint in the baseline is now binding in only the last three years.

The shifts in the pattern of trade are now more complicated, however. When the Soviets are projected in the baseline case to have sufficient hard currency earnings to finance practically all import needs—as in 1981 and 1982—the oil released from export to Eastern Europe is used domestically in place of oil imports from the West and the hard currency savings are diverted to finance more nonoil imports from hard currency countries. Net oil exports to the world would then be unchanged from baseline levels. When, instead, the Soviets are projected to be under a hard currency constraint in the baseline—as in 1983-85—the oil diverted from Eastern Europe is used along with baseline projections of Western oil imports to ease internal oil shortages. In these years, imports of Western oil and other goods would be unchanged from the baseline, but net Soviet oil exports to the world would fall by the amount of reduced oil exports to Eastern Europe.

A Preliminary Assessment

Our experience with SOVSIM—in historical analysis, in forecasting experiments, and in impact analysis—indicates that a Soviet macroeconometric model of this kind can be a reliable and useful tool in studying Soviet growth prospects. It provides a consistent framework for investigating the effects of alternative sets of analytical assumptions and for examining the linkages between sets of interrelated issues.

Table 5

Impact Analysis With SOVSIM:
Effects on Selected Economic Variables

Variable	1978	1979	1980	1981	1982	1983	1984	1985
Changes Due to Higher Labor Participation Rates								
GNP (Billion 1970 Rubles)	0	1.0	1.9	2.5	3.5	4.2	5.1	6.2
Consumption (Billion 1970 Rubles)	0	0.6	1.0	1.3	1.9	2.2	2.7	3.3
Net Hard Currency Oil Exports (Million Metric Tons)	0	0.4	0.7	0.9	0	0	0	0
Net Oil Exports (Million Metric Tons)	0	0.4	0.7	0.9	0	0	0	0
Hard Currency Imports Other Than Grain and Oil (Billion US $)	0	0.1	0.2	0.2	0	0	0	0
Changes Due to Slower Western Growth								
GNP (Billion 1970 Rubles)	0	0	0	0	−1.8	−2.3	−2.7	−3.1
Consumption (Billion 1970 Rubles)	0	0	0	0	−1.1	−1.4	−1.6	−1.8
Net Hard Currency Oil Exports (Million Metric Tons)	0	0	−0.1	−0.2	10.7	13.4	15.2	17.0
Net Oil Exports (Million Metric Tons)	0	0	−0.1	−0.2	10.7	13.4	15.2	17.0
Hard Currency Imports Other Than Grain and Oil (Billion US $)	−0.2	−0.5	−0.8	−1.3	0	0	0	0
Changes Due to Lower Oil Exports to Eastern Europe								
GNP (Billion 1970 Rubles)	0	0	0	0	0.3	4.8	6.5	8.1
Consumption (Billion 1970 Rubles)	0	0	0	0.1	0.3	3.0	4.1	5.1
Net Hard Currency Oil Exports (Million Metric Tons)	0	0	0	10.0	18.1	0	0	0
Net Oil Exports (Million Metric Tons)	0	0	0	0	−1.9	−29.0	−39.3	−48.0
Hard Currency Imports Other Than Grain and Oil (Billion US $)	0	0	0	1.5	2.9	0	0	0

Applications of SOVSIM to growth studies should help improve our understanding of both the long-term prospects for Soviet economic development and the methods we use to analyze them. Therefore we tend to focus on the use of SOVSIM in the next phase of our research. This means applying the present version of the model to analysis of trends in such areas as labor supply, energy, and foreign trade, and their impacts on Soviet growth potential in the 1980s. These applications studies should serve as a comprehensive test of the usefulness of a Soviet macroeconometric model in improving our perceptions of the range of Soviet growth options, Soviet flexibility in the face of expected shifts in resource growth patterns, and the general interrelatedness of issues facing Soviet policymakers.

In the long run, however, the usefulness of SOVSIM can be enhanced by further development, especially in several specific areas. Production functions play a crucial role in any Soviet model and SOVSIM now conventionally employs a straightforward Cobb-Douglas specification. Considerable research has been done since 1970 on the application of constant elasticity of substitution (CES) production functions to highly aggregated Soviet data. A potentially fruitful area for future research is the application of CES or other more complex specifications to the description of Soviet production on a sector basis. These changes would be aimed at an improved depiction of the substitutability of capital and labor, and its variation across producing sectors. However, applications of more sophisticated techniques to highly disaggregated data are certain to be plagued by greater data shortcomings than aggregate analysis, because of the lack of offsetting error possibilities. Such problems are not fatal to disaggregated estimates of the less sensitive Cobb-Douglas function, but they will become important in estimating more sensitive functional forms for highly disaggregated sectors.

There are also several other areas of SOVSIM that demand further development. More detail must be given to the description of production in the agricultural sector. At least a partial behavioral foundation must be established for projections of private consumption. It may be possible to explain changes in participation rates through changes in real incomes. Also, the process of adjustment to intersectoral disequilibriums, which is the focus of current SRI-WEFA research, may be amenable to simulation within the framework of a macroeconometric model and will be incorporated in our own work if present experiments prove successful.

Of course, any modeling effort uses much outside information to describe processes not embodied within the model itself. In SOVSIM, questions of labor supply and demographic patterns, improvements in total factor productivity at the sector level, and gains in energy conservation are all handled outside the model, but they obviously have a strong bearing on the character of any analysis conducted with the model. Improvements in our understanding of such issues is a necessary ingredient in upgrading the quality of Soviet growth analysis in general.

It is unlikely, though, that the near future will see much of an improvement in our ability to analyze the planning process explicitly. Ideally a Soviet macromodel should endogenize the reaction functions of the planners and thus provide a description of the planning process itself, including the effects of plan on performance and the feedbacks of performance on future plan formulation. The failure of Soviet macroeconometric models to meet this requirement has been the center of recent criticisms of current approaches.[10]

Given our limited theoretical understanding of planner decisionmaking, the sharp discontinuities possible in planning behavior, and the insufficient set of historical precedents that exist, it is not likely that a purely statistical solution to modeling planning behavior will be found. A second best procedure may be combining, within a series of analyses or conditional forecasts, the use of a macroeconometric model with sound judgment on how underlying policies might change as decisionmakers adapted to events projected by the model. It is this approach that we will continue to follow in our research.

[10] See Richard Portes, *Macroeconometric Modelling of Centrally Planned Economies: Thoughts on SOVMOD I* (Harvard Institute for Economic Research, May 1978).

Appendix A:

Specification of SOVSIM

This appendix describes the structural equations in SOVSIM. The equations are divided into seven blocks, corresponding to the groups of endogenous variables discussed in the condensed version of the model. Brief discussions of each block and tables listing the equations are provided below. For regression equations, the R^2 statistic is adjusted for degrees of freedom while t-statistics appear in parentheses below estimated parameters.

