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A MODEL OF INTERINDUSTRY IN THE USSR

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A quantitative analysis of the development of interindustry flows in the Soviet economy showed that traditional input-output methods needed to be expanded and generalized for use in Soviet medium-term (5-7 year) planning. In particular, it is necessary to account for supply constraints on some products and relative surpluses of others. This paper describes a model which accounts for these influences, fits closely the development of the Soviet economy from 1950 to 1975, and can be and has been used in the exploratory stages of Soviet planning.

The model is based upon eighteen-sector input-output flow tables in comparable 1958 prices for the twenty-six years from 1950 to 1975. The preparation of these tables is described in [1]. Besides the eighteen interindustry columns, the tables have twelve final demand columns for a total of thirty columns. Table 1 lists the sectors with which we shall be concerned, together with the abbreviation used for them in this paper. We shall use Q(i) to refer to the total demand for product i, X(i,j) to refer to the flow from industry i to industry j, and t to be time, measured in years with t = 1 in 1950.

The essence of our method is to replace the traditional input-output equation of the form

Table 1. Sectors of the Model

Number	Abbreviation	Contents
1	ferr	ferrous metals
2	nfer	non-ferrous metals
3	petr	petroleum
4	coal	coal mining
5	gas	natural gas
6	chem	chemicals
7	mach	machinery
8	elec	electricity
9	wood	wood and wood products, paper
10	bmat	building materials
11	light	textiles and clothing, and footwear
12	food	food manufacturing
13	misc	miscellaneous manufacturing
14	cstr	construction
15	agri	agriculture
16	tran	transportation and communications
17	trad	trade
18	othr	other services
20	PCE	Personal Consumption Expenditure
24	CAP	Productive Capital Investment
29	exp	Exports
30	imp	Imports

(1) $$X(i,j,t) = a_{ij}(t) * Q(j,t)$$

by

(2) $$x(i,j,t) = a_o + a_1(t)\ Q(j,t) + a_2(t)\ Q^*(i,t) + a_3(t)\ *(m,n,t) + a_4(t)$$

(where the a's in all equations depend, of course on i and j). The term $a_2(t)\ Q^*(i,t)$ in (2) reflects the influence of supply availability of product i. The $Q^*(i,t)$ may be either

- -- set exogenously
- -- set equal to the demand for product i obtained by summing up all the intermediate and final demand for i. This sum we call $Q(i,t)$ (without an asterisk). Likewise the term

  $$a_3(t)\ X^*(m,n,t)$$

  shows the influence of some *other* inter-industry flow on flow $x(k,j)$. Again, this $x^*(m,n,t)$ can be either taken exogenously or set equal to the $x(m,n,t)$ flow calculated by its own equation.

These equations are designed and estimated if possible to reflect in the model the following:

1. Changes in the structure of economy go in a definite direction for a long period of time. To each stage of economic development, there corresponds the sensible relation between levels and rates of growth in different industries. Accordingly, there is a connection between the levels of input-output coefficients and the rates of growth in a set of industries.

2. The supply of a product influences the input-output coefficients in that product's (industry's) row, and the output of a product can serve as a proxy for its supply. Moreover, the necessary priorities given to one industry

in distribution of a product will reduce the availability of that product and some other goods to the rest of industry. Certainly, on different stages of economic development the system of priorities is changed.

3. Usually, the interaction between dynamics of intermediate flows, reflects the intensity of their substitution, for example, between different types of materials in machinery or between energy sources in electricity generation.

   This process of substitution can be realized in two forms:

   a) New products substitute traditional input-output flows according to some economical and technological reasons, and flows of new materials are in the right side in our equation in that case. In other words, their dynamics determine the changes in growth of traditional resources in our model.

   b) Sometimes there is a shortage in supply of traditional goods in economy and the rate of growth of new goods is stimulated by the total demands for materials according to the level of elasticity of substitution. In that case, the variation in dynamics of traditional flow generates the changes in rates of growth of new goods.

