FINAL REPORT TO
NATIONAL COUNCIL FOR SOVIET AND EAST EUROPEAN RESEARCH

TITLE: LATENT VARIABLE MODELS OF SOVIET ECONOMIC POLICY

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COUNCIL CONTRACT NUMBER: 803-04

DATE: October 1989

The work leading to this report was supported by funds provided by the National Council for Soviet and East European Research. The analysis and interpretations contained in the report are those of the author.

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EXECUTIVE SUMMARY

The objective of my research is to explain the determinants of Soviet economic policy. The principal questions addressed in my report are the following: Of the various time series on political and economic developments available to Soviet policy-makers, which have the greatest influence on their decisions? How aggregated or compressed is the information dealt with by top policy-makers? How do the time series available to policy-makers influence the priorities they set? How do their priorities affect allocation of investment, labor, and government expenditures? My major findings are as follows: (1) Time series with significant influence on Soviet policies concerning resource allocation include lagged values of sectoral capital stocks; the price level; population; the ratio of stocks to sales in retail trade; U.S. defense expenditures; the real prices of gold, oil, and wheat on world markets; and the real interest rate in world markets. (2) The information dealt with by top policy-makers is compressed enough so that it can be represented by four or five factors, which are combinations of particular individual time series. The precise number of factors depends in part on the policies analyzed and in part on the tests applied to test for their importance. (3) A few time series have a predominant influence on each factor. The patterns of influence suggest that several factors represent information about particular sectoral imbalances or bottlenecks. (4) The factors that are shaped primarily by domestic conditions have the greatest impact on policy, while those determined

primarily by foreign conditions have less impact. Thus foreign countries have limited opportunities to influence Soviet economic policy.

My study is motivated by the fact that Soviet policy formation is important but poorly understood and seldom modeled. Soviet policy is worthy of study because it influences the performance of a major economy. It is inadequately understood and rarely modeled because its proximate or direct political determinants are largely unobservable to foreigners and its ultimate determinants are too complex to disentangle by means of conventional techniques.

The proximate political determinants of Soviet economic policy are treated in my study as unobservable factors that have observable causes and consequences. In the statistical literature, such unobservable factors are called latent variables. By utilizing statistical techniques designed for latent variables, I am able to overcome problems that have hindered previous efforts to understand Soviet economic policy.

My investigation consists of two stages. The first is an analysis of the sectoral allocation of investment and labor. From time series on real investment in 13 sectors (1960-83) and employment in 20 sectors (1950-83), I obtain estimates of the underlying "innovations" or independently distributed shocks. The estimated "innovations" are then subjected to three types of statistical analysis with the aim of determining how many factors, or combinations of time series, exist and how they influence policy.

The results of the first stage of the investigation indicate that the allocation of investment and labor can be well explained by five factors. Some earlier investigators, believing that bureaucratic inertia led to a fixed pattern of resources allocation, suggested that a one-factor model might be appropriate; however my statistical results lead me to reject that hypothesis. Other investigators, believing that Soviet leaders are primarily concerned with internal stability and external security, suggested a two-factor model. The statistical evidence against a two-factor model is not so strong as that against a one-factor model. However, the two leading factors are not easily interpreted as concern with external security. In my preferred five-factor model, the factors are most naturally interpreted in terms of perceived sectoral imbalances or bottlenecks.

The second stage of the investigation is a study of the determinants of the allocation of investment and government expenditure. Real investment (1962-88) is disaggregated into ten sectors: agriculture, housing, electricity, coal, oil and gas, chemicals, ferrous metallurgy, machine-building and metal-working, construction materials, and light industry. The most significant influences on real investment include lagged values of sectoral capital stocks, the price level, population, the ratio of stocks to sales in retail trade, U.S. defense expenditures, and the real price of oil on world markets. Statistical criteria indicate that a five-factor model is optimal for investments.

The determinants of each factor and its effects on investment suggest its interpretation. For example, the most important factor--which increases with population, decreases with the capital stocks of the housing and service sectors, stimulates investment in housing, and dampens investment in ferrous metallurgy and construction materials--can be interpreted as the pressure of the population on housing and services. The second factor might be thought of as the strain put on the transportation, energy, and petrochemical sectors by the requirements of households and the machine-building and metal-working industry. The third factor can be interpreted as the strain placed on the service and transportation sectors by the needs of agriculture, industry, and their workforce. The fourth factor appears to be the strain on the chemical and metallurgical industries in supplying the requirements of agriculture. The fifth factor may represent the adequacy of housing for the workforce in industry and services.

Nominal government expenditure (1955-85) is disaggregated into ten categories: industry and construction, transportation and communication, education, science, health and physical culture, social security, social insurance, aid to mothers, defense, and administration. The most significant determinants of government expenditure include lagged values of the aggregate capital stock; the price level; population; the ratio of stocks to sales in retail trade; U.S. defense expenditures; the real prices of gold, oil, and wheat on world markets; and the real interest rate in world markets. Statistical criteria indicate that a four-factor model is optimal for explaining government expenditures.

The most important factor for government expenditures is closely related to the capital stock per capita. It stimulates most forms of government expenditure, with the significant exception of labor-intensive components of defense spending. An increase in capital stock per capita has income and substitution effects. The income effect tends to raise all forms of expenditure, but the substitution effect may reduce expenditure on labor-intensive activities. The second factor behaves much like the labor force participation rate and tends to divert government expenditure from investment toward social consumption. When the labor participation rate is high, newly created capacity may be hard to staff, a consideration that contributed to the slowdown of investment in the Brezhnev era. Resources diverted from investment are available for social consumption. The third factor can be interpreted as the unit cost of government services. The fourth factor is a channel through which the capital stock and price level stimulate most forms of government expenditure while real interest rates in world markets dampen them.

Although my models are designed primarily to improve understanding of how Soviet policy has been made, they could be adapted to simulate or forecast policy and to represent rational expectations about policy.

1. Introduction

Soviet economic policy is important because it heavily influences economic performance. Unfortunately, it is poorly understood and seldom modeled, in part because its proximate political determinants are largely unobservable to foreigners and its ultimate determinants are too complex to disentangle by conventional techniques. To illuminate the policy-making process, I have constructed statistical models that reveal the latent (unobserved) proximate determinants of policy and the channels through which the ultimate determinants act. While the models are designed primarily to improve understanding of the Soviet policy-making process, they may also be used to simulate Soviet responses to foreign initiatives, forecast Soviet policy conditional on projections of predetermined variables, or represent rational expectations of policy.

My research breaks with tradition inasmuch as most existing econometric models of the Soviet Union treat policy variables (targets and instruments) as exogenous (Hildebrandt 1985; Shapiro 1977). This traditional treatment may be motivated either by a focus on the effects of policy, or by difficulties in modeling policy determination by conventional econometric methods. In any case, models that treat policy variables as exogenous have four serious limitations.

First, such models cannot forecast targets and instruments. This limitation is more serious in a model of the Soviet economy than in a model of a market economy, where the influence of policy is less pervasive.

Second, a model that does not forecast policy variables cannot incorporate rational expectations concerning them. If actual expectations are more closely approximated by rational expectations than by alternative expectational formulas, then models that treat policy variables as exogenous will be at a disadvantage in dealing with any behavior influenced by expectations concerning policy variables (Wallis 1980).

Third, policy-makers can observe more of the determinants of household behavior than can foreign modelers. As a result, policy variables in equations for household behavior are correlated with the disturbance terms and models that treat policy variables as exogenous yield biased estimates of the effect of these variables on household behavior.

Fourth, policy-makers may make use of knowledge of lagged endogenous variables in choosing values for policy variables. Models that abstract from the influence of lagged endogenous variables on policy variables yield biased forecasts (Engle, Hendry, and Richard 1983).

To avoid treating policy variables as exogenous, one must explicitly model policy formation processes. An obvious approach to this task would be to simply regress each policy variable on all relevant predetermined variables. One drawback of this approach is that the number of potential regressors is so large that the estimates would have very large variances. Another drawback is that the sheer number of parameters would disqualify them as a parsimonious description of the policy-making process. In an effort to overcome these problems, one might be tempted to delete a regressor from any equation in which it appeared insignificant. However, such ad hoc restrictions would violate the symmetries characteristic of the solution to any multivariate optimization problem. Clearly, a better approach is needed.

The approach that I follow exploits a widely recognized characteristic of the Soviet policy-making elite--namely, its limited capacity to absorb information. The Soviet elite, culminating in the Politburo, has access to more information (of varied quality) than it can fully utilize in the conduct of policy. Hence, information compression is a necessary part of the policy-making process (Cave 1980; Ellman 1979; Kornai 1970; Rutland 1985). In physical terms, we may think of the policy-making mechanism as a black box that has fewer internal transmission channels than ports for either receiving or emitting signals. In terms of linear algebra, we may represent such a black box as a matrix of less than full rank that transforms the vector of predetermined variables into a vector of jointly dependent (policy) variables (Brillinger 1969). The rank of the matrix is equal to the number of latent variables required to represent the transmission channels through which predetermined variables influence policy variables. By adopting techniques suitable for matrices of less than full rank, we can reduce the number of estimated coefficients, increase their reliability, and facilitate their interpretation, while preserving symmetry (Robinson 1973).