Production Block (Table A1)

There are 14 endogenous variables describing sector production levels in this block and they are influenced by eight exogenous variables. Value added in agriculture is estimated in a two-step procedure. First, normal agricultural output is estimated based solely upon land, labor, and capital inputs. Then, actual output is estimated from normal output and current indexes of temperature and rainfall. Production functions for agriculture and the eight nonagriculture, nonenergy sectors were estimated using a constant-returns-to-scale [1] Cobb-Douglas specification, implying an elasticity of substitution among inputs equal to unity. Other production-function specifications gave generally inferior statistical results. The nonagriculture production functions were estimated using generalized least squares (GLS) since results using ordinary least squares (OLS) showed strong autocorrelation of the residuals.

[1] The constant-returns-to-scale assumption requires only the capital coefficient to be estimated statistically. The labor coefficient is simply one minus the capital coefficient and it does not have an associated t-statistic.

Because we expect over the next decade substantial reductions from historical levels in the marginal products of labor and capital in the energy sectors, we have not used production functions estimated from historical data for these sectors. Value added in the energy sectors is calculated instead from scale relationships that apply value-added weights to exogenous indexes of gross output. Gross outputs of the energy sectors are exogenous to the model, but provision exists for computing marginal changes from reference output levels in response to marginal shifts in labor and capital inputs to these sectors.

The capital stocks for the machinery, chemicals, and oil-producing sectors are separated into domestically produced and imported components, although it was not possible to estimate separate coefficients for each type of capital.

Table A1

Equation List for the Production Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic	Estimation Method
1	Normal agriculture output	log (normal agriculture output) = -5.08 (−16.07) + 0.01 × time + 0.738 (12.82) × log (agriculture employment) + 0.111 (15.98) × log (fixed capital in agriculture sector) + 0.151 × log (sown area)	0.974	1.10	Ordinary Least Squares
2	Actual agriculture output	actual agriculture output = normal agriculture output 0.969 (78.71) + 0.140 × precipitation index (5.10) + 0.519 (2.52) × temperature index	0.699	1.32	Ordinary Least Squares
3	Construction output	log (construction output) = -4.49 (−54.77) + 0.779 × log (construction employment) + 0.221 × log (capital in construction sector) (17.14)	0.978	1.59	Generalized Least Squares
4	Transport and communications output	log (transport and communications output) = -1.87 (−15.11) + 0.173 × log (transport and communications employment) + 0.827 (31.74) × log (capital in transport and communications sector)	0.989	2.04	Generalized Least Squares
5	Trade and services output	log (trade and services output) = -5.33 (−69.19) + 0.836 × log (trade and services employment) + 0.164 × log (capital in trade and services sector) (11.97)	0.958	0.72	Generalized Least Squares
6	Industrial materials output	log (industrial materials output) = -3.10 (−40.71) + 0.538 × log (industrial materials employment) + 0.462 × log (capital in industrial materials branches) (30.36)	0.995	1.15	Generalized Least Squares

Table A1 (Continued)

Equation List for the Production Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic	Estimation Method
7	Consumer goods output	log (consumer goods output) = $-2.97 + 0.635 \times \log$ (consumer goods employment) (-17.84) $+ 0.365 \times \log$ (capital in consumer goods branches) (12.73)	0.975	1.39	Generalized Least Squares
8	Machinery output	log (machinery output) = $-2.57 + 0.452 \times \log$ (machinery employment) (-16.63) $+ 0.548 \times \log$ (domestic capital in machinery branch (20.08) + imported capital in machinery branch)	0.988	1.65	Generalized Least Squares
9	Chemicals output	log (chemicals output) = $-2.92 + 0.507 \times \log$ (chemicals employment) (-29.07) $+ 0.493 \times \log$ (domestic capital in chemicals branch (23.65) + imported capital in chemicals branch)	0.987	1.28	Generalized Least Squares
10	Other industry output	log (other industry output) = $-4.22 + 0.690 \times \log$ (other industry employment) (-41.13) $+ 0.310 \times \log$ (capital in other industry) (16.87)	0.982	1.00	Generalized Least Squares
11	Gas output	Gas output $= 1.798 \times \left(\frac{\text{gross gas output}}{197.9}\right)$			
12	Oil output	Oil output $= 7.549 \times \left(\frac{\text{gross oil output}}{353.4}\right)$			
13	Coal output	Coal output $= 4.945 \times \left(\frac{\text{gross coal output}}{624.1}\right)$			
14	Electric power output	Electric power output $= 7.268 \times \left(\frac{\text{gross electric power output}}{740.9}\right)$			

Consumption Block (Table A2)

The consumption block consists of nine endogenous variables and is affected by 11 exogenous variables. GNP is computed as the sum of value added in the 13 producing sectors. Total private consumption is calculated as the residual claimant on GNP once the other end uses (investment, public consumption, and the balance of trade) are deducted. Reduced-form equations that allow for both demand and supply influences were estimated for per capita food consumption and per capita durable goods consumption. In both equations the demand influence is represented by national income per capita. The supply influence in the food consumption equation is lagged agricultural output per capita, and in the durables equation it is machinery output per capita. Unallocated production as a GNP residual is estimated as a function of time and serves to close the GNP accounts on a sector-of-origin basis.

Table A2

Equation List for the Consumption Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic
1	Gross national product	Gross national product = industrial materials output + machinery output + chemicals output + consumer goods output + other industry output + gas output + oil output + coal output + electric power output + construction output + transport and communications output + trade and services output + agriculture output + (unit wage of military × military manpower)		
2	Total consumption	Total consumption = gross national product − (total new fixed investment + capital repair + livestock investment) − (government administration share + government R&D share) × gross national product − (nonpersonnel defense spending + (unit wage of military × military manpower)) − (0.001 × (ruble balance of trade) + invisibles ruble/dollar ratio × earnings on invisibles except official transfers) − end-use residual		
3	Consumption per capita	Consumption per capita = $\frac{\text{total consumption}}{\text{population}}$		
4	Food consumption per capita	$\log(\text{food consumption per capita}) = -0.937 + 0.652 \log\left(\frac{\text{gross national product}}{\text{population}}\right) + \underset{(3.57)}{0.132} \times \log\left(\frac{\text{actual agriculture output}_{(-1)}}{\text{population}}\right)$ (−16.96) (37.56)	0.995	1.77
5	Food consumption	Food consumption = food consumption per capita × population		
6	Durables consumption per capita	$\log(\text{durables consumption per capita}) = \underset{(-2.15)}{-1.69} + \underset{(1.69)}{0.868} \times \log\left(\frac{\text{gross national product}}{\text{population}}\right) + \underset{(2.67)}{0.857} \times \log\left(\frac{\text{machinery output}}{\text{population}}\right)$	0.987	0.56
7	Durables consumption	Durables consumption = durables consumption per capita × population		
8	Nonpersonnel defense	Nonpersonnel defense spending = (1 + growth in nonpersonnel defense spending) × nonpersonnel defense spending$_{(-1)}$		
9	Sector-of-origin residual	Sector-of-origin residual = $\underset{(4.18)}{3.00} + \underset{(56.43)}{1.81} \times$ time	0.997	2.36

Investment Block (Table A3)

Investment calculations involve 19 endogenous variables and are affected by four exogenous variables. New fixed investment is set by the supply of capital goods and does not reflect demand considerations. Deliveries to final demand from construction and machine building are estimated by scaling value-added figures that are derived from production functions. Scaling coefficients are calculated from Soviet input-output data. The claims of defense, capital repair, consumer durables, and exports are deducted from gross construction and machinery output to give net domestic production available for new fixed investment. In addition, the calculation of construction available for new fixed investment involves an adjustment to maintain consistency between the estimated new fixed investment component of the GNP accounts and the estimated output of machinery and construction available for investment.[2] Total new fixed investment is then distributed among the 13 producing sectors and housing according to given shares reflecting historical trends or assumed policies. Investment models using endogenous share calculations have also been investigated, but they have a weak statistical basis and generally lead to unacceptable projections in long-run growth analysis.