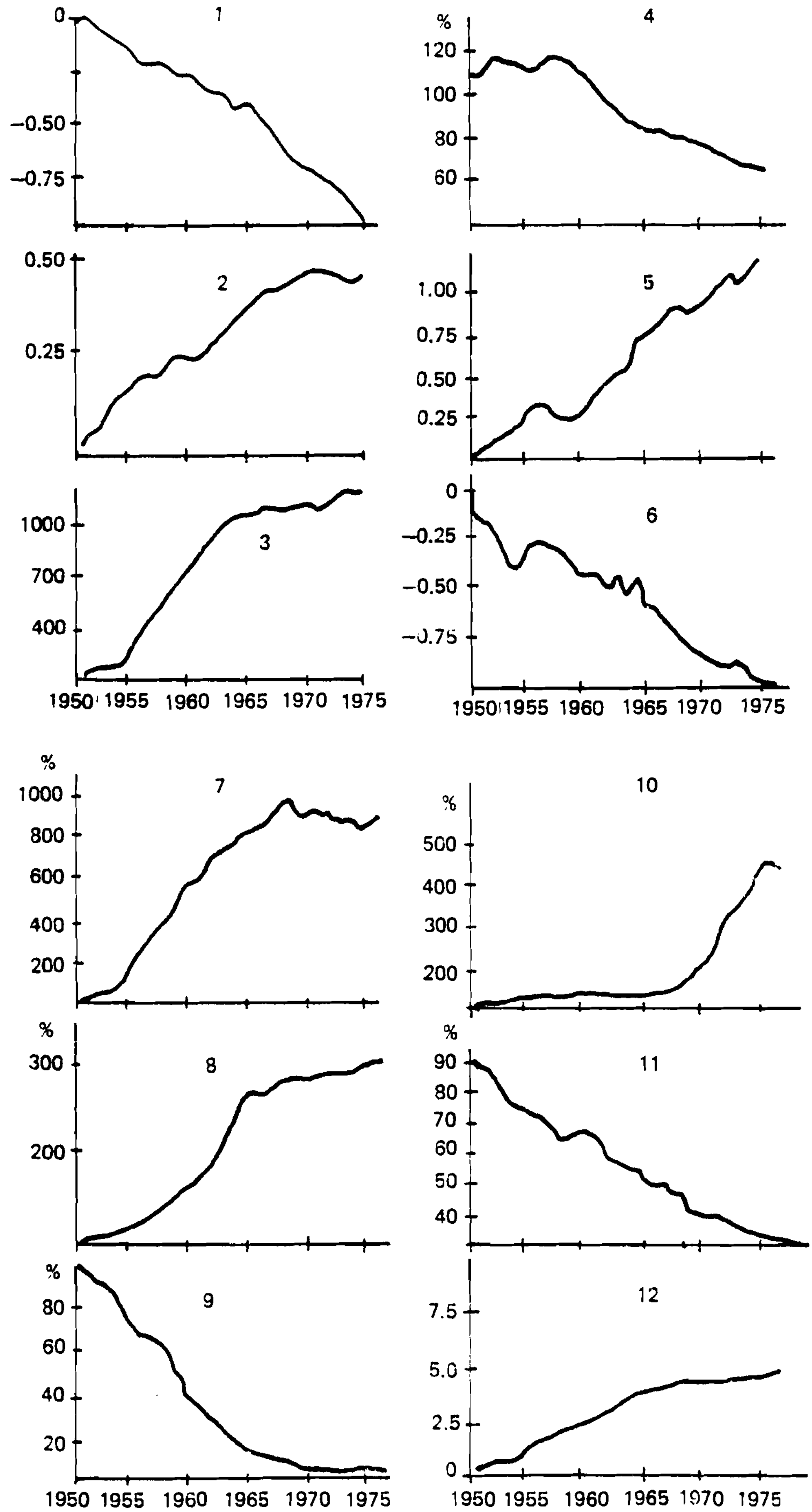
   For example, electricity (a new good) used by transportation enters the equation for coal and oil requirements by this branch of the economy. On the other hand, natural fibre (an old good) enters the equation for chemical fibre demand by the textile industry.