While there is wide agreement that information compression is characteristic of the planning process, there is no consensus about the number and nature of the transmission channels. Let us note three alternative hypotheses, starting with the simplest. The work of Lacko (1984) suggests that in Hungary and perhaps other socialist economies investment policy is characterized by a single transmission channel. Policy-makers are presumed to choose the total volume of investment, which is then divided among sectors in stable proportions governed by fixed norms. The work of Kirkpatrick (1986) suggests that policy in COMECON countries fits a two-factor model. The policy-makers are assumed to base all decisions on their perceptions of external security and internal stability. The work of Portes (1981) suggests many channels of transmission. Policy-makers in centrally planned economies are assumed to act as if they optimize over an aggregative but multidimensional model.

In our model X denotes an observable q-dimensional vector of information available to Soviet policy-makers. Y denotes a latent r-dimensional vector of signals transmitted by the elite; its elements constitute the minimal set of linearly independent variables (summary statistics or directives) dealt with by top policy-makers. Z is an observable s-dimensional vector of policy variables. We assume that $q \geq r$ and $r \leq s$ and expect that these inequalities hold strictly.

With regard to the latent variables, we assume that

(1) $$Y_t = A(L)X_t,$$

where A(L) is a polynomial in the lag operator L and the subscript t represents time. It is plausible and convenient to presume that the maximum lag is finite. (We avoid introducing an infinite lag or, equivalently, an autoregressive term or a partial adjustment mechanism for two reasons. First, Y represents summary statistics and directives, which can be easily revised. Second, an infinite lag would create difficulties in filtering the data prior to factor analysis.)

As to the policy variables, we assume that

(2) $$Z_t = BZ_{t-1} + \Gamma(L)Y_t + \epsilon_t,$$

where B is a coefficient matrix, $\Gamma(L)$ is a polynomial in L and ϵ_t is a vector of disturbances. This specification indicates that a partial adjustment mechanism governs the response of policy variables to summary statistics and directives. The partial adjustment mechanism is appropriate because the policies that we shall analyze--indeed, almost all resource allocation policies--resist instantaneous change. We assume that the disturbance vector is free of serial correlation, but we do not assume that its covariance matrix is diagonal.[2]

Substituting (1) into (2), we obtain

(3) $$Z_t = BZ_{t-1} + \Gamma(L)A(L)X_t + \epsilon_t.$$

Note that while $\Gamma(L)A(L)$ is of order qxs, its rank is r.

The empirical investigation consists of two stages. First, data on Z alone are analyzed in order to obtain a preliminary impression about the number and nature of the latent variables. Second, data on X as well as Z are analyzed so as to estimate the coefficients of eq. (3).

2. Filtering and Factor Analysis of Data on Soviet Policy Variables

The first stage of the investigation, fully described in Burkett (1989), can be summarized as follows. Two sets of variables were studied: real investment in 13 sectors (1960-83) and employment in 20 sectors (1950-83). Investment is a good policy indicator because it is under relatively tight central control. Indeed, in most cases both the suppliers and recipients of investment goods are state enterprises responding to plan directives. Employment is not as good a policy indicator because it is subject to disturbances from the side of supply (households) as well as demand (state). Nonetheless, it is useful to analyze employment as a check on the robustness of findings based on investment.[3]

Factor analytic techniques are applicable only to observations that are independently and identically distributed. Hence before time series can be subjected to factor analysis they must be filtered to remove serial correlation. The filtering can be accomplished by Box-Jenkins techniques--i.e., building autoregressive integrated moving average (ARIMA) models. The first step is to transform the series so as to render them stationary. The series were expressed in logarithms so as to stabilize their variance. The series were then differenced twice in order to remove the effects of decelerating growth. After second differencing, eq. (3) becomes

$$\Delta^2 Z_t = B\Delta^2 Z_{t-1} + \Gamma(L)A(L)\Delta^2 X_t + \Delta^2 \epsilon_t, \text{ or} \tag{4}$$
$$\Delta^2 Z_t = B\Delta^2 Z_{t-1} + u_t, \text{ where}$$
$$u_t = \Gamma(L)A(L)\Delta^2 X_t + \Delta^2 \epsilon_t.$$

Eq. (4) is a vector autoregression with a rather complicated disturbance term. Assuming that the behavior of u_t is dominated by $\Delta^2 X_t$, we shall treat $\Delta^2 \epsilon_t$ as negligible for the remainder of the first stage of the investigation.

The Soviet Union, its major trade partners, and many other economies have experienced decelerating growth since the mid-1950s. Hence if X represents the logarithms of stocks or flows in these economies, it is likely to be stationary after twice differencing. Assuming $\Delta^2 X$ to be stationary and indeterministic, we deduce from Wold's decomposition theorem that it has a moving average representation. Thus eq. (4) is seen to be an s-dimensional autoregression with a moving average disturbance whose covariance matrix has rank r. Assuming B to be approximately diagonal, we can estimate eq. (4) as a collection of s ARIMA models.[4]

To specify ARIMA models we must choose the length of the moving average process. Because the time series are too short to permit profligate parameterization, our strategy is to begin with the shortest plausible length and then extend it if diagnostic statistics reject the original specification. Supposing that the moving average representation of $\Delta^2 X$ has lag length one and that $\Gamma(L)$ and $A(L)$ each have lag length zero, we arrive at an ARIMA(1,2,1) model as our initial specification.

Estimated ARIMA(1,2,1) models of investment and employment were assessed on statistical and theoretical grounds.[5] From a statistical point of view, if the models are correctly specified the residuals should be white noise. The hypothesis that the residuals are white noise was tested using the Q statistic proposed by Ljung and Box (1978). None of the Q statistics is large enough to be significant at the .05 level and only one is significant at the .10 level. Thus there is no compelling statistical evidence for rejecting the ARIMA(1,2,1) specification.

From a theoretical point of view, we expect the autoregressive coefficients to be in the interval (0,1). Only in one case does an estimated autoregressive coefficient lie outside this interval and it is insignificantly different from zero. Since the ARIMA(1,2,1) models appear satisfactory from a theoretical as well as a statistical standpoint, we proceed to subject their residuals to factor analysis.

Construed broadly, factor analysis includes principal components analysis and image analysis as well as maximum likelihood factor analysis. Applied to large samples, the last technique is advantageous because its asymptotic properties provide a sound basis for testing hypotheses about the number of factors. However, since our samples are small, it is more prudent to use all three methods rather than rely exclusively on maximum likelihood estimation.

Because both investment and employment presumably respond to a common set of latent variables, there is a strong theoretical case for basing analysis on the correlation matrix of the residuals from all 33 ARIMA models. Unfortunately, we have only 21 observations on the residuals for investment and only 31 on those for labor. A sample correlation matrix based on more variables than observations is singular, making maximum likelihood factor analysis impossible. Thus there is a case for conducting one analysis of the correlation matrix of investment residuals and another of the correlation matrix of employment residuals. In view of these conflicting considerations, I subjected the correlation matrix of all residuals to principal components and image analyses and subjected the separate correlations matrices for investment and employment residuals to all three types of factor analysis.[6]

Principal components analysis does not provide any single decisive indicator of how many components are needed to characterize the data. Two criteria are commonly used in practice. First, components corresponding to eigenvalues greater than 1 may be retained. Second, a sharp bend in a scree plot of eigenvalues may suggest at what point additional components become inconsequential (Kim and Mueller 1978).

Principal components analysis of the correlation matrix of investment residuals reveals 5 eigenvalues greater than 1 but the scree plot suggests that the first 2 are by far the most important. Image components analysis of the image covariance matrix reveals 4 eigenvalues greater than 1, but again the scree plot suggests that the first 2 are substantially more important than the rest. On the basis of maximum likelihood factor analysis, we can reject the hypothesis that there is no more than 1 factor, but we cannot reject the hypothesis that 2 factors are sufficient. Overall, the evidence suggests that 2 to 5 factors are sufficient.

A two-factor model is of particular interest in view of Kirkpatrick's hypothesis that policy is shaped by perceived threats to external security and internal stability. This hypothesis would be supported if one factor loaded heavily on, say, metallurgy and machine-building and metal-working, while another loaded heavily on, say, agriculture, trade, nonproductive services, food processing, and light industry. However, no such pattern was found, either before or after varimax and Harris-Kaiser rotations.

When applied to employment residuals, both principal components analysis and image components analysis reveal only a single eigenvalue greater than 1. The scree plots confirm that the first eigenvalue is far more important than the remainder. However, maximum likelihood factor analysis leads one to reject the hypothesis that 1 or even 2 factors are adequate. Unfortunately, the maximum likelihood algorithm fails to converge for models with more than 2 factors.

Applied to pooled investment and labor residuals, both principal and image components analysis reveal 5 eigenvalues greater than 1, although the scree plots suggest that the first eigenvalue is by far the most important. Maximum likelihood estimation is impossible due to the singularity of the correlation matrix.

The briefest possible summary of this section is that disturbances to 13 investment variables and 20 employment variables can be well accounted for by no more than 5 latent variables. Because policy-makers exert tighter control over investment than employment, results for the former deserve a fuller summary. A one-factor model of investment is too simple. A two-factor model is supported by scree plots and maximum likelihood tests. However, the two factors are not easily interpreted in terms of external security and internal stability. Based on the number of eigenvalues exceeding 1, a five-factor model may be preferred.

3. Policy Variables and Predetermined Variables

In this section we consider two sets of policy variables: investments and expenditures from the state budget. We recall that the case for regarding investments as policy variables rested on the fact that both the suppliers and the recipients of investment goods are under state control. The case for treating expenditures from the state budget as policy variables is somewhat different. The government expenditures entail some direct purchases from households, notably in the labor market. Hence labor supply disturbances could affect the unit cost and quantity of government services. However, these disturbances should move unit cost and quantity in *opposite* directions and thus have relatively little effect on expenditures.