[2] Construction and machinery output data are not fully consistent with independent figures on investment. To maintain correct accounting in the model, we have developed an adjustment applied to the construction series, where consistency is established with the smallest distortion of original sector output figures.

Table A3

Equation List for the Investment Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic
1	Machinery for new fixed investment	Machinery for new fixed investment = 1.238 × machinery output − (0.5 × capital repair + military equipment + durables consumption + machinery exports)		
2	Investment adjustment factor	Investment adjustment factor = 0.877 + 0.0122 × time (32.40) (10.03)	0.893	0.98
3	Construction for new fixed investment	Construction for new fixed investment = 2.751 × investment adjustment factor × construction output − (0.5 × capital repair + military construction)		
4	Total new fixed investment	Total new fixed investment = machinery for investment + construction for investment $+\sum_{i=1}^{3}$ (net imported capital formation in the ith sector + 0.06 × imported machinery in the ith sector)		
5-17	New fixed investment in the ith sector	New fixed investment in the ith sector = the ith sector share of total new fixed investment × total new fixed investment		
18	Capital repair	Capital repair = 0.234 × total new fixed investment		
19	New fixed investment in the housing sector	New fixed investment in the housing sector = the housing share of total new fixed investment × total new fixed investment		

Capital Formation Block (Table A4)

Capital formation in SOVSIM is described by 32 endogenous variables and is influenced by one exogenous variable. This process is concerned with the increase in the productive capital stock that comes from commissionings of new plants, which in turn depends on expenditures on capital goods. The stock of productive capital in a particular producing sector during a given year is computed from an accounting relationship involving last year's stock and last year's net formation of productive capital. Net capital formation equations are estimated for each producing sector based on assumed depreciation rates and investment levels in the last two time periods. A plan cycle variable representing the Soviet tendency to start a wide range of capital projects during the early plan years and to push projects to completion in the later years was found to be a significant explanatory variable in the gas and coal sectors and was therefore also included in those net capital formation equations. The estimated net capital formation equations reflect two factors: the general failure of Soviet capital stock census data to be fully consistent with data on annual investment expenditures, and the variable gestation periods and patterns of unfinished investment across producing sectors. For the machinery, chemicals, and oil sectors, distinctions are made between capital produced domestically and capital imported from hard currency and other Communist countries. For imported equipment, we simply assume a one-year average lag between the import of capital goods and their inclusion in the stock of productive capital.

Table A4

Equation List for the Capital Formation Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic
1	Capital in the agriculture sector	Capital in the agriculture sector = net capital formation in the agriculture sector $_{(-1)}$ + capital stock in the agriculture sector $_{(-1)}$		
2-10	Capital in the ith sector	Capital in the ith sector = net capital formation in the ith sector $_{(-1)}$ + capital stock in the ith sector $_{(-1)}$		
11-13	Domestic capital in the jth sector	Domestic capital in the jth sector = net domestic capital formation in the jth sector + domestic capital in the jth sector $_{(-1)}$		
14-16	Imported capital in the jth sector	Imported capital in the jth sector = net imported capital formation in the jth sector $_{(-1)}$ + imported capital in the jth sector $_{(-1)}$		
17	Net capital formation in the agriculture sector	Net capital formation in the agriculture sector + 0.05 × capital in the agriculture sector = $\underset{(0.05)}{0.0312} + \underset{(17.86)}{0.796} \times \left(\frac{\text{investment in the agriculture sector} + \text{investment in the agriculture sector}_{(-1)}}{2}\right)$	0.952	0.84
18	Net capital formation in the construction sector	Net capital formation in the construction sector + 0.06 × capital in the construction sector = $\underset{(0.26)}{0.0348} + \underset{(22.19)}{1.11} \times \left(\frac{\text{investment in the construction sector} + \text{investment in the construction sector}_{(-1)}}{2}\right)$	0.968	2.22
19	Net capital formation in the transport and communications sector	Net capital formation in the transport and communications sector + 0.025 × capital in the transport and communications sector = $\underset{(2.01)}{1.11} + \underset{(14.19)}{1.03} \times \left(\frac{\text{investment in the transport and communications sector} + \text{investment in the transport and communications sector}_{(-1)}}{2}\right)$	0.926	1.99
20	Net capital formation in the trade and services sector	Net capital formation in the trade and services sector + 0.02 × capital in the trade and services sector = $\underset{(-0.72)}{-0.873} + \underset{(10.22)}{1.01} \times \left(\frac{\text{investment in the trade and services sector} + \text{investment in the trade and services sector}_{(-1)}}{2}\right)$	0.866	1.57

Table A4 (Continued)

Equation List for the Capital Formation Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic
21	Net capital formation in the industrial materials branches	Net capital formation in the industrial materials branches + 0.045 × capital in the industrial materials banches = $\underset{(-0.99)}{-0.459} + \underset{(9.40)}{0.679} \times \left(+ \frac{\text{investment in the industrial materials branches}}{\text{investment in the industiral materials branches}_{(-1)}} \right) / 2$	0.845	2.18
22	Net capital formation in the consumer goods branches	Net capital formation in the consumer goods branches + 0.05 × capital in consumer goods branches = $\underset{(0.85)}{0.209} + \underset{(12.29)}{0.935} \times \left(+ \frac{\text{investment in consumer goods branches}}{\text{investment in consumer goods branches}_{(-1)}} \right) / 2$	0.904	1.38
23	Net domestic capital formation in the machinery branch	Net domestic capital formation in the machinery branch + 0.05 × domestic capital in the machinery branch = $\underset{(2.34)}{1.03} + \underset{(12.08)}{0.985} \times \left(+ \frac{\text{investment in machinery goods branch}}{\text{investment in machinery goods branch}_{(-1)}} \right) / 2$	0.901	2.36
24	Net imported capital formation in the machinery branch	Net imported capital formation in the machinery branch + 0.06 × imported capital in the machinery branch = $\frac{0.05 \times \text{total machinery imports}}{1{,}000}$		
25	Net domestic capital formation in the chemicals branch	Net domestic capital formation in the chemicals branch + 0.04 × domestic capital in chemicals branch = $\underset{(0.53)}{0.169} + \underset{(6.02)}{0.795} \times \left(+ \frac{\text{investment in chemicals branch}}{\text{investment in chemicals branch}_{(-1)}} \right) / 2$	0.688	1.64
26	Net imported capital formation in the chemicals branch	Net imported capital formation in the chemicals branch + 0.06 × imported capital in the chemicals branch = $\frac{0.05 \times \text{total machinery imports}}{1{,}000}$		
27	Net capital formation in other industry	Net capital formation in other industry + 0.045 × capital in other industry = $\underset{(-0.75)}{-0.177} + \underset{(6.36)}{1.14} \times \left(+ \frac{\text{investment in other industry}}{\text{investment in other industry}_{(-1)}} \right) / 2$	0.711	1.36
28	Net capital formation in the gas branch	Net capital formation in the gas branch + 0.025 × capital in the gas branch = $\underset{(2.64)}{0.0980} + \underset{(14.52)}{0.489} \times \left(+ \frac{\text{investment in the gas branch}}{\text{investment in the gas branch}_{(-1)}} \right) / 2 + \underset{(1.92)}{0.659} \times$ five-year plan cycle	0.940	2.36