4. Supply factors influence not only intermediate deliveries but also final demand such as personal consumption, investment, exports and imports. For these flows as for the intermediate flows, the explanatory variable may be either the old product in some cases and the new one in others.

Some graphs for input-output coefficients are presented in Figure 1.

Equations of type (2) have been estimated for all of the major flows including flows to elements of final demand. Where a time-variable coefficient is needed, we have used functions

Figure 1.



1. Ferrous metals to machinery (in logarithm scale)
2. Chemical products to machinery (in logarithm scale)
3. New building materials to construction
4. Traditional building materials to construction
5. Chemical products to light industry (in logarithm scale)
6. Agriculture produvts to light industry
7. Petroleum products to light industry (in logarithm scale)
8. Electricity to transportation
9. Coal to transportation
10. Petroleum products to electricity generation
11. Solid fuels to electricity generation
12. Natural gas to ferrous metals (in logarith scale)

of the form $a(t) = b + c/(t+10)$. The asymptotic value will be "b". In principle, the "10" should be an estimated coefficient. In the equations reported here, however, only the value "10" has been used.

It is, of course, entirely possible, that when $Q^*(i,t)$ is picked exogenously in equation (2), the demand for commodity i, $Q(i,t)$ given by the balance equation:

$$Q(i,t) = \sum_j X(i,j,t)$$

will turn out to be different from $Q^*(i)$. On this basis, we can carry out two ways of forecast estimates of the economic structure.

1. Traditional forecast of the industries growth from the exogenous estimates of all elements of the final demand. In that case, the input-output coefficients are not to be exogenous but are the results of the solution. Probably the sum of the compounds of each element of the final demand is not equal to its estimate that we use, for example:

$$\sum_{i=1}^{18} X(i,j,t) \neq Q^*(j,t)$$

   where $X(i,j,t)$ is defined by the equation of type (2) for $j = 19..30$.

2. It is the coordination of the results of separate industry's forecasts and some other exogenous information about the future economic structure. It means that we can estimate the input-output coefficients and the level and the structure of the final demand according to estimates of industry's outputs $Q^*(i)$. Usually, the solution of the model $Q(i)$ is not equal to these $Q^*(i)$.

The design of the interindustry interaction model is sufficiently flexible and we can replace some of the endogenous variables by their exogenous estimates and vice versa.

The determination of the gap between exogenous, initial (on first iteration of solution process) and the solution for industry's output is the significant result of coordination of numerous autonomous estimates of future development. It helps us to judge the efficiency of economic growth because that level is compared with the restrictions for industry's growth.

If we start from a set of final demands and a projection of $Q^*(i)$, and find $Q(i) < Q^*(i)$ then a plan with that level of final demand and that level of capacity expansion in product i will make this product unusually abundant. If, on the other hand, $Q(i) > Q^*(i)$, product i will be unusually scarce in this plan. Such analysis of proposed plans has proven quite useful. It is, of course, also possible to set $Q^*(i)$ equal to $Q(i)$ for all i and compute equilibrium values. All of the equations are linear in the flows and outputs, so no unusual computational problems arise.

In the following section, we set out several of the equations of type (2) and comment on their significance. The model consists of about 120 equations, the first eighteen are the balance equations of type (3), the next sixty are the equations for the input-output flows of type (2), 25 equations of the same form relate to the final demand and the model includes 12 balance equations for all elements of final demand that are of form:

$$Q^*(j) = \sum_{i=1}^{18} X(i,j) \text{ or } Q^*(j) = \text{const}$$

and 18 equations for the estimates of $Q^*(i)$, i = 1, 18, that is:

$$Q^*(i) = Q(i) \text{ or } Q^*(i) = \text{const}$$

So the reduced form of the model can be written and solved as the usual linear system:

$$Q(i,t) = \sum_{j \in J_i} X(i,j,t) + \sum_{j \in \bar{J}_i} a_{ij}(t)\, Q(j,t) + \bar{q}_i(t)$$

where $x(i,j,t)$ for $j \in J_i$ are defined by equations of type 2. $a_{ij}(t)$ for $j \bar{\in} J_i$ are usual input-output coefficients or structural characteristics of final demand elements, and $\bar{q}_i(t)$ are fixed elements of final demands.