The set of predetermined variables considered includes indicators of both domestic and external conditions. Among the former are lagged population, employment, capital stock by sector, real national income produced (nmp), the nmp deflator, and the ratios of savings deposits and retail inventories to retail sales. Among the latter are lagged exports and imports, world market prices of oil, gold and grain (deflated by the U.S. producers' price index), the real interest rate, and U.S. military expenditures. The predetermined variables selected as most significant by likelihood ratio tests are fully documented in the data appendix. The variables that are strictly positive are used in logarithmic form.

3.1 Investment and Its Determinants

We have data on investment in 12 sectors of the national economy and branches of industry for 26 years (1962-88). Equation (3) suggests that we should begin analysis with an unrestricted vector autoregression (VAR) with exogenous variables. However, estimating the coefficients of the lagged endogenous variables would leave us with only 14 degrees of freedom and drastically curtail the number of exogenous variables that could be included. Furthermore, the 12x12 residual covariance matrix is close to singular, causing numerical difficulties in computing statistics based on the logarithm of its determinant. To reduce the dimensionality of the estimation problem I aggregated 3 industries (wood and paper, food, and narrowly defined light industry) into one (broadly defined light industry), thus reducing the order of the covariance matrix to 10x10. Data for the ten series are presented in the appendix, where their logarithms are graphed in Fig. A1a-j. Investments in agriculture, housing, electricity, coal, oil and gas, chemicals, ferrous metallurgy, machine-building and metal-working, construction materials, and light industry are denoted IAGR, IHOU, IELE, ICOA, IOIL, ICHE, IFER, IMBM, ICON, and ILIT.

Even after this aggregation, it is necessary to be selective in choosing elements of the vector X, lest the available degrees of freedom be exhausted. I selected elements of X by adding predetermined variables from the list above, one at a time, to the VAR (including a constant term) and choosing the ten that scored highest on a likelihood ratio test: the ratio of retail stocks to sales--STOKSAL; the nmp deflator--NMPDEFL; population--POP; capital stocks in agriculture, industry, housing, services, and transportation--CAPAGR, CAPIND, CAPHOU, CAPSER, CAPTRAN; the price of oil deflated by the U.S. producers' price index--OILR; and real U.S. military expenditures--USDEF; all in logarithmic form. POP is evaluated in January of the current year, while the other stock variables are evaluated at the end of the previous year. Flows are evaluated over the previous year. In view of the limited sample size I did not attempt to estimate distributed lags.

Ten autoregressive terms, a constant, and ten exogenous variables would leave us with only 5 degrees of freedom, after dropping the 1962 observation to allow a one period-lag. Because some further restriction is clearly needed, I assume that the matrix of autoregressive coefficients (B) is diagonal, thus saving 9 degrees of freedom. (I take that step with reluctance because the diagonality restriction prevents ordinary least squares estimation [OLS] from being fully efficient and means that procedures appropriate to maximum likelihood estimates are only approximately valid for the restricted model. However, the small sample size leaves no practical alternative.)

Regression of investments, expressed in logarithmic form, on a constant, own first lags, and the ten exogenous variables produced generally satisfactory summary statistics. The estimated coefficients of the exogenous variables are shown in Table I. Since the variables are in logarithmic form, the coefficients represent elasticities. A few of the estimated coefficients are significant and readily understandable. For example, it is not surprising that IAGR is high when CAPAGR is low; that is what we would expect if partial adjustment to a desired capital stock proceeds faster than depreciation. However, most of the estimated coefficients of the exogenous variables are insignificant and hard to interpret, a fact that heightens our interest in proceeding to reduced rank regression.

The key to reduced rank regression is the singular value decomposition theorem,[7] which states that any sxq matrix C of rank r can be written as $U\Sigma V'$, where U is an sxs matrix whose columns are eigenvectors of CC', V is a qxq matrix whose columns are eigenvectors of C'C, and Σ is a sxq matrix composed of zeros apart from its principal diagonal, which contains the singular values of C--i.e., the square roots of the r positive eigenvalues of CC' or C'C. The matrices involved in the decomposition are not unique, and not all combinations yield C. Conventionally, the eigenvectors are standardized to unit length, the eigenvalues are arranged in descending order, and the corresponding eigenvectors are ordered to match. Given an arbitrary choice of the sign of the eigenvectors in U, the sign of the eigenvectors in V can be chosen so as to satisfy the theorem (Searle 1982). A very useful corollary is that if Σ_k is obtained from Σ by replacing all but the k largest singular values by 0, then $D = U\Sigma_k V'$ is the matrix of rank k that minimizes the sum of squared differences between elements of C and the corresponding elements of D. Accordingly, some authors call D "the rank-k least squares approximation" to C (Healy 1986, p. 65). The sum of the squared differences is the sum of the squares of the replaced singular values (Good 1969).

To apply the theorem, we collect the estimated coefficients of the exogenous variables and constant terms into a 10x11 matrix C. Each row of C represents one equation and each column one variable. The matrix, with the column of constant terms deleted, is shown in Table 1. Performing a singular value decomposition on C, we get U, the singular values, and V, as shown in Table 2. Looking at the singular values, we notice that the first is much bigger than the rest and that the first six exceed one. Obviously, the same can be said of the squared singular values--i.e., the eigenvalues. These facts are interesting in connection with the two criteria commonly applied in principal components analysis, as discussed above. Applied to our case, the scree plot criterion suggests a one-factor model, while the unit eigenvalue criterion suggests a six-factor model. Hence we might expect to approximate C rather well by a matrix of rank 6 or less. However, our ultimate objective is not to approximate C but rather to explain investment. Accordingly, we shall subsequently choose the rank of the matrix on the basis of investments' residual covariance matrix.

In the U matrix each row represents an investment variable and each column a latent variable (denoted YINV1,...,YINV10). Looking at this matrix, we get a first impression of the effects of the latent variables. For example, the first latent variable is seen to drive ICOA up and ICON down, while the second latent variable drives ICOA, IOIL, and ICHE up together. However, there is no need to dwell on the U matrix because we will shortly obtain more efficient estimates of the effects of the latent variables.

In the V matrix each row represents an exogenous variable from the X matrix, and each column corresponds to a latent variable. (There are 11 latent variables in the V matrix, but the last--denoted YINV11--has no influence on investment because there are only 10 positive singular values.)

Inspecting the V matrix, we see how the latent variables are generated. The first latent variable has a large constant term, increases with POP, and declines with CAPHOU and CAPSER. We may tentatively interpret it as the pressure of the population on housing and services. (We will reconsider the interpretation of latent variables after obtaining final estimates of their effects.)

The second latent variable increases with CAPIND and CAPHOU and declines with CAPTRAN. It could be interpreted as an imbalance among sectors. In principle this imbalance could be either a shortage of transportation facilities serving the needs of industry and households or a surplus of industrial capacity and housing serving the transportation sector and its workforce. However, the former interpretation is more plausible in view of the widely acknowledged importance of shortage, at least within the state sector (Kornai 1980; Portes and Winter 1980). Henceforth, imbalances will generally be interpreted in terms of shortage.

The third latent variable is positively related to CAPAGR and CAPIND and negatively related to CAPHOU, CAPSER, and CAPTRAN. It might tentatively be considered an indicator of shortages of housing, services, and transportation serving agriculture and industry.

The fourth factor increases with CAPAGR and decreases with CAPIND and NMPDEFL. The fifth factor increases with CAPHOU and decreases with CAPIND and CAPSER. The sixth factor is a decreasing function of CAPSER and NMPDEFL. Only when we get to the seventh and higher order factors do we find major roles for USDEF and OILR. Overall, the more important factors appear to be expressions of domestic imbalances, while the lesser ones reflect the external environment.

The first five factors are graphed in Fig. 1a-e. The first exhibits little variation but does decline slightly during the late 1960s. The second factor trends upward, while the third and fourth trend downward. The fifth is U-shaped. The second, fourth, and fifth exhibit appreciable short-term fluctuations. We shall return to the problem of interpreting the latent variables after we select a model and obtain final estimates of its coefficients.

As a basis for choosing a model, I estimated models with 0 to 10 factors--i.e., models including as regressors all factors up to YINVk, where k = 0,..,10. (The use of columns from V to construct YINV1,...,YINV10 is analogous to the use of estimated cointegrating vectors to construct the error correction terms in vector error correction mechanisms.) I then computed the logarithms of the determinants of the residual covariance matrices, and examined two model-selection statistics based on these logarithms: Schwarz's criterion (SC) and the likelihood ratio (LR) for testing each smaller model against the ten factor model.[8] SC takes its optimal value in the five-factor model. The LR test is ambiguous in the sense that it can favor large or small models depending on what significance level is chosen. However this test is consistent with SC in the sense that if the .01 level is chosen, the LR test fails to reject the five-factor model but does reject the four-factor model. Hence I have selected the five-factor model.

The five-factor model was estimated as a system of seemingly unrelated equations (SUR), and the results are displayed in Table 3. The Ljung-Box Q statistics indicate serial correlation in the disturbances to IELE and probably IMBM, but otherwise the summary statistics are gratifying. The estimated autoregressive coefficients are negative for IFER and ICON but otherwise are in the expected interval between 0 and 1. Each factor has a significant estimated coefficient in 3 or more equations. Each equation, apart from that for IAGR, contains 2 or more significant factors.