Table A4 (Continued)

Equation List for the Capital Formation Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic
29	Net domestic capital formation in the oil branch	Net domestic capital formation in the oil branch + 0.025 × capital in the oil branch = $-0.574 + 0.675 \underset{(-4.40)\quad(13.09)}{\times}\left(\frac{\text{investment in the oil branch} + \text{investment in the oil branch}_{(-1)}}{2}\right)$	0.919	1.97
30	Net imported capital formation in the oil branch	Net imported capital formation in the oil branch + 0.06 × imported capital in the oil branch = $\frac{0.05 \times \text{total machinery imports}}{1{,}000}$		
31	Net capital formation the coal branch	Net capital formation in the coal branch + 0.03 × capital in the coal branch = $-0.0970 + 0.595 \underset{(-0.62)\quad(5.61)}{\times}\left(\frac{\text{investment in the coal branch} + \text{investment in the coal branch}_{(-1)}}{2}\right) + \underset{(3.62)}{0.172} \times \text{five-year plan cycle}$	0.738	2.05
32	Net domestic capital formation in the electric power branch	Net domestic capital formation in the electric power branch + 0.04 × capital in the electric power branch = $0.0455 + 1.15 \underset{(0.10)\quad(6.89)}{\times}\left(\frac{\text{investment in the electric power branch} + \text{investment in the electric power branch}_{(-1)}}{2}\right)$	0.744	1.57

Energy Block (Table A5)

The energy block is the largest single block of SOVSIM. It includes 91 endogenous variables and is influenced by 13 exogenous variables. Separate calculations are performed for oil, coal, gas, and electric power. Each energy component is described by a balance relationship that compares domestic production (given exogenously) with domestic use estimated from separate demand equations for each producing sector and final demand.

Deliveries of fuels and power to each producing sector depend on the sector's capital stock, the fuel or power use per unit of capital in that sector, a fuel or power use adjustment factor, and the allocation of fuels and power as a fraction of nominal requirements. Deliveries to final demand are projected in a similar manner, with expenditures on public and private consumption replacing capital stock in calculations. The use adjustment factors introduce variability over time into the fuel and power use rates estimated from input-output data, to the extent that such variations can be observed historically or are expected to occur in the future because of such factors as technological improvements in efficiency and substitution among fuels. A separate issue to consider with respect to coal is the declining energy content per unit produced as old, high-quality deposits in the European regions are depleted.

Given projections of oil, coal, gas, and power deliveries to producing sectors and consumption, we can compute the residual of domestic production over domestic deliveries. If this figure is positive, it represents a potential for export; if it is negative, it indicates the need for imports to maintain the particular fuel or power balance considered.

For each producing sector, we calculate an average energy allocation factor, which is total energy delivered to the sector as a fraction of total nominal demand. These average factors are then combined with the sector capital stock and the elasticity of capital use with respect to energy deliveries to yield estimates of the capital stock active in production. The more important a fuel in short supply is to a particular sector's energy consumption and the more sensitive its capital stock use is to energy shortfalls, the larger the reduction expected in active capital in response to a fuel or power allocation below 100 percent of requirements.

Table A5

Equation List for the Energy Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic
1-13	Gas deliveries to the ith sector	Gas deliveries to the ith sector = capital in the ith sector $\times \frac{\text{gas use coefficient for the ith sector}}{\text{gas use adjustment factor}}$ $\times$ allocation rate of gas for the ith sector		
14-26	Oil deliveries to the ith sector	Oil deliveries to the ith sector = capital in the ith sector $\times \frac{\text{oil use coefficient for the ith sector}}{\text{oil use adjustment factor}}$ $\times$ allocation rate of oil for the ith sector		
27-39	Coal deliveries to the ith sector	Coal deliveries to the ith sector = capital in the ith sector $\times \frac{\text{coal use coefficient for the ith sector}}{\text{coal use adjustment factor}}$ $\times$ allocation rate of coal for the ith sector $\times \frac{0.685}{\text{coal quality index}}$		
40-52	Electric power deliveries to the ith sector	Electric power deliveries to the ith sector = capital in the ith sector $\times \frac{\text{electric power use coefficient for the ith sector}}{\text{electric power use adjustment factor}}$ $\times$ allocation rate of electric power for the ith sector		
53	Gas deliveries to final demand	Gas deliveries to final demand = (total consumption + government administration + government R&D + nonpersonnel defense spending + (unit wage of military $\times$ military manpower)) $\times \frac{\text{gas use coefficient for final demand}}{\text{gas use adjustment factor}}$ $\times$ allocation rate of gas for consumption		
54	Oil deliveries to final demand	Oil deliveries to final demand = (total consumption + government administration + government R&D + nonpersonnel defense spending + (unit wage of military $\times$ military manpower)) $\times \frac{\text{oil use coefficient for final demand}}{\text{oil use adjustment factor}}$ $\times$ allocation rate of oil for consumption		
55	Coal deliveries to final demand	Coal deliveries to final demand = (total consumption + government administration + government R&D + nonpersonnel defense spending + (unit wage of military $\times$ military manpower)) $\times \frac{\text{coal use coefficient for final demand}}{\text{coal use adjustment factor}}$ $\times$ allocation rate of coal for consumption $\times \frac{0.685}{\text{coal quality index}}$		

Table A5 (Continued)