AGRICULTURE AND CONSUMPTION FUNCTIONS

The exogenous estimates of the supply side play an especially large role in the agriculture sector and accordingly in the modeling of structure of the personal consumption expenditure. The last term Q*(PCE) is generated from the macro-economic model and depends on the net incomes.

The exogenous estimates of X* (agri, food), Q* (light) and Q* (mach) in our equations are the characteristics of the supply side, Q*(PCE) is generated from the macroeconomic model and it depends on the net incomes.

There are three principal features of interactions between these flows:

1. X (light,PCE) is influenced by the X (food, PCE) because the gap between demand and supply of food products is realized in changes of the demand for textile and clothing, and footwear (with negative sign, respectively). Consequently, it defines the rates of growth of actual X (light, PCE).
2. The level of satisfaction for demand of the flows (indicated above) determines the scale of X (mach, PCE).
3. The growth of the consumption of the "secondary" agriculture products X (food, PCE) limits the demand for primary agriculture products in consumption.

The difference between the exogenous estimate of personal consumption expenditures Q*(PCE) and its solution from input-output model:

$$Q\ (PCE) = \sum_{i=1}^{18} Q(i,PCE)$$

means a difference between the availability and the demand for consumption resources. The time series analysis shows us that the demand for the resources increases more steadily than the agriculture production. In other words, the ensuring of the stable dynamics for some flows means the wide variance in the rate of growth for others. The estimates of coefficients in our equations show that the development of the agriculture has the large weight in the actual structure of consumption expenditures. The traditional way of ensuring steady rates of growth of food industry's products X (food, PCE) means that X (agri,agri) and inventory in the agriculture perform the compensating part. The connection between the resources of growth of industries that form personal consumption expenditures is expressed in long-term trends in its structure. We then have the following functions for it:[1/]

$$X(\text{food, PCE}) = 18264 + 0.300\ PCE + (1,194 - \frac{3.48}{t+10}\ X(\text{agri,food}) + 532t$$

$$v = 1,4; \quad dw = 1,5$$

The equation shows a marginal propensity to spend on food of about two-thirds the present average propensity. The supply variable, X*(agri,food) has a rising coefficient at present only slightly below its asymptotic value of a 1.19 ruble increase in X(food,PCE) per ruble increase in agricultural deliveries to food manufacturers. In addition to the income and supply influence, there is also a positive time trend. For sales of agriculture directly to personal consumption, we find

$$X(\text{agri,PCE}) = 442 + (0.119 + \frac{2.89}{t+10})\,PCE + .091\ Q^*(\text{agri})$$

$$- .346\ X(\text{food,agri}) + 316.5t$$

$$v = 3.4; \quad dw = 2.5$$

The coefficient on PCE is declining to an asymptote forty percent below its 1975 value. Also each additional ruble of manufactured

---

1/ v and dw are average error variance in percentage and Durbin-Watson statistic, respectively.

foods, X(food,PCE), reduces the demand for food purchases directly from farms by 34.6 kopeks. (1 ruble = 100 kopeks.)

Consumer demand for clothing and textiles is also influenced by X(food,agri):

$$X(\text{light},\text{PCE}) = -16104 + .155\ Q^*(\text{light}) + (.217 + \frac{3.81}{t+10})\ \text{PCE}$$

$$- .179\ X(\text{food},\text{agri}) - 174.6t$$

v = 1.6; dw = 1.6 .