To see the effects of each factor on all investments, we turn to Table 4, which contains the matrix of factor coefficients. YINV1 is seen to affect IHOU, IFER, and ICON negatively, which is consistent with our interpretation of this factor as the pressure of the population on housing and services. YINV2--which, we recall, increases with CAPHOU and CAPIND but declines with CAPTRAN--depresses IHOU and IMBM but stimulates IELE, ICOA, IOIL, and ICHE. Hence the second factor might be interpreted as the strain put on the transportation, energy and petrochemical sectors by the requirements of households and the machine-building and metal-working industry. YINV3, which was seen to increase with CAPAGR and CAPIND but decrease with CAPSER and CAPTRAN, depresses investment in agriculture and all branches of industry except chemicals. Thus the third factor could be interpreted as the strain placed on the service and transportation sectors by the needs of agriculture, industry, and their workforce. Concern with such imbalances is expressed by Val'tukh (1985).

YINV4, which we saw increased with CAPAGR but decreased with CAPIND, depresses IAGR but stimulates ICHE and IFER. Hence it may be interpreted as the strain on the chemical and metallurgical industries in supplying the requirements of agriculture. YINV5, increasing with CAPHOU but decreasing with CAPIND and CAPSER, retards IHOU but promotes ICOA, IOIL, ICHE, IFER, and ICON. Accordingly, it might represent the adequacy of housing for the labor force in industry and services or the strain on the industrial and service sectors in heating, furnishing, and maintaining the housing stock.

To reconstruct the effect of exogenous variables on investment, we premultiply the transpose of the first 5 columns of the V matrix (Table 2) by the matrix of SUR estimates (Table 4). The product (without the column of constants) is shown in Table 5. It may be compared to the OLS estimates in Table 1.

3.2 Government Expenditure and Its Determinants

We have time series for 10 categories of nominal government expenditure: industry--GIND; transportation and communication--GTRN; education--GEDU; science--GSCI; health--GHEA; social security--GSEC; social insurance--GINS; aid to mothers--GMAT; defense--GDEF; and administration--GADM. GIND includes investment by the industrial ministries, capital repair, supplements to working capital, prototype development and testing, and certain subsidies to the food processing industry. GTRN is predominantly expenditure on transportation, with communications playing a secondary role. GEDU embraces general education, cultural enlightenment, cadre training, professional-technical education, publication, and broadcasting. GSCI includes basic research, applied research in civilian and military areas, and space exploration. GHEA covers hospitals, clinics, public health institutions, and physical culture. GSEC and GINS, between which the distinction is obscure, cover pensions and disability payments. GMAT consists of aid to single mothers and mothers of many children. GDEF is believed to cover current military expenditures (e.g., pay, food, and utilities) but to exclude research and development, stockpiling, civil defense, foreign military aid, and space exploration. GADM embraces the operating costs (salaries, benefits, and office expenses) of legislative, judicial, planning, and executive organs (CIA 1977; *Gosudarstvennyi biudzhet SSSR ... 1976-1980 gg.*; Hutchings 1983; McAuley 1979; Noah 1966). All variables are used in logarithmic form. The variables are further discussed in the data appendix, where their logarithms are graphed in Fig. A2a-j.

Having only 31 observations (1955-85) on government expenditure, we must be selective in choosing explanatory variables. I selected variables from the list given in the previous section by adding them one at a time to a VAR for government expenditure and choosing the 10 with the highest scores on a likelihood ratio test. These 10 include 5 that appeared in the investment equations: STOKSAL, POP, NMPDEFL, OILR, and USDEF. The other 5 are total capital--CAPTOT; employment--LABOR; the world market prices of wheat and gold (deflated by the U.S. producers' price index)--WHEATR and GOLDR; and the real interest rate--RTBILL.[9] All except RTBILL are used in logarithmic form. CAPTOT is evaluated at the end of the previous year. LABOR is measured in the middle of the previous year. The other 3 new variables are averages for the previous year.

To conserve degrees of freedom I again assume that the B matrix is diagonal. Regression of expenditures on a constant, own first lags, and the ten exogenous variables yielded satisfactory summary statistics. The estimated coefficients of the exogenous variables, which represent elasticities, are shown in Table 6. A few of these estimated coefficients are significant and easily interpreted. For example, GHEA and GINS increase with CAPTOT, which makes sense if CAPTOT is regarded as a proxy for national wealth. Similarly, GSEC and GINS increase with STOKSAL, which is plausible if policy-makers give thought to the macroeconomic impact of transfer payments. However, most of the estimated coefficients are insignificant and difficult to interpret, encouraging us to forge ahead to reduced rank regression.

After augmenting the matrix of estimated coefficients shown in Table 6 by a column of estimated constant terms, we subject it to singular value decomposition and obtain the results shown in Table 7. The first singular value is again much larger than the rest. The first four exceed unity. Hence

1 to 4 factors are likely to be sufficient to approximate the matrix of estimated coefficients. However, we again reserve final judgment on the number of factors pending examination of the residual covariance matrices.

The U matrix affords a preliminary view of the effects of the latent variables. The first, for example, is seen to depress GSCI and GDEF while stimulating other expenditures. However, in the expectation of getting more efficient estimates of these effects, we can pass quickly to the V matrix, which shows how the latent variables (denoted YGOV1,..., YGOV11) are generated.

The first latent variable, which again has a large constant term, increases with CAPTOT and decreases with POP. It can be thought of as closely related to the capital stock per capita. The second increases with LABOR and decreases with POP. It can be thought of as related to the labor force participation rate. The third factor increases with NMPDEFL and RTBILL. We might interpret it as a measure of the unit costs of government services. The fourth factor declines with CAPTOT and NMPDEFL, while increasing with RTBILL. Not until we get to the fifth and higher order factors do we find dominant roles for STOKSAL, WHEATR, OILR, GOLDR, RTBILL, and USDEF.

The first 5 factors are graphed in Fig. 2. The first and second vary within a narrow range, the former trending upward, the latter tracing out a mountain. The third factor resembles a random walk with positive drift. The fourth and fifth trend downward. We postpone further discussion of the latent variables until a model has been selected and estimated.

To select a model I again estimated models with 0 to 10 factors and considered their SC and LR statistics. The former takes its optimal value for a four-factor model. The latter indicates that this model is the most parsimonious that is acceptable at the .01 level. Hence I have selected the four-factor model.

SUR estimates of the four-factor model are shown in Table 8. The Q statistic for GDEF indicates serial correlation in the disturbances, but the other summary statistics are gratifying. The estimated autoregressive coefficients are all in the expected interval (0, 1). Each factor has in at least 5 equations an estimated coefficient that is significant at the .05 level. In each equation at least 2 factors are significant.

Table 9 collects the coefficients in a form that makes it easy to see the effect of each factor on all forms of government expenditure. YGOV1 has a positive or insignificant effect on all forms of government expenditure except GDEF. Insofar as GDEF includes the labor costs but not the capital costs of defense, it is understandable that YGOV1, which behaves much like capital per capita, should depress this variable.

YGOV2 reduces GIND and GTRAN but increases GEDU, GHEA, GINS, GDEF, and GADM. Since it behaves much like the labor force participation rate and since investment is concentrated in GIND and GTRN, an explanation for its effects on these variables is not hard to find. When the labor participation rate is high, newly created capacity may be hard to staff. This consideration contributed to the slowdown of investment in the Brezhnev era. Resources diverted from investment are available for (inter alia) education, health, social insurance, defense, and administration.

YGOV3, which we tentatively interpreted as the unit cost of government services, has a positive or insignificant effect on all forms of government expenditure except GTRN. YGOV4 has a negative or insignificant effect on all forms of government expenditure except GMAT and GADM.

The reconstructed effects of exogenous variables on government expenditures are shown in Table 10. They may be compared with the OLS estimates in Table 6.

4. Conclusions

We have treated the Soviet policy-making mechanism as a black box with more ports for receiving and emitting signals than internal channels for transmitting information. In the first of two stages of our investigation we built ARIMA models of investment in 13 sectors and employment in 20 sectors. When we subjected the ARIMA residuals to principal components, image, and factor analyses, we found a five-factor models to be adequate, while smaller models were rejected by some or all criteria.

In the second stage of the investigation, we estimated reduced-rank regressions for investment and government expenditure, each broken down into 10 sectors. Applying Schwarz's criterion, supplemented by the likelihood ratio test, we selected a five-factor model of investment and a four-factor model of government expenditure. While these models are more complex than the one- and two-factor models suggested by some previous investigators, they are far more parsimonious than our unrestricted models. The selected models were re-estimated as systems of seemingly unrelated regressions.

Our interpretation of the latent variables was based on their causes and effects. In the case of investment, the most important factor increases with POP, decreases with CAPHOU and CAPSER, stimulates IHOU, and dampens IFER and ICON. We interpret this factor as the perceived pressure of the population on housing and services. In the case of government expenditure, the most important factor is determined primarily by the capital stock per capita. It stimulates most forms of government expenditure, with the significant exception of the labor-intensive components of defense spending.

Because of the tradition of treating policy variables as exogenous, there are few previous studies with which our results can be compared. Virtually the only useful points of comparison are the equations for investment in SOVMOD and the equations for government expenditure in Pryor (1968). Relative SOVMOD, we have made progress by explaining investment strictly in terms of information available to policy-makers.[10] Relative to Pryor's study, we have made progress by expanding the set of exogenous variables and estimating the latent variables which mediate their effects on policy.[11]

When larger data sets become available further progress can be made in five directions. First, when times series for additional policy variables become available, they can be modeled as we have modeled investment and government expenditures. Second, when longer time series become available, the number of policy variables included in a single model can be increased, so as to improve our measurement and understanding of the latent variables.[12] Third, longer time series will permit estimation of unrestricted vector autoregressions, facilitating tests to determine the number of latent variables. Fourth, longer time series will permit estimation of distributed lags, a prerequisite to serious analysis of policy dynamics. Fifth, a portion of longer a larger sample could be reserved for evaluating the performance of the models in out-of-sample forecasting.

