THE PROJECTION OF SOVIET INPUT-OUTPUT STRUCTURE BY MEANS OF VINTAGE COEFFICIENTS

Final rept.

June 1978

Technical Note
SSC–TN–5943–2

By: Daniel L. Bond
Everett J. Rutan (WEFA)

Prepared for:
Office of Economic Research
Central Intelligence Agency
Washington, D.C.

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SRI Project 5943

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ABSTRACT

In this report, a technique for projecting input-output coefficients is presented, and the results of applying this technique to Soviet data are analyzed. The basic assumptions of the approach used are that the material input requirements of each branch of production are determined by the technology embedded in the capital stock used in that branch, and that, once installed, the technology of each vintage of capital is fixed.

Thus, the process of coefficient projection consists of two phases. In the first phase projections are made of input coefficients associated with each future vintage of capital. Then, in a second phase, the coefficient structure characterizing the total capital stock in each branch is calculated. These latter coefficients are determined in each year as a weighted average of the coefficients of the various vintages, where the weights are the share of the corresponding vintage of capital in the total capital stock of that year.

The projection of the vintage coefficients is based on exprapolation (using logistic functions) of time trends in vintage coefficient derived from Soviet input-output data for 1959, 1966, and 1972 (after these had been converted to a constant, producer price basis). The calculation of future average coefficients used projections of capital stock formation obtained with the SRI-WEFA Soviet Econometric Model (SOVMOD).

FOREWORD

In various types of quantitative analysis of the Soviet economy, and particularly those involving econometric models, there is a need for detailed information on the structure of interindustry relations. As part of an on-going effort to meet this need, researchers of the Foreign Demographic Analysis Divison (Department of Commerce), the Office of Economic Research (Central Intelligence Agency), Wharton Econometric Forecasting Associates, Inc., and SRI-International have undertaken the task of making usable data from Soviet input-output accounts. As part of a study supported by the Office of Economic Research, the SRI-WEFA team has used the reconstructed 1959, 1966 and 1972 Soviet input-output tables (prepared at the FDAD) as a basis to prepare a time series of constant price accounts interpolated over the historic period (1959-1972), and projections of input-output structure to 1985. This paper presents the techniques used to prepare the 1973-1985 projected input-output coefficients.

The analysis was conducted by Everett Rutan and Daniel Bond. The authors wish to acknowledge the ideas and assistance provided by Yacov Sheinin and Gene Guill.

Richard B. Foster.
Senior Director
Strategic Studies Center

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I Introduction

In recent years, several attempts have been made to integrate input-output analysis with macroeconometric models. The Brookings model, the Maryland Interindustry Forecasting Model, and the Wharton Annual and Industry Forecasting Model provide examples of various forms of such integration for models of a market economy. In the early stages of development of the SRI-WEFA Soviet Econometric Model (SOVMOD), the decision was made to explore the possibilities for utilizing an input-output component within the macro-model. The impetus for this endeavor came from various sources. First and foremost was the valuable technological detail that input-output adds to a macroeconometric model, especially one of the Soviet Union, in which supply constraints play such an important role. Second was the availability of usable input-output accounts for the Soviet economy which was provided by the ongoing efforts of Dr. Vladimir Treml working with researchers of the Foreign Demographic Analysis Divison (Department of Commerce) and Duke University on the reconstruction and analysis of Soviet input-output statistics. Third was the fact that input-output models had already been used for various types of studies of the Soviet economy by analysts in several U.S. Government agencies, so these techniques were familiar, and to some degree, of proven utility. And fourth, the substantial research efforts within the Soviet Union during the 1960's and early 1970's on the use of input-output techniques for planning and the extensive Soviet economic literature describing this work created the basis for a new conceptualization of the workings of a planned economy--a conceptualization which found expression in both Soviet and Western literature via the description of the planning process in terms borrowed from input-output economics.

The initial research on SOVMOD was oriented toward the modeling of behavioral responses (of both individuals and the bureaucracy) with essential technological relations formulated in non-input-output terms. Parallel to this early modeling work, substantial effort and progress was made in developing a sequence of balanced annual input-output tables for the period 1959-1972, and in the testing of techniques for modeling input-output coefficient change. Thus, one of the barriers to the use of input-output techniques--unavailability of time series data--was being overcome.

Given that a macroeconometric model of the Soviet economy already existed, there were numberous ways in which an input-output component could be introduced into the existing framework. Each approach differs in the role played by the input-output sector, and each presents its own problems of data availability and computational difficulty. In the initial integration studies, the input-output component was designed to interact with the production functions in the determination of sectoral outputs. This interaction was carried out by introducing material inputs as a third factor, along with labor and capital, in the production functions and utilizing the input-output component in the endogenous determination of a vector of material input flows. The calculation of material inputs in this manner enabled the model to account for the structural interdependencies among the producing sectors. The first empirical test of this integration scheme was conductd using constant 1972 coefficients over the projection period. The results of this exercise found that the exogenous input-output component imposed a "leveling" effect on sectoral growth rates which rendered unbalanced or disproportional development more difficult to maintain.[1/] Although the constraints imposed by this input-output system were partially valid, it was not possible to separate the effects of the introduction of sectoral interdependencies into the model from the assumption of unchanging structural relationships among the sectors of the model.