A ruble increase in X(food,PCE) reduces X(light,PCE) by 17.9 kopeks as consumers shift their expenditure towards food as more of it becomes available. Increasing the output of light industry, Q*(light), by a ruble increase X(light,PCE) by only 15.5 kopeks. Thus, supply factors appear to be less important in light industry than in food production. Q*(light) is usually taken equal to Q(light). Both the declining time trend and declining coefficient on PCE mark clothing and textiles as typical "necessities".

Both flows enter the equations for consumption of the remaining manufactured items. Their equations are:

For machinery (automobiles, households appliances):

$$X(\text{mach},\text{PCE}) = -107 + 26596/t+10) + .095\ Q^*(\text{mach})$$

$$- .0093\ X(\text{light},\text{PCE}) - .0247\ X(\text{food},\text{PCE})$$

v = 2.2; dw = 2.7

For Chemicals (soaps, cosmetics, medicines):

$$X(\text{chem},\text{PCE}) = 789 - 342/(t+10) + .0434\ \text{PCE} -$$

$$- .0668\ X(\text{light},\text{PCE}) - .0265\ X(\text{food},\text{PCE})$$

v = 4.7; dw = 1.9

For wood products (furniture, paper products):

$$X(\text{wood},\text{PCE}) = 560.3 - 18048/(t+10) + .053\ \text{PCE} - .100\ X(\text{light},\text{PCE}) - .018\ X(\text{food},\text{PCE})$$

$v = 4.5$; $dw = 1.2$

No supply terms appear in the chemicals and paper equations. On the other hand, PCE, the income term, does not appear in the machinery equation where supply, Q(mach), plays the dominant role.

Agriculture Materials

Sales of cotton, wool, and other agricultural products to Light industry follow the equation

$$X(\text{agri},\text{light}) = 3685 - 26063/(t+10) + + .014\ Q^*(\text{agri}) + .0138\ Q(\text{light})$$

$v = 3.2$; $dw = 2.3$

Finally, the important "diagonal" flow from agriculture to itself is determined from

$$X(\text{agri},\text{agri}) = 5435 - 125238/(t+10) + .415\ Q(\text{agri}) - .4988\ X^*(\text{agri},\text{food})$$

$v = 4.9$; $dw = 1.0$

Although, as mentioned, X(agri,food) is often taken exogenously, we also need an equation for it for scenarios where we do not want to pre-specify it. For these cases, we use

$$X(\text{agri},\text{food}) = -1605 + .289\ Q^*(\text{agri}) + .092\ Q(\text{food}) - 1.342\ X(\text{agri},\ \text{light}) + 350.6t$$

$v = 4.1$; $dw = 1.9$

Industrial Materials

With X(agri,light) known, we can proceed to the first of the industrial material equations, namely that for artificial fibers in textiles and plastics in footwear and rainwear:

$$X(chem,light) = -169.1 + .0503\ Q(light) - .299\ X(agri,light)$$
$$v = 14.2; \quad dw = .5$$

Although the equation clearly shows the substitution between natural and synthetic materials, it has a large error, and we may well wish to take X(chem,light) to be exogenous in the following equations for chemicals (plastics, paints, acids) used in machinery.

$$Q(chem,mach) = 1180 + .040\ Q^{*}(chem) + (.100 - 2.137/(t+10)\ Q(mach)$$
$$-.344\ X(chem,light)$$
$$v = 0.7; \quad dw = 2.4$$

This equation makes clear the close connection between the chemicals used in light industry and those used in machinery. A ruble increase in the output of the chemical industry increases X(chem,mach) by only four kopeks, but a one ruble reduction of the chemicals used by light industry allows X(chem,mach) to increase by 33.4 kopeks.