TABLE 1: OLS ESTIMATES OF EFFECTS OF EXOGENOUS VARIABLES ON INVESTMENT[a]

	STOKSAL	NMPDEFL	POP	CAPAGR	CAPIND	CAPHOU	CAPSER	CAPTRAN	OILR	USDEF
IAGR	.075	-.556	-14.240	*-1.952*	1.654	*2.757*	.879	-.569	.038	-.054
IHOU	.173	.054	6.241	*-1.366*	-.981	.744	.303	1.188	.045	.003
IELE	.089	.951	2.875	-1.365	.154	.994	-.297	.911	.016	-.175
ICOA	.198	.709	19.548	-.156	.192	.932	*-1.126*	-1.706	-.074	*-.467*
IOIL	.133	.421	4.329	-.171	.645	2.513	-.620	-1.756	-.037	-.280
ICHE	.501	-2.287	-11.440	.401	2.116	2.794	1.530	-4.527	.038	.031
IFER	.095	-2.675	-6.985	.067	-2.881	2.179	*2.509*	.395	.024	.260
IMBM	.106	-.737	-5.615	-2.078	.040	.680	.901	1.574	*.146*	.190
ICON	-.568	-.888	-38.171	-1.314	1.646	3.445	*3.377*	-.840	-.041	*.633*
ILIT	.169	-.081	5.964	*-1.788*	.619	-.793	*1.121*	.278	*.092*	-.040

[a]Estimated coefficients that are significantly different from zero at the .05 level are printed in *italics*.

TABLE 2

SINGULAR VALUE DECOMPOSITION OF THE COEFFICIENT MATRIX FOR INVESTMENT

The U Matrix

	YINV1	YINV2	YINV3	YINV4	YINV5	YINV6	YINV7	YINV8	YINV9	YINV10
IAGR	-.2904	.2147	-.1772	-.3897	.0390	.4540	.1288	-.6341	.2345	-.0717
IHOU	.1332	-.0153	-.4612	-.1184	.0416	-.0468	-.3162	.3210	.7368	-.0732
IELE	.0663	.0196	-.2494	-.3709	.2269	-.0415	-.5934	-.0698	-.4217	.4554
ICOA	.4141	.4746	-.1441	-.1060	.0862	-.2944	.5222	-.0397	.0895	.4415
IOIL	.1012	.4588	-.0947	-.1473	.4247	-.0474	-.0190	.1884	-.2759	-.6737
ICHE	-.2345	.7048	.1604	.2503	-.3803	.2219	-.3028	.2124	.0276	.1688
IFER	-.1413	.0162	-.6561	.6733	.0966	-.0353	.0277	-.2367	-.1693	.0005
IMBM	-.1156	-.1357	-.3855	-.2404	-.2275	.4481	.3744	.5316	-.2839	.0764
ICON	-.7800	.0396	-.0331	-.1813	.1281	-.5336	.1411	.1551	.0528	.0901
ILIT	.1229	.0239	-.2409	-.2388	-.7316	-.4063	-.0753	-.2123	-.1651	-.3015

The Singular Values

562.3653	7.216792	5.332725	4.660848	2.780240
1.282781	.2284625	.1919693	.1087223	.03106595

The V Matrix

	YINV1	YINV2	YINV3	YINV4	YINV5	YINV6	YINV7	YINV8	YINV9	YINV10	YINV11
CONST	-.996	-.015	.014	.006	-.010	.022	-.020	-.035	.051	-.043	-.021
STOKSAL	.001	.068	-.038	.022	-.107	.271	-.873	.183	-.015	.327	.071
NMPDEFL	.004	-.161	.265	-.493	.418	-.592	-.295	-.054	.194	-.043	.081
POP	.086	-.085	.082	.067	-.150	.236	-.230	-.391	.571	-.530	-.286
CAPAGR	.002	-.015	.497	.596	.337	-.100	-.158	.047	-.363	-.191	-.279
CAPIND	-.003	.316	.383	-.551	-.354	.127	.002	.081	-.380	-.186	-.350
CAPHOU	-.007	.585	-.491	-.093	.549	.088	-.072	-.004	-.058	-.212	-.213
CAPSER	-.007	.072	-.399	.197	-.472	-.659	-.206	-.082	-.181	-.156	-.183
CAPTRAN	.002	-.715	-.355	-.210	.155	.200	-.069	.041	-.364	-.148	-.306
OILR	.000	-.005	-.019	-.008	-.048	.075	-.113	.206	-.208	-.653	.683
USDEF	-.001	-.047	-.019	.045	-.043	-.082	.080	.866	.380	-.139	-.259

TABLE 3: SUR ESTIMATES OF FIVE-FACTOR MODEL OF INVESTMENT

DEPENDENT VARIABLE IAGR
FROM 1963 UNTIL 1988
TOTAL OBSERVATIONS 26 SKIPPED/MISSING 0
USABLE OBSERVATIONS 26 DEGREES OF FREEDOM 20
R**2 .99474525 RBAR**2 .99343156
SSR .27768785E-01 SEE .37261766E-01
DURBIN-WATSON 1.31763655
Q(13)= 11.1621 SIGNIFICANCE LEVEL .597241

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
1	IAGR	1	.8519330	.1267407	6.721861
2	YINV1	0	9.180589	30.48752	.3011261
3	YINV2	0	-1.029050	.7565358	-1.360214
4	YINV3	0	-.4464045	.5333014	-.8370586
5	YINV4	0	-.6887020	.5347175	-1.287973
6	YINV5	0	-.8424775	.4461236	-1.888440

DEPENDENT VARIABLE IHOU
FROM 1963 UNTIL 1988
TOTAL OBSERVATIONS 26 SKIPPED/MISSING 0
USABLE OBSERVATIONS 26 DEGREES OF FREEDOM 20
R**2 .99462356 RBAR**2 .99327945
SSR .16239007E-01 SEE .28494742E-01
DURBIN-WATSON 2.52628354
Q(13)= 6.05972 SIGNIFICANCE LEVEL .943952

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
7	IHOU	1	.7814411	.4168004E-01	18.74857
8	YINV1	0	111.0323	26.77834	4.146349
9	YINV2	0	-1.328586	.4860228	-2.733589
10	YINV3	0	-1.404751	.4153746	-3.381889
11	YINV4	0	-.5409452	.4104655	-1.317882
12	YINV5	0	-.3208560	.1472649	-2.178767

TABLE 3 (continued)

DEPENDENT VARIABLE IELE
FROM 1963 UNTIL 1988

TOTAL OBSERVATIONS	26	SKIPPED/MISSING	0
USABLE OBSERVATIONS	26	DEGREES OF FREEDOM	20
R**2	.98830661	RBAR**2	.98538326
SSR	.27051053E-01	SEE	.36777067E-01

DURBIN-WATSON 1.94877619
Q(13)= 29.3229 SIGNIFICANCE LEVEL .588907E-02

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
13	IELE	1	.1080632	.1024574	1.054713
14	YINV1	0	41.62199	29.89740	1.392161
15	YINV2	0	2.168199	.6134790	3.534268
16	YINV3	0	-.9334452	.4803384	-1.943308
17	YINV4	0	-2.221366	.5388744	-4.122233
18	YINV5	0	.6927717	.1850417	3.743867

DEPENDENT VARIABLE ICOA
FROM 1963 UNTIL 1988

TOTAL OBSERVATIONS	26	SKIPPED/MISSING	0
USABLE OBSERVATIONS	26	DEGREES OF FREEDOM	20
R**2	.98737604	RBAR**2	.98422005
SSR	.21180296E-01	SEE	.32542508E-01

DURBIN-WATSON 2.36216838
Q(13)= 9.84025 SIGNIFICANCE LEVEL .706943

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
19	ICOA	1	.5896888	.8913720E-01	6.615518
20	YINV1	0	53.05627	26.85026	1.976006
21	YINV2	0	1.937565	.5497498	3.524448
22	YINV3	0	-.2026178	.4241051	-.4777537
23	YINV4	0	-.5454928	.4632128	-1.177629
24	YINV5	0	.8510191	.2365100	3.598238

TABLE 3 (continued)

DEPENDENT VARIABLE IOIL
FROM 1963 UNTIL 1988
TOTAL OBSERVATIONS 26 SKIPPED/MISSING 0
USABLE OBSERVATIONS 26 DEGREES OF FREEDOM 20
R**2 .99813616 RBAR**2 .99767020
SSR .21819049E-01 SEE .33029569E-01
DURBIN-WATSON 2.17833149
Q(13)= 6.99747 SIGNIFICANCE LEVEL .902282

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
25	IOIL	1	.7359165	.3699502E-01	19.89231
26	YINV1	0	46.66761	27.00867	1.727875
27	YINV2	0	3.577053	.6501626	5.501782
28	YINV3	0	-.9590916E-01	.4058274	-.2363299
29	YINV4	0	-.7396185	.4781973	-1.546681
30	YINV5	0	.9144388	.2190310	4.174928

DEPENDENT VARIABLE 20 ICHE
FROM 1963 UNTIL 1988
TOTAL OBSERVATIONS 26 SKIPPED/MISSING 0
USABLE OBSERVATIONS 26 DEGREES OF FREEDOM 20
R**2 .95992612 RBAR**2 .94990765
SSR .10428923 SEE .72211228E-01
DURBIN-WATSON 1.98328511
Q(13)= 10.9081 SIGNIFICANCE LEVEL .618516