An alternative approach has been studied in which the input-output relations are determined endogenously in response to information generated within the macromodel. This approach is similar to that used in the Wharton Annual Model, where material input substitution is induced by price changes. Due to the inappropriateness of Soviet official prices, and lacking a means for deriving meaningful shadow prices. it was necessary to resort to average wage rates as the explanatory variables in the coefficient change equations.[2/]

[1/]These results are reported in Green, Guill, Levine and Miovic, "An Evaluation of the 10th Five-Year Plan Using the SRI-WEFA Econometric Model of the Soviet Union," in JEC, Soviet Economy in a New Perspective (1976).

[2/]This research has been presented in Gene Guill, "Input-Output Within the Context of the SRI-EFA Soviet Econometric Model," in Vladimir G. Treml, ed. Studies in Soviet Input-Output Analysis (New York: Praeger Publishers, 1977).

At the present time, a third alternative is being examined, one in which the input-output component serves as one part of a comprehensive balancing and adjustment mechanism for SOVMOD. In this appraoch either exogenously or endogenously determined intermediate input requriements are combined with information on final demand and net trade to measure total demand by sector. This is then compared with total domestic supply as obtained from the sectoral production functions. The appearance of any imbalances then initiates a process of adjustment in both supply and demand components.[3]

In order to meet the needs for this continuing research in the integration of input-output into the macroeconometric model, further work was necesry on the input-output database. One such area was the conversion of the series of reconstructed and interpolated tables from current prices to constant prices. This has now been completed and the methods and results of this effort reported elsewhere.[4] The second area was the development of techniques to use in projecting Soviet technological coefficient change, when these data were to be introduced into the model exogenously.

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[3] See Daniel L. Bond, "Initial Testing of a Disequilibrium Adjustment Mechanism for CPE Macroeconometric Models," Draft Final Report, SSC-TN-5943-3.

[4] See Vladimir G. Treml, "Price Indexes for Soviet 18-Sector Input-Output Tables for 1959-1975," Draft Final Report, SSC-TN-5943-1, and Gene Guill, "Deflation of the 18-Sector Soviet Input-Output Tables," Draft Final Report, SSC-TN-5943-4.

II The Projection of Technological Coefficient Change

The purpose of this paper is to explain the method used to generate our projections of Soviet technological coefficient change. Basically, we assume the material input structure of each branch of the economy is determined by the nature of its capital stock, and we use the "putty-clay" hypothesis that allows for changes in the technological characteristics of new capital, but requires that once installed the chosen technology for each vintage of capital be treated as fixed. Thus the process of coefficient projection consists of two phases. In the first phase projections are made of input coefficients associated with each future vintage of capital. We will call these vintage coefficients. Then, in a second phase, the coefficient structure characterizing the total capital stock in each branch is calculated. These average coefficients, which are simply the branch input-output coefficients in common usage, are determined in each year as a weighted average of the vintage coefficients, where the weights are the share of the corresponding vintage of capital in the total capital stock of that year. Thus,

$$(1) \quad a_{ij,t} = \sum_{v=t-n}^{t} \tilde{a}_{ij,v} \left(\frac{KI_{j,v}^{t}}{K_{j,t}}\right)$$

where $a_{ij,t}$ is the coefficient of input from sector i to sector j in period t; $\tilde{a}_{ij,v}$ the vintage input-output coefficient for capital put into use in period v, that is capital of vintage v; $KI^{t}_{j,v}$ is the value of capital stock put into use in sector j at time v and which remains in use in period t; and $K_{j,t}$ is the total capital stock in branch j at time t. Note that this definition embodies an assumption of constant capacity utilization of capital at all times and across all branches and vintages.

In terms of the variables defined above, the first phase of coefficient projection is to forecast values for the $\tilde{a}_{ij,v}$, and the second phase is to calculate the $a_{ij,t}$. This requires projection of the necessary capital stock variables (both total capital and vintage capital) and knowledge of the historic values of $K_{j,t}$, $KI^{t}_{j,v}$ and $\tilde{a}_{ij,v}$ for a number of years prior to the projection base year (theoretically for n years, where n is the maximum useful life of capital).