Equation List for the Energy Block

Equation Number	Dependent Variable	Equation	$\bar{R}^2$	Durbin-Watson Statistic
56	Electric power deliveries to final demand	Electric power deliveries to final demand = (total consumption + government administration + government R&D + nonpersonnel defense spending + (unit wage of military × military manpower)) × $\frac{\text{electric power use coefficient for final demand}}{\text{electric power use adjustment factor}}$ × allocation rate of electric power for consumption		
57	Gas use adjustment factor	Gas use adjustment factor=0.979		
58	Oil use adjustment factor	log (oil use adjustment factor) = $-0.321 + 0.0159 \times \text{time}$ $(-10.60) \quad (11.68)$	0.919	0.83
59	Coal use adjustment factor	Coal use adjustment factor = $-0.106 + 0.0491 \times \text{time}$ $(-5.64) \quad (58.45)$	0.997	1.73
60	Electric power use adjustment factor	Electric power use adjustment factor = $0.850 + 0.00663 \times \text{time}$ $(58.69) \quad (10.22)$	0.896	1.27
61	Coal quality index	Coal quality index = $0.806 - 0.00505 \times \text{time}$ $(55.99) \quad (-7.84)$	0.834	1.13
62	Gas residual	Gas residual = gross output of gas − gas deliveries to final demand $- \sum_{i=1}^{13}$ gas deliveries to the ith sector		
63	Oil residual	Oil residual = gross output of oil − oil deliveries to final demand $- \sum_{i=1}^{13}$ oil deliveries to the ith sector		
64	Coal residual	Coal residual = gross output of coal − coal deliveries to final demand $- \sum_{i=1}^{13}$ coal deliveries to the ith sector		

Table A5 (Continued)

Equation List for the Energy Block

Equation Number	Dependent Variable	Equation	$\overline{R}^2$	Durbin-Watson Statistic
65	Electric power residual	Electric power residual = gross output of electric power − electric power deliveries to final demand $- \sum_{i=1}^{13}$ electric power deliveries to the ith sector		
66-78	Average allocation of energy in the ith sector	Average allocation of energy in the ith sector = ($\sum_{j=1}^{4}$ deliveries of energy type j to the ith sector × conversion factor to standard fuel units for energy type j) ÷ ($\sum_{j=1}^{4}$ nominal requirements of energy type j in the ith sector × conversion factor to standard fuel units for energy type j)		
79-91	Active capital in the ith sector	Active capital in the ith sector = capital in the ith sector × (1 − (elasticity of active capital with respect to energy inputs in the ith sector) × (1 − average allocation of energy in the ith sector))		

Employment Block (Table A6)

This block contains 16 endogenous variables, which depend on eight exogenous variables. The total Soviet labor force is estimated from the able-bodied population, the number of pensioners, and the participation rates for each group. The civilian labor force is simply the total labor force after deduction for military manpower. Agriculture is allocated an exogenously determined share of the civilian labor force and agricultural employment is scaled from the labor force estimate. Employment in other producing sectors is then scaled from the nonagricultural labor force and is distributed among individual sectors based on an exogenously given employment pattern reflecting either historical trends or policy assumptions.

Table A6

Equation List for the Employment Block

Equation Number	Dependent Variable	Equation	$\overline{R}^2$	Durbin-Watson Statistic
1	Total labor force	Total labor force = (able-bodied participation rate × able-bodied population) + (pensioners participation rate × pensioners)		
2	Civilian labor force	Civilian labor force = total labor force − (military manpower × 1000)		
3	Agriculture employment	Agriculture employment = agriculture employment rate × agriculture share of civilian labor force × civilian labor force		
4	Nonagriculture employment	Nonagriculture employment = nonagriculture employment rate × (1 − agriculture share of civilian labor force) × civilian labor force		
5-16	Employment in the ith nonagriculture sector	Employment in the ith nonagriculture sector = the ith sector share of nonagriculture employment × nonagriculture employment		

Foreign Trade Block (Table A7)

The foreign trade block is the least endogenized block in SOVSIM, because outside forces and internal policy shifts have such a pronounced effect on the trade variables. Nonetheless, the model does contain 25 endogenous trade variables in addition to the 32 exogenous variables that influence trade projections. The key endogenous elements in the foreign trade block are (a) exports of fuels to hard currency countries, (b) nongrain imports from hard currency countries, and (c) nonfuel exports to and nonfuel imports from Communist countries.

Net exports of gas, oil, and coal to hard currency countries are calculated in physical units by deducting exogenous net exports to Communist and other countries from the residuals of the energy sector balance equations. The dollar values of net exports of fuels to hard currency, Communist, and other countries are estimated from these physical net exports and projections of unit export values made outside the model.

Grain imports from the West tend to reflect an upward trend in the protein content of the average Soviet citizen's diet as well as fluctuations in Soviet grain harvests. Our structural equation connecting hard currency grain imports with deviations between normal and actual value added in agriculture shows that grain imports are above normal in the year following a poor harvest and also have tended to increase over time.

The service on hard currency debt is assumed to vary in proportion to the size of medium- and long-term debt. Projections of debt service, fuel exports, and grain imports all enter into the calculation of nonfuel, nongrain import capacity. This specification assumes that grain and oil imports have first priority in trade with the West and that other hard currency imports reflect the import capacity not required to finance grain and oil imports. Actual nonfuel, nongrain imports from the West are specified as a function of the residual import capacity, and the estimated import elasticity of about one shows that actual imports move in proportion to the import capacity.

Debt and debt-service ratios are also calculated for hard currency trade. The accounting relation for total Soviet exports to hard currency countries assumes that the USSR does not import Western coal and gas and includes Soviet exports of oil to the West only when they are positive (negative exports mean net imports).

A floor on nonfuel, nongrain imports from hard currency countries is calculated as a fixed percentage of Soviet GNP.

These imports are constrained to stay above the floor by imposing, when necessary, an allocation policy that reduces domestic deliveries of fuels below nominal requirements. This either releases additional fuels for export or reduces requirements for hard currency fuels imports. In either case, capacity to finance nonfuel, nongrain imports increases and so does the projected level of such imports. Reduced allocations of fuels will necessarily lead to a fall in capital utilization rates and thus dampen growth in production.

Exports of fuels to Communist countries are assumed to be determined mainly by political factors and are therefore exogenous. Most of the nonfuel exports to Communist countries consist of raw materials and semifinished goods and requirements for such Soviet exports will depend to a large degree on the rate of economic growth in Eastern Europe. The estimated equation for growth in these exports indicates that Soviet nonfuel exports to Communist countries are very elastic with respect to economic growth in Eastern Europe. Although the Soviet export equation assumes that external East European growth draws Soviet exports to Communist countries, trade between the USSR and its Communist partners also reflects efforts to balance bilateral trade. Therefore, Soviet imports from these countries are assumed to depend on the level of Soviet exports to them. The estimated equation suggests that the Soviet Union tends to subsidize trade with other Communist countries, because the average value of incremental changes in Soviet imports is projected to be lower than the value of the corresponding incremental change in Soviet exports.

Capital goods imported from the West and from other Communist countries are calculated using exogenously specified shares of nonfuel, nongrain imports from the West and nonfuel imports from Communist countries. These shares are generally taken at their 1977 levels, although they can take any form consistent with a particular analysis. These imported capital goods then feed into the productive capital stock of specific producing sectors.