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
31	ICHE	1	.3559665	.8465901E-01	4.204709
32	YINV1	0	-32.85721	59.26056	-.5544533
33	YINV2	0	5.900398	1.426263	4.136963
34	YINV3	0	1.166906	.8838398	1.320269
35	YINV4	0	1.290974	1.052910	1.226101
36	YINV5	0	-1.777094	.3375635	-5.264474

TABLE 3 (continued)

DEPENDENT VARIABLE 21 IFER
FROM 1963 UNTIL 1988

TOTAL OBSERVATIONS	26	SKIPPED/MISSING	0
USABLE OBSERVATIONS	26	DEGREES OF FREEDOM	20
R**2	.96715456	RBAR**2	.95894321
SSR	.59597112E-01	SEE	.54588054E-01
DURBIN-WATSON	2.00809939		
Q(13)=	14.2837	SIGNIFICANCE LEVEL	.354171

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
37	IFER	1	-.1801243E-01	.1034152	-.1741758
38	YINV1	0	-120.1613	45.28058	-2.653704
39	YINV2	0	.8825250	.9019587	.9784539
40	YINV3	0	-3.547003	.6904922	-5.136919
41	YINV4	0	3.436468	.8164745	4.208911
42	YINV5	0	.4240859	.2340199	1.812179

DEPENDENT VARIABLE IMBM
FROM 1963 UNTIL 1988

TOTAL OBSERVATIONS	26	SKIPPED/MISSING	0
USABLE OBSERVATIONS	26	DEGREES OF FREEDOM	20
R**2	.99466466	RBAR**2	.99333083
SSR	.45867213E-01	SEE	.47889045E-01
DURBIN-WATSON	2.07752820		
Q(13)=	22.7777	SIGNIFICANCE LEVEL	.444227E-01

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
43	IMBM	1	.9566311	.8845792E-01	10.81453
44	YINV1	0	-13.28009	49.05657	-.2707097
45	YINV2	0	-1.586395	1.149304	-1.380309
46	YINV3	0	-.6775804	.5812368	-1.165756
47	YINV4	0	-.5919125E-01	.7018352	-.8433782E-01
48	YINV5	0	-.2516183	.2252914	-1.116857

TABLE 3 (continued)

DEPENDENT VARIABLE ICON
FROM 1963 UNTIL 1988

TOTAL OBSERVATIONS	26	SKIPPED/MISSING	0
USABLE OBSERVATIONS	26	DEGREES OF FREEDOM	20
R**2	.96020859	RBAR**2	.95026073
SSR	.64197852E-01	SEE	.56655914E-01
DURBIN-WATSON	2.09925385		
Q(13)=	10.6855	SIGNIFICANCE LEVEL	.637146

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
49	ICON	1	-.2747009	.9651146E-01	-2.846304
50	YINV1	0	-730.7365	68.83451	-10.61584
51	YINV2	0	.5627151	.8954706	.6284016
52	YINV3	0	-.7446257	.6692652	-1.112602
53	YINV4	0	-1.852162	.8013614	-2.311269
54	YINV5	0	2.026086	.2762117	7.335266

DEPENDENT VARIABLE ILIT
FROM 1963 UNTIL 1988

TOTAL OBSERVATIONS	26	SKIPPED/MISSING	0
USABLE OBSERVATIONS	26	DEGREES OF FREEDOM	20
R**2	.99573339	RBAR**2	.99466673
SSR	.89660467E-02	SEE	.21173151E-01
DURBIN-WATSON	2.42555054		
Q(13)=	17.4084	SIGNIFICANCE LEVEL	.181302

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
55	ILIT	1	.1199849	.9887527E-01	1.213498
56	YINV1	0	-7.128097	18.15580	-.3926071
57	YINV2	0	.4167317	.3499624	1.190790
58	YINV3	0	-1.341288	.3053592	-4.392494
59	YINV4	0	-1.480128	.3118315	-4.746563
60	YINV5	0	-1.205753	.1428634	-8.439901

TABLE 4: SUR ESTIMATES OF EFFECTS OF LATENT VARIABLES ON INVESTMENT[a]

	YINV1	YINV2	YINV3	YINV4	YINV5
IAGR	9.180589	-1.029050	-.4464045	-.6887020	-.8424775
IHOU	*111.0323*	*-1.328586*	*-1.404751*	-.5409452	*-.3208560*
IELE	41.62199	*2.168199*	-.9334452	*-2.221366*	*.6927717*
ICOA	53.05627	*1.937565*	-.2026178	-.5454928	*.8510191*
IOIL	46.66761	*3.577053*	-.0959091	-.7396185	*.9144388*
ICHE	-32.85721	*5.900398*	1.166906	1.290974	*-1.777094*
IFER	*-120.1613*	.8825250	*-3.547003*	*3.436468*	.4240859
IMBM	-13.28009	-1.586395	-.6775804	-.0591913	-.2516183
ICON	*-730.7365*	.5627151	-.7446257	*-1.852162*	*2.026086*
ILIT	-7.128097	.4167317	*-1.341288*	*-1.480128*	*-1.205753*

[a]Estimated coefficients that are significantly different from zero at the .05 level are printed in *italics*.

TABLE 5: RECONSTRUCTED EFFECTS OF EXOGENOUS VARIABLES ON INVESTMENT

	STOKSAL	NMPDEFL	POP	CAPAGR	CAPIND	CAPHOU	CAPSER	CAPTRAN	OILR	USDEF
IAGR	.029	.072	.924	-.883	.153	-.844	.300	.924	.059	.050
IHOU	.068	.418	9.589	-.881	-.893	-.969	-.294	1.713	.049	-.075
IELE	.091	.952	3.077	-1.502	1.175	2.031	-.539	-.571	-.010	-.271
ICOA	.076	.470	4.231	-.059	.368	1.391	-.674	-.972	-.045	-.222
IOIL	.168	.330	3.526	-.138	1.031	2.395	-.622	-2.144	-.056	-.304
ICHE	.553	-2.151	-2.890	.596	2.332	2.010	1.288	-5.241	.023	-.121
IFER	.134	-3.080	-10.566	.170	-2.747	2.989	2.828	-.243	.022	.330
IMBM	-.067	-.053	-1.032	-.461	-.598	-.638	.361	1.325	.034	.115
ICON	-.742	-1.454	-63.577	-2.301	2.479	6.944	4.314	-.752	-.040	.834
ILIT	.170	-.226	-.679	-1.977	.882	.427	.895	.288	.094	.002

TABLE 6

OLS ESTIMATES OF EFFECTS OF EXOGENOUS VARIABLES ON GOVERNMENT EXPENDITURE[a]

	CAPTOT	STOKSAL	POP	LABOR	NMPDEFL	WHEATR	OILR	GOLDR	RTBILL	USDEF
GIND	*1.981*	-.239	-4.845	-.572	.899	-.020	.036	.021	.125	-.055
GTRN	1.392	-.309	-.059	-2.529	-.453	.144	-.042	-.018	-.363	-.091
GEDU	.636	.254	-2.917	.057	-.767	.033	-.036	.002	-.030	.101
GSCI	-.269	.009	.090	.639	.227	-.099	.017	.064	.167	.012
GHEA	*1.244*	.032	-4.860	-.011	-.984	.020	-.050	-.012	.046	.151
GSEC	1.440	*.925*	-10.931	1.152	-1.975	-.205	.110	.022	-1.045	*.500*
GINS	*2.152*	*.723*	*-15.174*	1.503	*-1.612*	-.018	.060	-.023	-.596	*.561*
GMAT	1.292	.510	-5.844	-.907	1.028	.283	-.045	-.041	1.642	.343
GDEF	*-1.641*	-.504	9.521	1.332	1.643	.040	.043	-.088	-.394	.103
GADM	.671	.265	-6.206	.871	-1.158	-.047	.018	.025	.132	.191

[a]Estimated coefficients that are significantly different from zero at the .05 level are printed in *itlalics*.

TABLE 7: SINGULAR VALUE DECOMPOSITION OF THE COEFFICIENT MATRIX FOR GOVERNMENT EXPENDITURE

The U Matrix

	YGOV1	YGOV2	YGOV3	YGOV4	YGOV5	YGOV6	YGOV7	YGOV8	YGOV9	YGOV10
GIND	.2118	-.2484	.3864	-.6703	-.0644	-.3703	.3419	.0663	.1787	.0189
GTRN	.0813	-.6167	-.4463	-.3252	.0294	.2793	-.2608	-.2727	-.0496	.2905
GEDU	.1236	.0139	-.1176	.0305	-.2832	.3127	.3340	.6606	-.1467	.4715
GSCI	-.0257	.1486	.1570	.0354	-.1079	-.1366	.2687	-.5147	-.6561	.3916
GHEA	.2030	-.0168	-.1006	-.1080	-.6951	.1975	.0234	-.0870	-.2426	-.5896
GSEC	.4337	.3178	-.2685	-.1128	.3922	.3628	.4870	-.2456	.1523	-.1413
GINS	.5966	.3354	.0914	-.2045	.1261	-.0783	-.5949	.1699	-.2580	.1004
GMAT	.2731	-.3680	.6713	.3304	.0846	.4615	-.0270	-.0916	.0267	-.0142
GDEF	-.4641	.3821	.2676	-.4842	-.0710	.5199	-.1765	-.0851	.0977	.0956
GADM	.2394	.2013	-.0158	.1814	-.4879	-.0913	-.0886	-.3279	.5956	.3906