As one would expect, there is a close connection between the chemicals available for machinery and the non-ferrous metals needed in machinery. In fact, a one ruble increase in chemicals to machinery makes possible a 68 kopek reduction in non-ferrous and a 19 kopek reduction in ferrous inputs, as is seen in the two following equations:

$$X(nfer,mach) = 1996 + (.126 - 2.27/(t+10))\ Q(mach)$$
$$- .681\ X(chem,mach) - 3.9t$$
$$v = 3.4; \quad dw = 1.5$$

$$X(ferr,mach) = -51.4 + .346\ Q^*(ferr) + .018\ Q(mach) - .24\ X(nfer,mach) - .19\ X(chem,mach)$$

$$v = 1.3; \quad dw = 2.0$$

The first of these equations shows the coefficient on Q(mach) for non-ferrous to be rising towards an asymptote seventy-five percent above the 1975 value. No supply factor was found necessary in this equation. On the other hand, the supply term, Q*(ferr), plays a major role in the equation for steel inputs into machinery. This latter equation is also noteworthy for the absence of any time trend.

Steel used in machinery cannot be used in construction, a fact reflected the next equation:

$$X(ferr,cstr) = -130.5 + .26\ Q^*(ferr) + .0043\ Q(cstr) - .31\ X(ferr,mach) - 26.7t$$

$$v = 2.0; \quad dw = 2.7$$

Availability of steel for construction slightly reduces inputs of other building materials.

$$X(bmat,cstr) = -1013.4 + .561\ Q^*(bmat) - .146\ (X(ferr,cstr) + X(mach,cstr)) + 231.3t$$

$$v = 1.0; \quad dw = 1.9$$

Note the absence of a demand term and the strong role played by the supply term.

Energy

The story of substitution of coal by oil and gas is clearly shown in the equation of the energy sector. First, the flow of petroleum products into transportation is entirely determined in the model by supply considerations and time trend.

$$X(petr,trans) = -478 + .075\ Q^*(petr) + 71.2t$$

$$v = 6.2; \quad dw = 1.0$$

Similarly, the flow of petroleum products into agriculture is determined by supply and a measure of mechanization in agriculture, X(mach,agri):

$$X(petr,agri) = -1186 + (-.118 + 11.14/(t + 10))\ Q^*(petr) + .868\ X(mach,agri) - 142.1t$$

$$v = 3.7; \quad dw = 1.6$$

The first of these flows, petroleum products to transportation, has made possible the shift away from coal for railroad power. This influence appears in the equation:

$$X(coal,trans) = 38.8 + .117\ Q^*(coal) + .066\ Q(trans) - .4531\ X(elec,trans) - .863\ X(petr,trans)$$

$$v = 2.6; \quad dw = 1.9$$

Here, electricity to transport also reduces the direct coal inputs. This flow is determined by the equation:

$$X(elec,trans) = -112.4 + (-.0462 + 3.61/(t + 10))\ Q^*(elec) + (.09/(t + 10)\ Q(trans) - 20.0t$$

$$v = 1.7; \quad dw = 1.4$$

This equation shows a declining coefficient both on the supply factor and on the demand term.

The reduction in coal use by railroads has made possible the increase in coal use by electricity:

$$X(coal,elec) = 432 + .1545\ Q^*(coal) + .0465\ Q(elec) + (.300 - 14.6/(t + 10))\ X(coal,trans)$$

$$v = 2.3; \quad dw = 2.2$$

And the increase in coal use in electrical generation has reduced electricity's requirements for natural gas:

$$X(gas,elec) = 64.1 + (.114 + .35/(t+10))\ Q^*(gas) - .178\ X(coal,elec)$$

$$v = 5.5; \quad dw = 2.4$$

The use of fuel oil in electrical generation is then given by

$$X(petr,elec) = -186.2 + .112\ Q^*(petr) + .27\ Q(elec) - .65\ (X(petr,agri) + X(petr,trans)) - .23\ X(coal,elec)$$

$$v = 9.3; \quad dw = 1.4$$

Thus, the use of oil products in agriculture and transportation reduce the oil available for electrical generation, while the use of coal in this industry reduces the need for oil.