Data on these historic vintage coefficients can also be useful in their projection, especially in cases where the only practical way to forecast these coefficients involves some mechanical extrapolation based on historic trends. If time series of input-output coefficients and capital stock variables are available, historic values of vintage coefficients can be calculated from (1) as follows:

$$\text{(2a)} \quad \tilde{a}_{ij,t} = \frac{a_{ij,t} - \sum_{v=t-n}^{t-1} \tilde{a}_{ij,v} \left(\frac{KI^{t}_{j,v}}{K_{j,t}}\right)}{\left(\frac{KI^{t}_{j,t}}{K_{j,t}}\right)}$$

The calculations are recursive, starting with t equal to the first year of the historic time-series. The obvious difficulty with this formula is that we must assume some values for the coefficients of the vintages of capital already put into use prior to the first period. As Sheinin[5] has proposed, a practical approach is to assume that the older vintages require the same inputs as the initial branch average, $a_{ij,o}$. Then each successive vintage coefficient may be calculated as:

$$\text{(2b)} \quad \tilde{a}_{ij,t} = \frac{a_{ij,t} - a_{ij,o}\left(\frac{KI^{t}_{j,o}}{K_{j,t}}\right) - \sum_{\substack{v=t-n \\ v>0}}^{t-1} \tilde{a}_{ij,v}\left(\frac{KI^{t}_{j,v}}{K_{j,t}}\right)}{\left(\frac{KI^{t}_{j,t}}{K_{j,t}}\right)}$$

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[5] Yacov Sheinin, "The Production Process for the Industry Level," Preliminary draft, Wharton Econometric Forecasting Associates, Inc., October 1977.

The degree of error introduced by this approach will diminish for later periods when long sample time-series of coefficients are used. (It is also possible that an improvement in estimation can be achieved by using the initial vintage coefficient estimates to extrapolate to periods before t = 1, and use these estimates to recalculate the vintage coefficients for t > 1.)

The distinction between technological coefficients of a branch in a given year, and the technological coefficients associated with each vintage of capital in a given branch is important for a number of reasons. First, the distinction is necessary if we wish to project coefficients in a way relating changes in the technological characteristics of capital (and thus input-output coefficients) to relative price changes for material inputs. In a "putty-clay" world, the impact of any price-responsiveness is centered in new capital. The degree of impact on the economy as a whole is transmitted to the degree of, and at the speed of, change in the capital stock. Thus a realistic specification requires that price-responsive coefficient change be focused on the process of investment and new capital formation, and that the general impact of such responses be expressed through the gradual change in average branch coefficients resulting from the cumulative effect of these incremental adjustments. This necessitates the distinction between vintage and average coefficients. Also, if we wish to econometrically estimate the responsiveness of coefficients to relative input price changes, it is likely that we will be successful only if we use vintage, not average, coefficients as our dependent variables.

There are also advantages to making this distinction if we choose to project coefficient change in a non-price-responsive manner. Here we must rely upon historical data or engineering studies as a guide to possible future paths of coefficients. In both cases, only vintage coefficient data is appropriate. In engineering studies, projections of technology are provided in this form, as they apply only to new capital. And in trend extrapolation, where one assumes that technological change will continue at a pace and direction similar to that observed in the recent past, average coefficients stand once removed from technological trends. Transformation of the capital stock is an intervening process, and unless one assumes that the rate of change of capital stock remains constant, technological change cannot be related directly to average coefficients, only to vintage coefficients.

This is best illustrated by reference to Figure 1 below.[6/] Here we see that if we were to project future levels of the <u>average</u> coefficient by simple extrapolation, we would project along a line such as A. Within the framework of the "putty-clay" assumptions, these projected values are inconsistent with average coefficients calculated on the basis of extrapolated vintage coefficients. Average coefficients obtained from this latter method would lie along paths such as B and C.

[6/] This example, in which the slopes of the two coefficient paths have an opposite sign, illustrates the most striking case for the following argument in that the path of extrapolated coefficients would diverge. But even if only the angle of the slopes differed, the results still hold. (The only case where the two paths can coincide is when the vintage coefficient is constant over time and equal to the average coefficient.)