The Singular Values

265.1702	5.014883	2.891248	1.738644	.7778801
.5721459	.2773255	.1102785	.0402439	.0324264

The V Matrix

	YGOV1	YGOV2	YGOV3	YGOV4	YGOV5	YGOV6	YGOV7	YGOV8	YGOV9	YGOV10	YGOV11
CONS	.996	-.049	-.015	.026	.028	-.020	.000	.006	.027	.019	.052
CAPTOT	.015	-.237	.045	-.670	-.473	.301	.362	.139	.103	.076	.108
STOKSAL	.005	.092	.012	.272	.404	.550	.574	.311	-.044	-.014	-.150
POP	-.089	-.544	-.252	.216	.208	-.112	.089	.092	.320	.229	.599
LABOR	.002	.735	.195	.004	-.090	-.125	.121	.168	.273	.214	.485
NMPDEFL	-.010	-.211	.797	-.275	.467	-.142	-.037	.014	-.021	.004	.066
WHEATR	-.000	-.053	.056	.031	-.059	.276	-.575	.579	.053	.464	-.174
OILR	.000	.022	.000	-.036	.096	-.024	.089	-.335	.743	.297	-.477
GOLDR	.000	.000	-.011	.018	-.007	-.140	.246	-.276	-.500	.768	-.056
RTBILL	-.001	-.208	.504	.593	-.569	.065	.117	-.068	.064	-.020	-.015
USDEF	.003	.074	.057	-.011	.080	.676	-.322	-.565	-.016	.038	.322

TABLE 8: SUR ESTIMATES OF 4 FACTOR MODEL OF GOVERNMENT EXPENDITURE

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DEPENDENT VARIABLE          GIND
FROM  1956  UNTIL  1985
TOTAL OBSERVATIONS      30      SKIPPED/MISSING         0
USABLE OBSERVATIONS     30      DEGREES OF FREEDOM     25
R**2              .99768337     RBAR**2          .99731271
SSR           .31701137E-01     SEE          .35609626E-01
DURBIN-WATSON  1.73041250
Q(  15)=   11.6880          SIGNIFICANCE LEVEL  .702477
NO.      VAR      LAG    COEFFICIENT    STAND. ERROR    T-STATISTIC
***    *******    ***    ************   ************    ************
  1      GIND       1     .1315402      .8608067E-01    1.528103
  2      YGOV1      0     29.49288      9.131494        3.229798
  3      YGOV2      0    -1.982493      .3658890       -5.418291
  4      YGOV3      0     .5620189      .1914833        2.935081
  5      YGOV4      0    -1.172297      .1161229       -10.09531
```