Finally, an overall Soviet trade balance in ruble terms is computed from regional dollar trade data. Separate ruble-dollar indexes are applied to nonfuel exports and imports. In addition, the export index is applied to all fuels trade since it is a better indicator of relative ruble-dollar fuel values. This trade balance in ruble terms becomes the net foreign investment component of GNP in the calculation of private consumption as the residual in GNP by end use.

Table A7

Equation List for the Trade Block

Equation Number	Dependent Variable	Equation	$\overline{R}^2$	Durbin-Watson Statistic
1	Hard currency net exports of gas	Hard currency net exports of gas = gas residual − Communist net exports of gas − other net exports of gas		
2	Hard currency net exports of oil	Hard currency net exports of oil = oil residual − Communist net exports of oil − other net exports of oil		
3	Hard currency net exports of coal	Hard currency net exports of coal = coal residual − Communist net exports of coal − other net exports of coal		
4	Hard currency net exports of fuel	Hard currency net exports of fuel = $\sum_{j=1}^{3}$ (hard currency net exports of fuel j × unit value of hard currency net exports of fuel j)		
5	Communist net exports of fuel	Communist net exports of fuel = $\sum_{j=1}^{3}$ (Communist net exports of fuel j × unit value of Communist net exports of fuel j)		
6	Other net exports of fuel	Other net exports of fuel = $\sum_{i=1}^{3}$ (Other net exports of fuel j × unit value of other net exports of fuel j)		
7	Hard currency grain imports index	Hard currency grain imports index = $0.412 - 0.676 \underset{(-3.08)}{\times}\left(\frac{\text{actual agricultural output}_{(-1)}}{\text{normal agricultural output}_{(-1)}}\right) + 0.0189 \underset{(5.90)}{\times} \text{time}$ (2.04)	0.663	1.30
8	Hard currency grain imports	Hard currency grain imports = hard currency grain imports index × normal agricultural output$_{(-1)}$ × unit value of hard currency grain imports		
9	Debt service	Debt service = 0.320 × medium- and long-term debt$_{(-1)}$		
10	Medium- and long-term debt	Medium- and long-term debt = (new medium- and long-term drawings − 0.640 × debt service) + medium- and long-term debt$_{(-1)}$		
11	Interest	Interest = 0.360 × debt service		
12	Debt service ratio	Debt service ratio = $\frac{\text{debt service}}{\text{total hard currency exports}}$		
13	Total hard currency exports	Total hard currency exports = hard currency nonfuel exports + hard currency net exports of coal + hard currency net exports of gas + hard currency exports of oil		
14	Debt ratio	Debt ratio = $\frac{\text{medium- and long-term debt}}{\text{total hard currency exports}}$		

Table A7 (Continued)

Equation List for the Trade Block

Equation Number	Dependent Variable	Equation	$\overline{R}^2$	Durbin-Watson Statistic
15	Hard currency nonoil, nongrain import capacity	Hard currency nonoil, nongrain import capacity = hard curency nonfuel exports + hard currency net exports of fuels + gold sales + hard currency arms exports + earnings on invisibles + new medium- and long-term drawings − debt service − hard currency grain imports		
16	Hard currency nonoil, nongrain imports	log (hard currency nonoil, nongrain imports) = −0.695 + 1.07 × log (hard currency nonoil, nongrain import capacity) (−1.71) (21.15)	0.963	1.76
17	Total machinery imports	Total machinery imports = imports ruble-dollar ratio × 0.894 × (0.40 × Communist nonfuel imports + 0.54 × hard currency, nonoil, nongrain imports)		
18	Hard currency balance of trade	Hard currency balance of trade = hard currency nonfuel exports − (hard currency, nonoil, nongrain imports + hard currency grain imports) + hard currency net exports of fuels		
19	Current account balance	Current account balance = hard currency balance of trade + hard currency arms exports + gold sales + earnings on invisibles − interest		
20	Basic balance	Basic balance = current account balance + (new medium- and long-term drawings − 0.640 × debt service)		
21	Nonenergy exports to Communist countries	log (nonenergy exports to Communist countries) = −4.08 + 2.70 × log (Eastern Europe GNP) (−7.37) (23.75)	0.979	1.00
22	Nonfuel imports from Communist countries	Nonfuel imports from Communist countries = 0.928 × (Communist net exports of fuel + Communist net exports of power (89.01) × unit value of Communist net exports of power + Communist nonfuel exports)	0.992	1.16
23	Balance of trade with Communist countries	Balance of trade with Communist countries = Communist nonenergy exports − Communist nonfuel imports + Communist net exports of fuel + Communist net exports of power × unit value of Communist net exports of power		
24	Balance of trade with other countries	Balance of trade with other countries = other nonfuel exports − other nonfuel imports + other net exports of fuel		
25	Ruble balance of trade with the world	Ruble balance of trade with the world = exports ruble-dollar ratio × (hard currency nonfuel exports + Communist nonenergy exports + other nonfuel exports + hard currency arms exports + Communist arms exports + other arms exports) − imports ruble-dollar ratio × (hard currency nonoil nongrain imports + hard currency grain imports + Communist nonfuel imports + other nonfuel imports) + exports ruble-dollar ratio × (hard currency net exports of fuel + Communist net exports of fuel + Communist net exports of power × unit value of Communist net exports of power + other net exports of fuel)		

Appendix B
Variable Lists

Table B1

Variable List for The Production Block

Name	Units	Description
Endogenous Variables		
Normal agriculture output	Billion 1970 rubles	Value-added in agriculture sector assuming normal weather
Actual agriculture output	Billion 1970 rubles	Actual value-added in agriculture sector
Consumer goods output	Billion 1970 rubles	Value-added in light industry and food branches of industry
Industrial materials output	Billion 1970 rubles	Value-added in ferrous metals, nonferrous metals and construction materials branches of industry
Other industry output	Billion 1970 rubles	Value-added in forest products branch of industry
Chemicals output	Billion 1970 rubles	Value-added in chemicals branch of industry
Construction output	Billion 1970 rubles	Value-added in construction sector
Machinery output	Billion 1970 rubles	Value-added in machinery branch of industry
Transport and communications output	Billion 1970 rubles	Value-added in transport and communications sector
Trade and services output	Billion 1970 rubles	Value-added in domestic trade and services sector
Gas output	Billion 1970 rubles	Value-added in gas branch of industry
Oil output	Billion 1970 rubles	Value-added in oil branch of industry
Coal output	Billion 1970 rubles	Value-added in coal branch of industry
Electric power output	Billion 1970 rubles	Value-added in electric power branch of industry
Exogenous Variables		
Sown area	Million hectares	Land area sown to grain
Precipitation index	Centimeters	Prescipitation index for representative regions of the USSR
Temperature index	Degrees centigrade	Winter temperature index for Southern Ukraine
Time	Years	1950=1 to 1977=28
Gross gas output	Billion cubic meters	Gross production of natural gas
Gross oil output	Million metric tons	Gross production of crude oil, including condensate
Gross coal output	Million metric tons	Gross production of coal
Gross power output	Billion kilowatt hours	Gross production of electric power