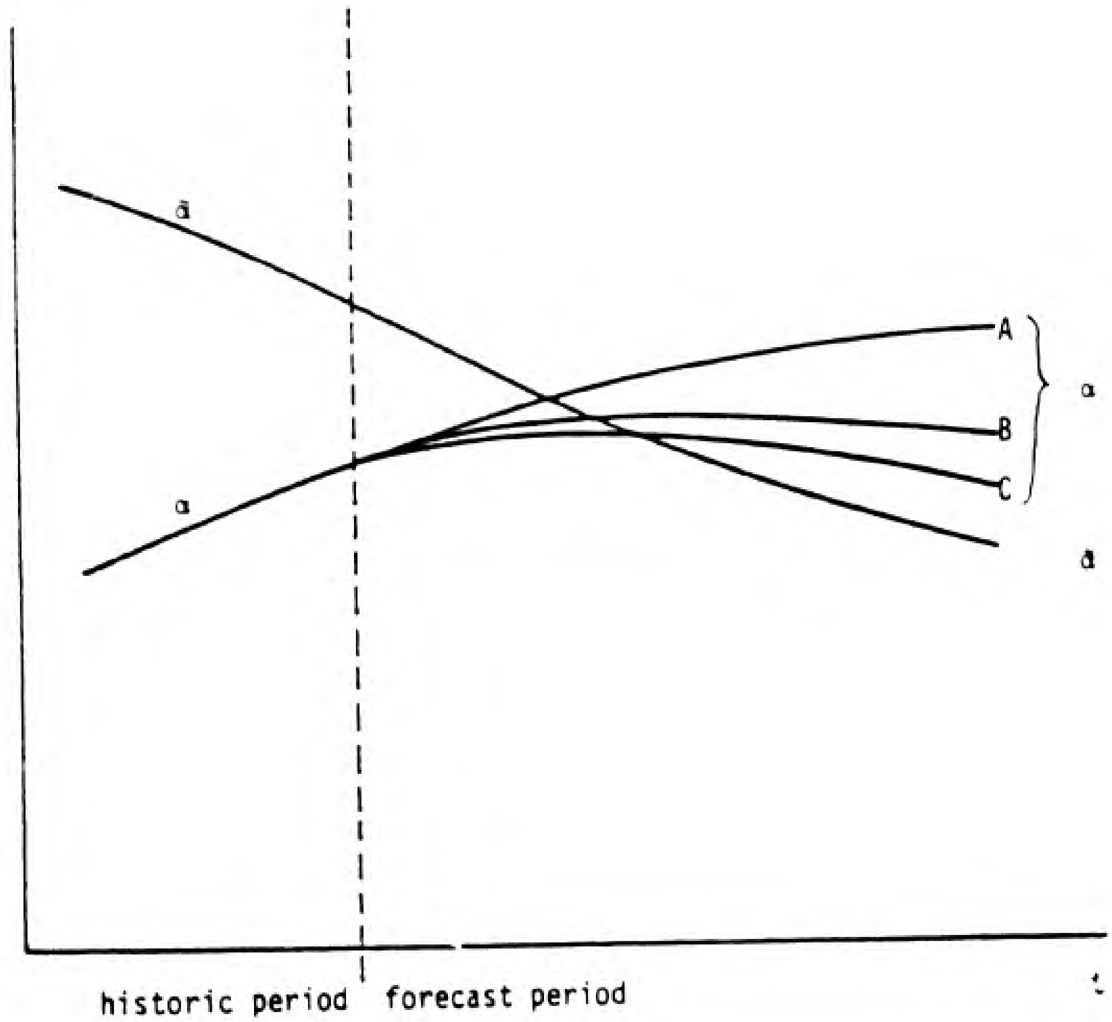

Figure 1

Projection of Technological Change

There is more than one alternative as different projections for capital stock will yield different projections for average coefficients, even where the vintage coefficient projection is unique. The more rapid the transformation of capital stock - as determined by rate of depreciation and investment - the more rapidly will calculated average coefficients approach the projected vintage coefficients. In this example, C is

Since this same type of relationship between the rate of average coefficient change and speed of capital transformation holds in the historic period as well as in future periods, any projection of average coefficients made without consideration of those relative rates of change is open to error. If technological progress is assumed to proceed in a direct relation to time, and if new technology is embedded in new capital, then we have some basis for projecting vintage coefficients as a function of time. But unless we further assume that capital stock transformation is also strictly time dependent, average coefficients cannot be projected as a function of time.

A final application for the distinction between average and vintage coefficients is to implement the concept of "best practice" technology in coefficient forecasting. It has been suggested that the average technology at some point in the future approximates what is the "best practice" technology today. As this level of technology is usually defined as that embedded in the newest forms of capital, it can be estimated by our vintage coefficient for the latest observation year. Then, by holding future vintage coefficients constant at this level, we can estimate the speed at which the average coefficient approaches this "best practice" technology based on forecasts of capital transformation.

III Application of the Approach to Soviet Data

When one attempts to apply the techniques discussed above to coefficient projection using Soviet data, several difficulties arise. Official Soviet national input accounts are available only in incomplete form, in current purchasers prices, and for three years (1959, 1966, 1972). Extensive efforts at reconstruction and adjustment of these accounts have resulted in estimates of complete producers'-price tables for these years. As part of the SRI-WEFA Soviet Econometric Model Project a time series of tables in constant-price form for the period 1959-1975 have been generated from these reconstructed tables, using a combination of linear interpolation and weighted RAS balancing.[7/] The annual data required by this procedure - observations on sectoral gross value of output and material inputs for the intervening years - was largely constructed from sebestoimost (cost structure) data available in periodic Soviet statistical publications. These tables were then deflated to constant 1970 prices, and form one set of estimates of the 1959 through 1972 input-output tables.