In ferrous metals, the principle effect in energy supply is the substitution between natural gas and coal as shown by the following two equations:

$$X(gas,ferr) = 124 + .059\ Q^*(gas) + .026\ Q(ferr) - 9.8t.$$

$$v = 2.6; \quad dw = 2.1$$

$$X(coal,ferr) = 374 + (.022 - .327/(t+10)\ Q^*(coal) + .086\ Q(ferr) - 1.93\ X(gas,ferr)$$

$$v = 1.3; \quad dw = 2.2$$

Note that one ruble of gas reduces coal inputs by 1.93 rubles.

The flow of machinery equipment to productive capital investment depends mainly on x(ferr,mach):

$$X(mach.,CAP) = -1{,}0 + 0{,}0792\ Q\ (CAP) + 0{,}0858Q^*(mach) + 1{,}735\ x\ (ferr,mach)$$

The machinery has the great gap between volumnes of total primary material inputs and output but the dynamics of equipment deliveries is close to change in the flow of ferrous metals.

Equations for the second element of investment has the same feature:

$$Q(cstr,CAP) = 26,9 - \frac{297,25}{t + 10} + 0,0787\ Q(CAP) + 0,0018Q^*(mach) + 1,242\ x\ (bmat,cstr) \quad .$$

These two equations describe roughly the trends in interaction between the available investment resources and the demand for the accumulation. If we have the exogenous estimate of Q(CAP) it will determine mostly the level of Q(cstr,CAP) than the dynamics of Q(mach,CAP). It depends on specific circumstances of growing their part in actual investment. The including of Q^*(mach) in both equations coordinates partly the dynamics of both of them. The estimate of difference between supply and demand for investment is produced by placing the exogenous x^*(ferr,mach), x^*(bmat,cstr) and Q^*(mach) in the equations and comparing the sum of x(mach,CAP) and x(cstr,CAP) with the exogenous level of Q^*(CAP).

A great many different hypothese were tested while developing export and import equations. The export equations proceed from the assumption that machinery exports are ratehr limited. This scarcity is compensated by raising both traditional raw materials and oil and gas exports. The imports may be divided into three groups. Group 1 includes imported raw materials and semi-fabricated goods. Their volume is determined to balance the needs of manufactuing industries with domestic supply. They fall if domestic supplies rise. Group 2 consists of machinery and chemicals which supplement domestic production and grow with it. The third group consists of light and food industry's products. Their dynamics is in close relation with the consumer's demand and the rates of growth of the primary agriculture products. Minor flows to final demand are estimated by the coefficients or exogenously.

Uses and Future Directions

This model is really many models, for any $X^*(j)$ appearing on the right side on one of the equations can either be taken exogenously or be set equal tot he $X(j)$ resulting from the balance equation. The same is true of any interindustry flow, $X(m,n)$, on the right side of any equation. Thus, the model lends itself to the study of many questions arising in practical planning. What are the effects on the demand for steel of a good harvest that increases food available to consumer? What effect does a change in the electricity allocated to transportation have on the demand for coal? How does changing the allocation of agricultural products to light industry (textiles) affect the input of ferrous metals into machinery? The traditional input-output model can answer these questions only from the demand side, and the answer to the last would certainly be "almost not at all". But our model also includes supply considerations; the increase in natural fiber input releases chemical capacity for making plastics which replace metals in machinery. Of course, the model is also useful for testing the consistency of plans. If we take $Q^*(petr)$ exogenously, we can calculate $Q(petr)$ from the balance equation. If $Q < Q^*$, then the planned resources will more than satisfy the demand for petroleum. If $Q^* < Q$, then in view of the influence of one or another factor on the development of this branch, a deficit in its production is possible.

The present model also includes a number of equations for compoments of exports, imports, and capital investment. Some of these are below. Plans for future development include:

- -- Simulation testing of the model over the sample period.
- -- Inclusion of equations for primary resources (labor, capital)
- -- Dynamic relations and branch production functions to reflect the influence ont he output of a sector of a deficit in one of its inputs.
- -- Integration with a macro model of the growth rate and distribution of final demand.
- -- Construction of a current-price and also a disaggregated variant of the model using natural units where possible.

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