Table B2

Variable List for The Consumption Block

Name	Units	Description
Endogenous Variables		
Total consumption	Billion 1970 rubles	Private expenditures on consumer goods
Consumption per capita	Thousand 1970 rubles	Ratio of total consumption to population
Food consumption	Billion 1970 rubles	Private expenditures on food
Food consumption per capita	Thousand 1970 rubles	Ratio of food consumption to population
Durables consumption	Billion 1970 rubles	Private expenditures on durable consumer goods
Durables consumption per capita	Thousand 1970 rubles	Ratio of durables consumption to population
Gross national product	Billion 1970 rubles	Sum of value added across sectors-of-origin
Sector-of-origin residual	Billion 1970 rubles	GNP not elsewhere classified and statistical discrepancy
Nonpersonnel defense spending	Billion 1970 rubles	Defense expenditures other than for personnel
Exogenous Variables		
Growth in nonpersonnel defense spending	Percent	Annual percentage change in nonpersonnel defense spending
Military manpower	Million persons	Size of armed forces
Population	Million persons	Total population
End-use residual	Billion 1970 rubles	End-use expenditure not elsewhere classified and statistical discrepancy
Government administration share	Percent	Expenditures for administration of government as percent of GNP
Government R&D share	Percent	Government expenditures on research and development as percent of GNP
Time	Years	1950=1 to 1977=28
Earnings on invisibles	Million US $	Net earnings on tourism and transportation and net transfers
Livestock investment	Billion 1970 rubles	Net additions to livestock
Unit wage of military	Thousand 1970 rubles	Ratio of defense expenditure for personnel to military manpower
Invisibles ruble-dollar ratio	Rubles per US $	Mean of the exports ruble-dollar ratio and the imports ruble-dollar ratio

Table B3

Variable List for
The Investment Block

Name	Units	Description
Endogenous Variables		
Investment in the ith sector	Billion 1970 rubles	Expenditures on new fixed investment (NFI) in the ith producing sector
Investment in housing sector	Billion 1970 rubles	Investment expenditures in housing sector
Total new fixed investment	Billion 1970 rubles	Sum of expenditures on new fixed investment across producing sectors and the housing sector
Capital repair	Billion 1970 rubles	Capital repair expenditures
Machinery for investment	Billion 1970 rubles	Deliveries of machinery output to NFI
Construction for investment	Billion 1970 rubles	Deliveries of construction output to NFI
Investment adjustment factor	Percent	Adjusts for discrepancy between total expenditures on NFI and deliveries of machinery and construction to NFI
Exogenous Variables		
Livestock investment	Billion 1970 rubles	Net additions to livestock
Military equipment	Billion 1970 rubles	Expenditures on military equipment
Military construction	Billion 1970 rubles	Expenditures on military construction
Total machinery exports	Billion rubles	Exports of machinery to the world

Table B4

Variable List for
The Capital Formation Block

Name	Units	Description
Endogenous Variables		
Capital in the agriculture sector	Billion 1955 rubles	Average of beginning and end-of-year values of fixed assets in agriculture sector
Capital in the ith sector	Billion 1955 rubles	Value (1 January) of capital in the following producing sectors: consumer goods, construction, transport and communications, trade and services, industrial materials, other industry, gas, coal, and electric power
Domestic capital in the jth sector	Billion 1955 rubles	Value (1 January) of capital minus value (1 January) of imported machinery in the following producing sectors: machinery, chemicals, and oil
Imported capital in the jth sector	Billion 1955 rubles	Value (1 January) of imported machinery in the following producing sectors: machinery, chemicals, and oil
Net capital formation in the ith sector	Billion 1955 rubles	Value of capital for year *t* minus this value for year *t-1* in the following producing sectors: agriculture, consumer goods, construction, transport and communications, trade and services, industrial materials, other industry, gas, coal, and electric power
Net domestic capital formation in the jth sector	Billion 1955 rubles	Value of domestic capital for year *t* minus this value for *t-1* in the following producing sectors: machinery, chemicals, and oil
Net imported capital formation in the jth sector	Billion 1955 rubles	Value of imported machinery for year *t* minus this value for year *t-1* in the following producing sectors: machinery, chemicals, and oil
Exogenous Variables		
5-year plan cycle	None	Equals 1 for the last two years of a 5-year plan and the initial year of the next plan, otherwise equals zero

Table B5

Variable List for The Energy Block

Name	Units	Description
Endogenous Variables		
Coal deliveries to the ith sector	Million metric tons	Allocation of coal to the ith sector
Electric power deliveries to the ith sector	Billion kilowatt hours	Allocation of electric power to the ith sector
Oil deliveries to the ith sector	Million metric tons	Allocation of oil to the ith sector
Gas deliveries to the ith sector	Billion cubic meters	Allocation of gas to the ith sector
Coal deliveries to consumption	Million metric tons	Allocation of coal to private and public consumption
Elecric power deliveries to consumption	Billion kilowatt hours	Allocation of electric power to private and public consumption
Oil deliveries to consumption	Million metric tons	Allocation of oil to private and public consumption
Gas deliveries to consumption	Billion cubic meters	Allocation of gas to private and public consumption
Average allocation of energy in the ith sector	Percent	Allocation of all energy as a percentage of nominal requirements in the ith sector
Coal quality index	Metric tons standard fuel	Metric tons of standard fuel per metric ton of coal
Active capital in the ith sector	Billion 1955 rubles	Capital in use in the ith sector
Coal use adjustment factor	Percent	Index of quantity of capital maintained by a unit of coal
Electric power use adjustment factor	Percent	Index of quantity of capital maintained by a unit of electric power
Oil use adjustment factor	Percent	Index of quantity of capital maintained by a unit of coal
Gas use adjustment factor	Percent	Index of quantity of capital maintained by a unit of gas
Gas residual	Billion cubic meters	Residual of gross gas output after subtraction of domestic deliveries
Oil residual	Million metric tons	Residual of gross oil output after subtraction of domestic deliveries
Coal residual	Million metric tons	Residual of gross coal output after subtraction of domestic deliveries
Power residual	Billion kilowatt hours	Residual of gross electric power output after subtraction of domestic deliveries
Exogenous Variables		
Allocation rate of gas for the ith sector	Percent	Deliveries of gas as percent of nominal requirements in the ith sector
Allocation rate of oil for the ith sector	Percent	Deliveries of oil as percent of nominal requirements in the ith sector
Allocation rate of coal for the ith sector	Percent	Deliveries of coal as percent of nominal requirements in the ith sector
Allocation rate of electric power for the ith sector	Percent	Deliveries of electric power as percent of nominal requirements in the ith sector
Allocation rate of gas for consumption	Percent	Deliveries of gas as percent of nominal requirements for private and public consumption
Allocation rate of oil for consumption	Percent	Deliveries of oil as percent of nominal requirements for private and public consumption
Allocation rate of coal for consumption	Percent	Deliveries of coal as percent of nominal requirements for private and public consumption
Allocation rate of electric power for consumption	Percent	Deliveries of electric power as percent of nominal requirements for private and public consumption
Time	Years	1950=1 to 1977=28
Gross gas output	Billion cubic meters	Gross production of natural gas
Gross oil output	Million metric tons	Gross production of crude oil, including condensate
Gross coal output	Million metric tons	Gross production of coal
Gross power output	Billion kilowatt hours	Gross production of electric power