[7/] The weighted RAS algorithm was designed to distribute the adjustments across the coefficient matrix according to the stability of individual coefficients.

However, the weighted RAS algorithm does not insure a smooth time series of coefficients. Because the 1966 table is reconstructed, and the 1965 and 1967 tables are interpolated, many coefficients show abrupt changes over these years. When used to calculate vintage coefficient time series the results are less than ideal. As there is no way, given existing data limitations, of determining the true average (or vintage) technological coefficients for years other than 1959, 1966 and 1972, we chose, within reason, estimates which would fit the theory described above. Average coefficients for the intervening years were estimated using a piecewise quadratic polynomial on each interval, 1959 through 1966 and 1966 through 1972. These polynomials were required to yield the known reconstructed average coefficients, and to have the same first derivative for the year 1966. That derivative was estimated as the average rate of change between the 1959 and 1972 coefficients.[8/] This technique is the mathematical analog to laying a thin metal strip on a graph of the three known coefficients and bending it just enough to touch all of them, taking the points on the strip as estimates for the intervening years. The result is a smooth time-series for each average coefficient. Unfortunately, use of quadratic polynomials tends to cause a greater absolute rate of change at either end of the time series as compared to the middle.

[8/]The choice of this estimate for the slope is arbitrary. We could just as well have chosen the slope of the regression line determined by the three points. Any value between the slopes of the lines defined by the pair (1959, 1966) and the pair (1966, 1972) would be reasonable. Tending to either limit will cause the approximation to be more nearly linear on that interval. By choosing the slope of the line defined by the (1959, 1972) pair, we take the average of these limits, and accept the same degree of non-linearity, in some sense, on each interval.

Thus a vector of 14 "observations" of average coefficients is used to generate estimates of vintage coefficients. This is adequate to meet our data needs, providing minimal degrees of freedom for estimation and projection. Of course, we have generated these vectors on the basis of complex transformations of only three, imperfect, observations.

There is no way around the problem created by lack of direct time series observations for input-output flows; if we wish to use the data available and make predictions on their basis, we must accept their weaknesses. The point to be emphasized is that even greater errors are to be expected if we attempt to project coefficient change using only average coefficient data than are likely from using vintage coefficient data, even if the latter require the use of approximate time series estimates.

A second data problem that must be faced in order to estimate vintage coefficients is the lack of direct information on capital stock of particular vintages still in use at a given time. We do have time series of total capital stock and capital stock put into use in each year. What we do not have is direct information on the physical depreciation rate of each vintage. Even assuming a single rate (or time path) of depreciation is applicable to all vintages, the task of obtaining the average rate for each industry remains.

There is also a question of the composition of capital. Various forms depreciate at different rates, and technological input characteristics may be embodied differently in each form. Here, once again, a pragmatic solution suggested by Sheinin[9/] seems most useful. He suggests that a distinction be made between capital stock in structures and in machinery. The technological (input-output) characteristics of an industry are assumed to be embodied in its machinery and equipment, and the stock of structures are treated as a requirement given the equipment stock. Adopting this approach, the variables K_t and $KI_{j,t}$ would refer only to the stock of machinery in total and by vintage.

This scheme makes the choice of an a priori physical deprecation rate somewhat easier, since we are now concerned only with the depreciation rate for machinery in each industry. The rates actually used, a constant for each industry, were derived by assuming that machinery depreciates three times as fast as structures, and assuming that the overall depreciation rate for each industry was the share-weighted average of the machinery and structure depreciation rates for that industry. The shares in each industry were assumed to remain constant at the 1966 values, for which we have information. (See Table 1.)

Note that given a constant rate of depreciation, d_j, in each industry, the formulas for calculating average and vintage coefficients simplify considerably. As

$$(4) \qquad KI^{t+1}_{j,v} = (1-d_j)\, KI_{j,v}$$

[9/] Y. Sheinin, op. cit.

Table 1

Derivation of Machinery Depreciation Rate

	INDUSTRY	AVERAGE DEPRECIATION RATE	SHARE OF MACHINERY	MACHINERY DEPRECIATION RATE *
1.	Metallurgy	.05	.550	.071
2.	Coal and Peat	.03	.742	.036
3.	Oil	.025	.759	.030
4.	Gas	.025	.779	.029
5.	Electrical Power	.02	.651	.026
6.	Machine Building and Metal Working	.05	.555	.071
7.	Chemicals	.04	.581	.056
8.	Timber and Wood Products	.045	.591	.062
9.	Paper	.045	.484	.069
10.	Construction Materials	.04	.625	.053
11.	Consumer Soft Goods	.05	.491	.076
12.	Processed Foods	.05	.513	.074
13.	Industry Not Elsewhere Classified		not available	
14.	Construction	.06	.319	.110
15.	Agriculture	.05	.466	.078
16.	Transportation and Communication	.025	.649	.033
17.	Trade and Distribution	.02	.744	.024
18.	Other		not available	

* Under the assumption that machinery depreciates three times as fast as structures, if r, s_m and r_m denote the average depreciation rate, the share of machinery and the depreciation rate of machinery, respectively, then

$$r = (1-s_m) \left(\frac{r_m}{3}\right) + s_m r_m$$

and therefore

$$r_m = (3r) / (1 + 2 s_m)$$

and we have

$$(5) \qquad \sum_{v=t-n}^{t-1} \tilde{a}_{ij,v} \left(\frac{KI^{t}_{j,v}}{K_{j,t}}\right) = a_{ij,t-1} \, (1-d_j) \, \frac{K_{j,t-1}}{K_{j,t}}$$

which implies

$$(6) \qquad a_{ij,t} = \tilde{a}_{ij,t} \left(\frac{KI^{t}_{j,t}}{K_{j,t}}\right) - a_{ij,t-1} \, (1-d_j) \, \frac{K_{j,t-1}}{K_{j,t}}$$

which, as the capital shares sum to 1, becomes

$$(1') \qquad a_{ij,t} = \tilde{a}_{ij,t} \left(\frac{K_{j,t} - (1-d_j) \, K_{j,t-1}}{K_{j,t}}\right) + a_{ij,t-1} \, (1-d_j) \left(\frac{K_{j,t-1}}{K_{j,t}}\right)$$

This year's average coefficient is the share-weighted average of this year's vintage coefficient and last years average coefficient, and we need not directly compute vintage capital stocks. Similarly

$$(2') \qquad \tilde{a}_{ij,t} = \frac{a_{ij,t} - a_{ij,t-1} \, (1-d_j) \left(\frac{K_{j,t-1}}{K_{j,t}}\right)}{\left(\frac{K_{j,t} - (1-d_j) \, K_{j,t-1}}{K_{j,t}}\right)}$$

Note also that by assuming a constant share of machinery, s_j, in each industry, as all capital terms occur in ratios, we no not need to calculate machinery stocks except indirectly, as

$$(7) \qquad \frac{s_j K_{j,t}}{s_j K_{j,t}} = \frac{K_{j,t}}{K_{j,t}} \quad \text{and} \quad \frac{s_j K_{j,t-1}}{s_j K_{j,t}} = \frac{K_{j,t-1}}{K_{j,t}}$$

In two sectors, 13 --Industry Not Elsewhere Classified--, and 18 --Other--, capital stock series were not available. In the other industries, in order to obtain usable estimates of the vintage coefficients, the historic capital stock time-series were smoothed by fitting an exponential curve for the years 1959 through 1972.

IV <u>Vintage Coefficient Projection</u>

We have approached the problem of projecting coefficients with the belief that in most cases we should not attempt to directly incorporate a model of price-responsiveness for input choice in SOVMOD. This stems partly from our conception of the Soviet economy as a disequilibrium system, and from past poor results in efforts to establish econometrically price-responsive behavior. But more so it is due to the absence in SOVMOD of endogenous determination of the necessary price variables. If price changes are set exogenously (usually in the form of assumptions for scenario analysis) then it is better that any accompanying coefficient changes also be determined outside the model. This avoids undue complexity in SOVMOD, and greater freedom in the design of techniques for simulating relations outside the model.

For instance, process models and linear programming models may be a realistic means for analyzing possible future changes in input structures industries, since not only the impact of prices, but also the impact of new technologies, environmental controls, scale effect, etc., may be considered. The very demanding nature of this approach in terms of data and modeling necessarily restricts its use to those cases where one has strong a priori reason to expect significant change in input structure, and only when the incorporation of such change is required in order to maintain the usefulness of the model.

An interesting example of such a model was developed by Prof. Leslie Dienes for estimating fuel mixes for boiler and furnace use by major economic regions of the Soviet Union.[10/] In this model were included expected cost and capital expenses of various boiler and furnace fuels by region, the approximate scale of production and the feasible direction and magnitude of inter-regional fuel transfers planned for the next 10 to 15 years, regional fuel consumption projections, and the impact of an accelerated program of nuclear power plant construction. Output from models such as this could be used to directly assign values to future vintage coefficients for use in SOVMOD. Although such models are costly and difficult to construct, the number of areas needing this detailed level of analysis are few enough so as not to rule out the use of these models.

[10/] L. Dienes, "Geographical Problems of Allocation in the Soveit Fuel Supply" in Energy Policy, June, 1973

Non-formal techniques are also of considerable use in setting values for coefficients of new capital. In our projections of fuel mix for thermal-electric power generation we have assumed that, as a consequence of post-1973 international fuel price changes, the Soviets will attempt to maximize use of solid fuels wherever it is feasible to substitute these for oil and gas. This means that new plants will be desgned to burn oil and gas only when required to cover peak-load demand for power.[11] An estimate of this fuel mix can be obtained from Soviet technical literature. Projections of average coefficients can be obtained by using this data to set vintage coefficents for future years and combining them with alternative projected rates of investment.