Table B6

Variable List for
The Employment Block

Name	Units	Description
Endogenous Variables		
Total labor force	Thousands of persons	Members of the population active in the economy
Civilian labor force	Thousands of persons	Total labor force other than military manpower
Agriculture employment	Thousands of man-years	Sum of employment on state and collective farms, and private plots
Nonagriculture employment	Thousands of man-years	Total employment other than agriculture
Employment in the ith sector	Thousands of man-years	Employment in the ith producing sector
Exogenous Variables		
Military manpower	Millions of persons	Size of armed forces
Able-bodied population	Thousands of persons	Population of ages 16 to 59/54
Pensioners	Thousands of persons	Population of pensioners
Able-bodied participation rate	Percent	Percentage of able-bodied population active in the economy
Pensioners participation rate	Percent	Percentage of pensioners active in the economy
Agriculture employment rate	Percent	Agriculture employment as a percentage of the agriculture labor force
Agriculture share of civilian labor force	Percent	Percentage of the civilian labor force in agriculture
Nonagriculture employment rate	Percent	Nonagriculture employment as a percentage of the nonagriculture labor force

This table is Unclassified.

Table B7

Variable List for The Trade Block

Name	Units	Description
Endogenous Variables		
Hard currency balance of trade	Million US $	Balance of trade with hard currency countries
Debt service	Million US $	Sum of payments of principal on medium- and long-term debt and interest on all debt
Medium- and long-term debt	Million US $	Medium- and long-term debt as of 31 December
Grain imports index	Metric tons per thousand 1970 rubles	Ratio of volume of grain imports from hard currency countries to last year's normal agricultural output
Grain imports value	Million US $	Value of grain imports from hard currency countries
Total hard currency exports	Million US $	Value of all merchandise exports to hard currency countries
Interest	Million US $	Interest payments on all debt
Current account balance	Million US $	Current account balance with hard currency countries
Basic balance	Million US $	Basic balance with hard currency countries
Debt ratio	Percent	Ratio of medium- and long-term debt to total hard currency exports
Debt service ratio	Percent	Ratio of debt service to total hard currency exports
Nonoil, nongrain import capacity	Million US $	Sum of earnings from hard currency trade and drawings of medium- and long-term debt, minus the sum of payments for debt service, oil imports, and grain imports
Nonoil, nongrain imports	Million US $	Imports from hard currency countries other than oil and grain
Total machinery imports	Billion 1955 rubles	Imports of machinery from the world
Hard currency net exports of gas	Billion cubic meters	Volume of net exports of gas to hard currency countries
Hard currency net exports of oil	Million metric tons	Volume of net exports of oil to hard currency countries
Hard currency net exports of coal	Million metric tons	Volume of net exports of coal to hard currency countries
Hard currency net exports of fuel	Million US $	Value of net exports of gas, oil, and coal to hard currency countries
Balance of trade Communist countries	Million US $	Balance of trade with Communist countries
Nonenergy exports to Communist countries	Million US $	Exports to Communist countries other than fuels and electric power
Nonfuel imports from Communist countries	Million US $	Imports from Communist countries other than fuels
Net exports of fuel to Communist countries	Million US $	Value of net exports of gas, oil, and coal to Communist countries
Balance of trade other countries	Million US $	Balance of trade with other countries
Net exports of fuel to other countries	Million US $	Value of net exports of gas, oil, and coal to other countries
Ruble balance of trade—world	Million Rubles	Balance of trade with the world in rubles
Exogenous Variables		
Net short-term drawings	Million US $	Drawings of short-term debt minus repayments of principal
Hard currency nonfuel exports	Million US $	Exports to hard currency countries other than fuel
Gold sales	Million US $	Annual sales of gold
Earnings on invisibles	Million US $	Net earnings on tourism and transportation and net transfers
Unit value of grain imports	US $	Ratio of value to volume of grain imports from hard currency countries
Unit value of hard currency net exports of gas	US $	Ratio of value to volume of net exports of gas to hard currency countries

Table B7 (Continued)

Variable List for The Trade Block

Name	Units	Description
Exogenous Variables		
Unit value of hard currency net exports of oil	US $	Ratio of value to volume of net exports of oil to hard currency countries
Unit value of hard currency net exports of coal	US $	Ratio of value to volume of net exports of coal to hard currency countries
New medium- and long-term drawings	Million US $	New drawings of medium- and long-term debt
Hard currency arms exports	Million US $	Exports of arms to hard currency countries
Net exports of gas to Communist countries	Billion cubic meters	Volume of net exports of gas to Communist countries
Net exports of power to -Communist countries	Billion kilowatt hours	Volume of net exports of electric power to Communist countries
Net exports of oil to Communist countries	Million metric tons	Volume of net exports of oil to Communist countries
Net exports of coal to Communist countries	Million metric tons	Volume of net exports of coal to Communist countries
Unit value of net exports of gas to Communist countries	US $	Ratio of value to volume of net exports of gas to Communist countries
Unit value of net exports of power to Communist countries	US $	Ratio of value to volume of net exports of electric power to Communist countries
Unit value of net exports of oil to Communist countries	US $	Ratio of value to volume of net exports of oil to Communist countries
Unit value of net exports of coal to Communist countries	US $	Ratio of value to volume of net exports of coal to Communist countries
Arms exports to Communist countries	Million US $	Exports of arms to Communist countries
Nonfuel exports to other countries	Million US $	Exports to other countries other than fuel
Nonfuel imports from Communist countries	Million US $	Imports from other countries other than fuel
Net exports of gas to other countries	Billion cubic meters	Volume of net exports of gas to other countries
Net exports of oil to other countries	Million metric tons	Volume of net exports of oil to other countries
Net exports of coal to other countries	Million metric tons	Volume of net exports of coal to other countries
Unit value of net exports of gas to other countries	US $	Ratio of value to volume of net exports of gas to other countries
Unit value of net exports of oil to other countries	US $	Ratio of value to volume of net exports of oil to other countries
Unit value of net exports of coal to other countries	US $	Ratio of value to volume of net exports of coal to other countries
Arms exports to other countries	Million US $	Exports of arms to other countries
Exports ruble-dollar ratio	Rubles per US $	Ratio of exports to the world in current rubles to exports to the world in current dollars
Invisibles ruble-dollar ratio	Rubles per US $	Mean of the exports ruble-dollar ratio and the imports ruble-dollar ratio
Imports ruble-dollar ratio	Rubles per US $	Ratio of imports from the world in current rubles to imports from the world in current dollars
Eastern Europe GNP	1965=100	Index of Eastern Europe GNP valued in constant dollars