A purely mechanistic approach is used in those cases where we feel that it is not feasible or useful to attempt an engineering/economic analysis of input technology change. In such cases we assume that recent time-trends in vintage coefficient values provide useful information for projecting future trends. Many shifts in input mix represent technological innovations which consistently favor the use of certain materials. The substitution of non-ferrous for ferrous metals, of plastic for metals or wood products, of electric for other heat sources are examples of such trends. However, at some point there usually occurs a saturation level in the shift towards technologically superior inputs.

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[11] A.M. Nekrasov, M.G. Pervukhin, Energetika SSR V 1976-1980 Godakh, Moscow, 1977.

A useful technique for projecting coefficient change fitting this pattern has been used by Clopper Almon.[12/] A logistic curve is fitted to observed coefficient values. This mathematical form causes projected values to approach a floor or ceiling value asymptotically, and is derived from a differential equation which expresses the rate of change as proportional to the distance between the current value and the goal. We have used Almon's technique with, of course, the difference that vintage, rather than average coefficients are used. The value of the vintage coefficient is assumed to be given by:

$$\text{(8a)} \qquad \tilde{\alpha}_{ij,t} = \frac{\bar{\alpha}_{ij}}{1 + e^{a + bt}} \quad \text{if } \tilde{\alpha}_{ij,t} < \bar{\alpha}_{ij}$$

or

$$\text{(8a)} \qquad \tilde{\alpha}_{ij,t} = \frac{\bar{\alpha}_{ij}}{1 - e^{a + bt}} \quad \text{if } \tilde{\alpha}_{ij,t} > \bar{\alpha}_{ij}$$

where $\bar{\alpha}_{ij}$ is the asymptotic value of the vintage coefficient in the projection period. If this asymptotic value is given we can fit the

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[12/] C. Almon, Jr., M.B. Buckler, L.M. Horwitz, T.C. Reimbold, 1985: Interindustry Forecasts of the American Economy, Lexington: D.C. Heath and Company, 1974 following linear forms in a and b:

$$(9a) \qquad \ln \left(\frac{\bar{\alpha}_{ij}}{\tilde{\alpha}_{ij,t}} - 1 \right) = a + bt \text{ if } \tilde{\alpha}_{ij,t} < \bar{\alpha}_{ij}$$

or

$$(9b) \qquad \ln \left(1 - \frac{\bar{\alpha}_{ij}}{\tilde{\alpha}_{ij,t}} \right) = a + bt \text{ if } \tilde{\alpha}_{ij,t} > \bar{\alpha}_{ij}$$

Note that in both cases, $b < 0$.

We arbitrarily set the asymptotic value to 50% below the smallest value for declining series, and 50% above the highest value for rising series, a choice similar to Almon's. An alternative and preferable approach would be to study each industry and input to try and develop judgmental estmates of the asymptotic coefficients. Although this value is an artificial construct, it is useful for technology projection since the analyst is required only to provide a single forecast figure, which can be described as the technology toward which the economy is heading. He need not provide a time path of technological change nor consider hypothetical alternative economic environments. And though some assumptions as to these environments are necessary in developing the projections, it is often better that they remain implicit when an economist is requesting information from an engineer. The usefulness of the asymptotic coefficient construct is also evident if one were to use input-output data from other country studies, for while the idea of convergence in technological structure can be easily ascribed to, it is extremely difficult to establish the pace at which it is occuring.

Note that over long periods of time the asymptotic coefficient will itself change, even to the point of causing the vintage coefficient time series to change from increasing to decreasing or vice versa. Thus in fitting the logistic curve to the 18 X 18 = 324 vintage coefficient time series a heuristic method was applied to determine the longest usable sub-series. Starting from the 1972 value and working backwards in time, three coefficients in either increasing or decreasing sequence were considered sufficient to establish the direction of the time series, and three coefficients in the opposite sequence would terminate the usable subsequence before the year 1959 if such occurred. While this did shorten several sequences to four usable data points, all but 15 were estimated with sequences of 7 or more values.

A second problem arises when change in the average coefficients occur faster than can be explained by investment. In these cases negative vintage input-output coefficients are calculated, and are perhaps indicative of input substitution in addition to technological change. Because such substitution is economically plausible, even if it does violate the "putty-clay" assumptions made earlier, we have chosen to accept and project negative vintage coefficients where they occur. This affected 50 of the 324 coefficients, about half when projecting back into the historic period (1959-1972) and half for the projection period (1973-1985).

The fit of the logistic curve to the vintage coefficient time series developed above was acturally very good. For all but 10% of the 324 series the R-squared was above 0.70, an encouraging result. Note that in the two industries for which capital stock series were unavailable, average coefficients were projected directly using the logistic curve.

The final estimates of the average coefficients were calculated from the projected vintge coefficients using historic capital stock data for the years 1959-1975, and SOVMOD-projected values for the years 1976-1985.[13/] As this calculation requires a base year, we chose 1972, the most recent year for which we have an accurate I-O table. The equation for projecting forward is:

$$(10a)\quad \alpha_{ij,\,t+1} = \frac{\tilde{\alpha}_{ij,t+1}\ (K_{jt+1} - (1 - d_j)\ K_{jt}) + (1 - d_j)\ K_{jt}\ \alpha_{ij,t}}{K_{j,t+1}}$$

and its counterpart for projecting backwards is:

$$(10b)\quad \alpha_{ij,t-1} = \frac{K_{jt}\ \alpha_{ij,t} + \tilde{\alpha}_{ij,t}\ (K_{jt} - (1- d_j)\ K_{j,t-1})}{(1-d_j)\ K_{j,t-1}}$$

This requires the average coefficients for the base year, and results in using these given values directly for that year's estimate.

13/The projected capital stock series were taken from a baseline forecast prepared in January of this year.

As the other average coefficients are computed by successively moving farther away from the base year, we can use recursively the estimates we generate of the average coefficients to continue the procedure.

Because we accepted as valid negative vintage coefficients in the calculations described above, we do, in 40 instances, project negative averge technological coefficients. As these are not economically valid, they are removed and replaced by the arbitrary value of .00001 (10^{-5}).[14/] It should also be noted that due to the lack of capital series for industries 13 (Industry Not Elsewhere Classified) and 18 (Other) the "projections" are simply those of the logistic curves fitted to the average coefficient time series.

Evaluating the accuracy of our method of I-0 coefficient projection is rather difficult, as we have only three actual I-0 tables available, and we use one of those as a base for projection. Comparing our projections for 1959 and 1966 with the reconstructed Soviet tables for these years, the average absolute deviation is .00384 and .00097 respectively. The average size of the coefficients for these two years is .02584 and .02600 respectively, so the average error is about 15% and 4% of the coefficient values for the two years.

[14/] We chose .00001 rather tthan 0 as the replacement value in order to highlight the fact that it is a replacement value to the reader of the I-0 tables. There are many coefficients which are, in fact, precisely 0, whereas there are almost no projected average coefficients which equal .00001. In tables printed with 5 digits after the decimal point, this value stands out. Without further a priori information or theoretical assumptions, arbitrarily altering the computational procedure to prevent negative coefficients from occuring would only serve to hide the fact from the reader and make the calculations more difficult to interpret.

For intervening years, we have no accurate standard. While variations of the RAS method, including the weighted RAS method, have been in use for many years, there is little reason to believe their interpolated coefficient values are any more accurate than our own, or than the method of polynomial interpolation we used above in generating vintage coefficients. However, as RAS methods do make use of inter-mediate year data for final demand and value added, the inter-industry coefficient row and column totals should be nearly correct. Examination of the row and column totals from the wieghted RAS average coefficient matrices and the vintage-projected average coefficient matrices over the years 1959 to 1972 reveals only two major discrepancies: 30% in the second row total and 50% in the fifth column total, corresponding to inputs from coal and peat to all industries, and inputs from all industries to electrical power, respectively. However, discrepancies of th s magnitude occur only in the years 1959 and 1960. From 1961 on, all differences are less than 20% of the weighted RAS values. The two 1959 and 1960 values mentioned appear to be strongly affected by negative projected average coefficients, and even when these are forced to be positive, the effect is not wholly countered. Note also the overall tendency of the methods used is to increase the errors away from the base year 1972.

The accuracy of the projections forward of 1972 will have to await the test of time and further analysis.

V Conclusions

Using a purely mechanical implementation of the method of vintage coefficients to project average IO coefficients, we have been able to obtain reasonable agreement with established methods. Because the proecdure is mechanical, many "special case" exceptions could have been made to particular estimates to obtain even better agreement. This is particularly true in constraining the vintage coefficient projections to avoid negative values. We have purposely not made such "improvements" because we feel it serves only to obscure a method which, even in rough form, appears to work quite well.

Future efforts in the projection of technological coefficient change by means of vintage coefficients should be directed at incorporating specialists' knowledge concerning the likely input structure of future additions to Soviet capital stock. For key sectors such as energy, industry specialists should be questioned for *a priori* estimates of vintage or asymptotic vintage coefficients. Certain questions need to be answered as to whether global or industry-specific constraints can be placed on vintage coefficients in order to identify the proper mathematical form for their projection. Because the number of available Soviet input-output tables is very small, the accumulation of additional data and improved interpolation methods are also needed.

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