```
DEPENDENT VARIABLE          GTRN
FROM  1956  UNTIL  1985
TOTAL OBSERVATIONS      30      SKIPPED/MISSING         0
USABLE OBSERVATIONS     30      DEGREES OF FREEDOM     25
R**2              .98999376     RBAR**2          .98839276
SSR           .61059289E-01     SEE          .49420356E-01
DURBIN-WATSON  1.98592708
Q(  15)=   10.2518          SIGNIFICANCE LEVEL  .803610
NO.      VAR      LAG    COEFFICIENT    STAND. ERROR    T-STATISTIC
***    *******    ***    ************   ************    ************
  6      GTRN       1     .4379547      .8761131E-01    4.998838
  7      YGOV1      0     39.37674      13.97637        2.817378
  8      YGOV2      0    -2.997032      .5999138       -4.995772
  9      YGOV3      0    -1.075994      .2570420       -4.186063
 10      YGOV4      0    -.4892351      .7676846E-01   -6.372866
```

TABLE 8 (continued)

DEPENDENT VARIABLE GEDU
FROM 1956 UNTIL 1985

TOTAL OBSERVATIONS	30	SKIPPED/MISSING	0
USABLE OBSERVATIONS	30	DEGREES OF FREEDOM	25
R**2	.99813041	RBAR**2	.99783128
SSR	.16933608E-01	SEE	.26025839E-01
DURBIN-WATSON	1.47669657		
Q(15)=	13.7173	SIGNIFICANCE LEVEL	.547068

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
11	GEDU	1	.7851525	.7076092E-01	11.09585
12	YGOV1	0	18.75226	12.00351	1.562232
13	YGOV2	0	1.308910	.3975595	3.292362
14	YGOV3	0	.2429151	.1296982	1.872926
15	YGOV4	0	-.1490023	.5400378E-01	-2.759109

DEPENDENT VARIABLE GSCI
FROM 1956 UNTIL 1985

TOTAL OBSERVATIONS	30	SKIPPED/MISSING	0
USABLE OBSERVATIONS	30	DEGREES OF FREEDOM	25
R**2	.99879432	RBAR**2	.99860141
SSR	.17498827E-01	SEE	.26456626E-01
DURBIN-WATSON	1.52753873		
Q(15)=	11.5797	SIGNIFICANCE LEVEL	.710525

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
16	GSCI	1	.8895438	.1975631E-01	45.02582
17	YGOV1	0	-17.53000	13.41880	-1.306376
18	YGOV2	0	-.2762613	.3455154	-.7995628
19	YGOV3	0	.3419264	.1297800	2.634662
20	YGOV4	0	-.1084392	.3392461E-01	-3.196476

TABLE 8 (continued)

DEPENDENT VARIABLE GHEA
FROM 1956 UNTIL 1985
TOTAL OBSERVATIONS 30 SKIPPED/MISSING 0
USABLE OBSERVATIONS 30 DEGREES OF FREEDOM 25
R**2 .99710758 RBAR**2 .99664479
SSR .20770696E-01 SEE .28824084E-01
DURBIN-WATSON 1.71627534
Q(15)= 16.9993 SIGNIFICANCE LEVEL .318907

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
21	GHEA	1	.6660407	.6746105E-01	9.872966
22	YGOV1	0	37.91332	14.21012	2.668051
23	YGOV2	0	.9813052	.3522303	2.785976
24	YGOV3	0	.1590894	.1450686	1.096649
25	YGOV4	0	-.1789029	.3866752E-01	-4.626698

DEPENDENT VARIABLE GSEC
FROM 1956 UNTIL 1985
TOTAL OBSERVATIONS 30 SKIPPED/MISSING 0
USABLE OBSERVATIONS 30 DEGREES OF FREEDOM 25
R**2 .99340789 RBAR**2 .99235315
SSR .68722032E-01 SEE .52429775E-01
DURBIN-WATSON 2.47108056
Q(15)= 8.60863 SIGNIFICANCE LEVEL .897076

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
26	GSEC	1	.5114830	.4999307E-01	10.23108
27	YGOV1	0	62.12520	17.35244	3.580200
28	YGOV2	0	1.027428	.5149684	1.995129
29	YGOV3	0	.3528586E-01	.2630341	.1341493
30	YGOV4	0	-.3603259	.5852493E-01	-6.156793

TABLE 8 (continued)

DEPENDENT VARIABLE GINS
FROM 1956 UNTIL 1985
TOTAL OBSERVATIONS 30 SKIPPED/MISSING 0
USABLE OBSERVATIONS 30 DEGREES OF FREEDOM 25
R**2 .99791477 RBAR**2 .99758114
SSR .36026193E-01 SEE .37961134E-01
DURBIN-WATSON 2.19547938
Q(15)= 9.06439 SIGNIFICANCE LEVEL .874127

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
31	GINS	1	.5943415	.5657784E-01	10.50485
32	YGOV1	0	171.3287	27.04646	6.334606
33	YGOV2	0	1.901379	.3984500	4.771938
34	YGOV3	0	-.1683416	.1965109	-.8566527
35	YGOV4	0	.2312968E-01	.4098534E-01	.5643403

DEPENDENT VARIABLE GMAT
FROM 1956 UNTIL 1985
TOTAL OBSERVATIONS 30 SKIPPED/MISSING 0
USABLE OBSERVATIONS 30 DEGREES OF FREEDOM 25
R**2 .87419216 RBAR**2 .85406290
SSR .11096496 SEE .66622808E-01
DURBIN-WATSON 2.09066249
Q(15)= 14.7751 SIGNIFICANCE LEVEL .467736

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
36	GMAT	1	.3643414	.1038788	3.507371
37	YGOV1	0	58.32188	17.57780	3.317928
38	YGOV2	0	-.9834344	.5839611	-1.684075
39	YGOV3	0	2.486064	.4276709	5.813031
40	YGOV4	0	.5816062	.1090950	5.331189

TABLE 8 (continued)

DEPENDENT VARIABLE GDEF
FROM 1956 UNTIL 1985

TOTAL OBSERVATIONS	30	SKIPPED/MISSING	0
USABLE OBSERVATIONS	30	DEGREES OF FREEDOM	25
R**2	.97820507	RBAR**2	.97471788
SSR	.36687429E-01	SEE	.38307925E-01
DURBIN-WATSON	1.13530538		
Q(15)=	25.3735	SIGNIFICANCE LEVEL	.451470E-01

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
41	GDEF	1	.2521718	.6204500E-01	4.064338
42	YGOV1	0	-112.0757	13.11521	-8.545474
43	YGOV2	0	3.146656	.3971753	7.922588
44	YGOV3	0	1.443491	.2145526	6.727912
45	YGOV4	0	-.7136571	.7582200E-01	-9.412270

DEPENDENT VARIABLE GADM
FROM 1956 UNTIL 1985

TOTAL OBSERVATIONS	30	SKIPPED/MISSING	0
USABLE OBSERVATIONS	30	DEGREES OF FREEDOM	25
R**2	.99128697	RBAR**2	.98989289
SSR	.30007034E-01	SEE	.34645077E-01
DURBIN-WATSON	1.65993055		
Q(15)=	19.8422	SIGNIFICANCE LEVEL	.178070

NO.	VAR	LAG	COEFFICIENT	STAND. ERROR	T-STATISTIC
***	*******	***	************	************	************
46	GADM	1	.8418280	.5833001E-01	14.43216
47	YGOV1	0	57.05981	14.33553	3.980308
48	YGOV2	0	1.005454	.3033035	3.315011
49	YGOV3	0	-.1592923	.1741148	-.9148693
50	YGOV4	0	.7804279E-01	.3789763E-01	2.059305

TABLE 9:

SUR ESTIMATES OF THE EFFECTS OF LATENT VARIABLES ON GOVERNMENT EXPENDITURE.[a]

	YGOV1	YGOV2	YGOV3	YGOV4
GIND	*29.49288*	*-1.982493*	*.5620189*	*-1.172297*
GTRN	*39.37674*	*-2.997032*	*-1.075994*	*-.4892351*
GEDU	18.75226	*1.308910*	.2429151	*-.1490023*
GSCI	-17.53000	-.2762613	*.3419264*	*-.1084392*
GHEA	*37.91332*	*.9813052*	.1590894	-.1789029
GSEC	*62.12520*	1.027428	.0352859	*-.3603259*
GINS	*171.3287*	*1.901379*	-.1683416	.0231297
GMAT	*58.32188*	-.9834344	*2.486064*	*.5816062*
GDEF	*-112.0757*	*3.146656*	*1.443491*	*-.7136571*
GADM	*57.05981*	*1.005454*	-.1592923	*.0780428*

[a]Estimated coefficients that are significantly different from zero at the .05 level are printed in *italics*.

TABLE 10:
RECONSTRUCTED EFFECTS OF EXOGENOUS VARIABLES ON GOVERNMENT EXPENDITURE

	CAPTOT	STOKSAL	POP	LABOR	NMPDEFL	WHEATR	OILR	GOLDR	RTBILL	USDEF
GIND	1.732	-.359	-1.949	-1.308	.885	.097	.003	-.024	-.016	-.026
GTRN	1.593	-.240	-1.719	-2.355	-.497	.079	-.043	.007	-.231	-.178
GEDU	.087	.170	-2.480	1.037	-.234	-.063	.038	-.003	-.249	.159
GSCI	-.114	-.132	1.606	-.163	.541	.033	-.005	-.008	.175	-.044
GHEA	.474	.220	-3.998	.809	-.420	-.054	.035	-.000	-.251	.179
GSEC	.949	.286	-6.192	.854	-.727	-.072	.046	.001	-.444	.238
GINS	2.145	.975	-16.284	1.624	-2.301	-.132	.070	.023	-.562	.561
GMAT	.847	.368	-5.173	-.148	1.430	.202	-.032	-.011	1.770	.210
GDEF	-1.918	-.406	7.777	2.421	1.836	-.095	.077	-.041	-.288	.040
GADM	.574	.377	-5.585	.794	-.946	-.068	.029	.010	-.275	.208

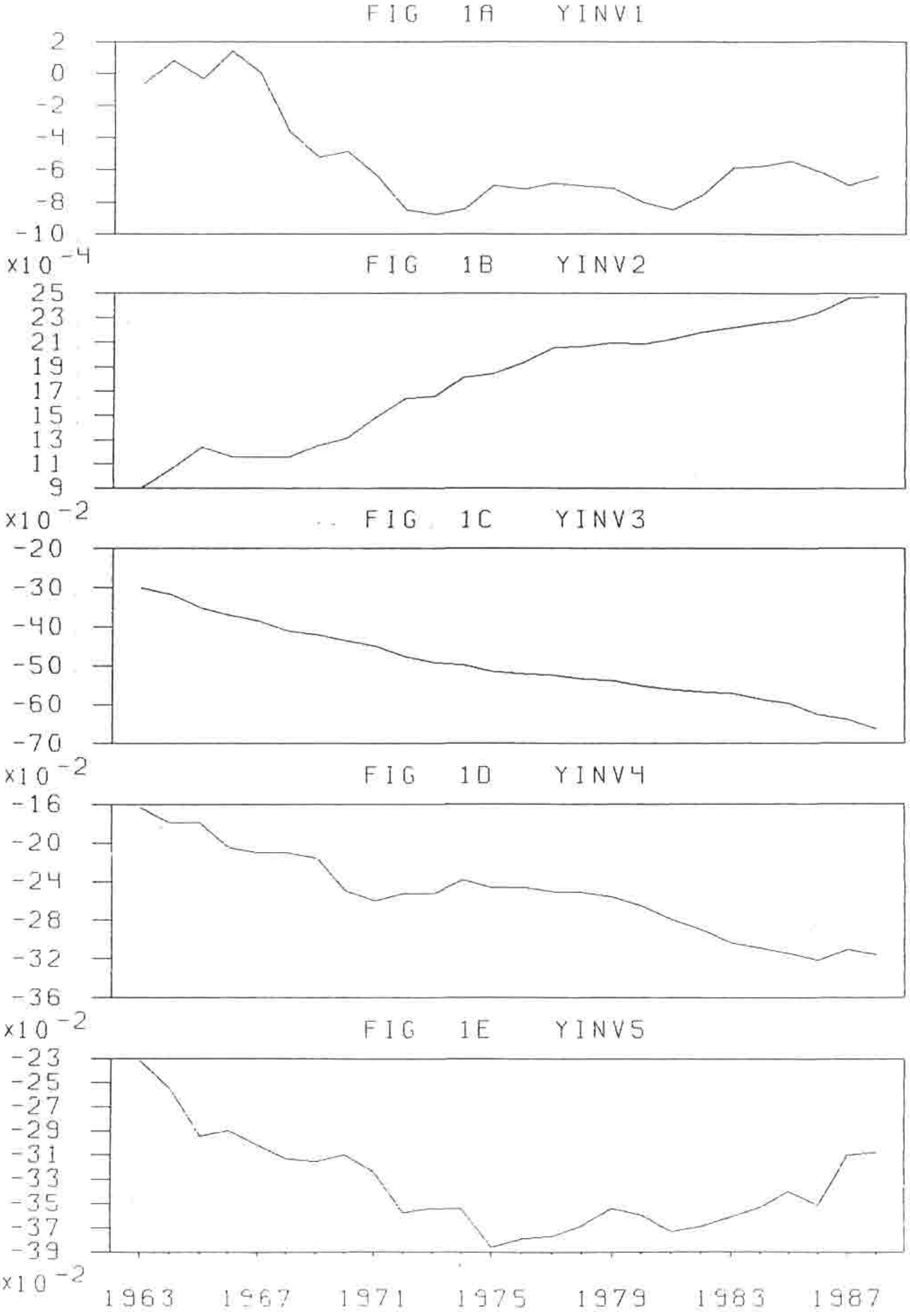
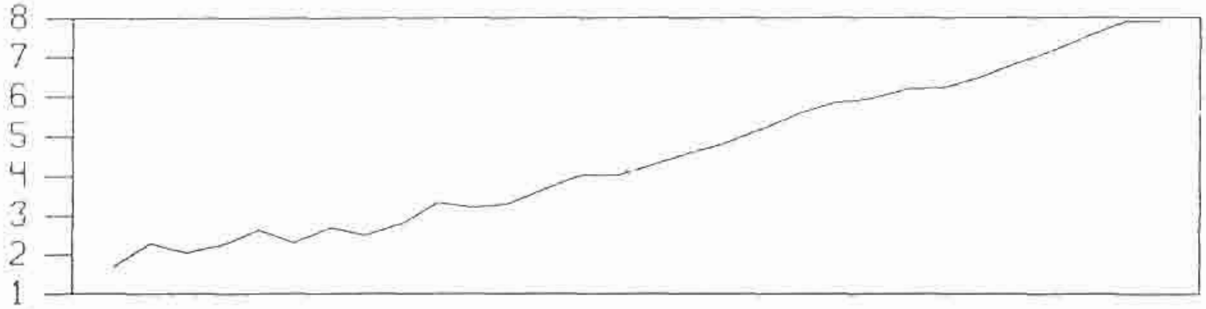


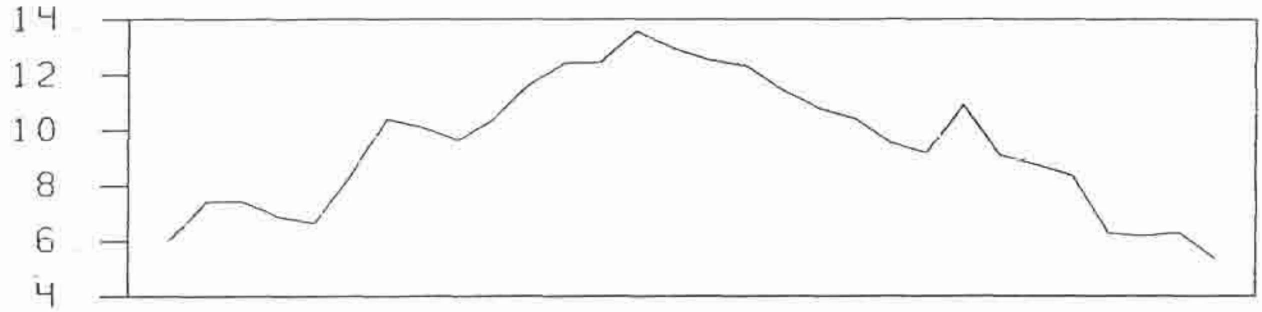
FIG 1A YINV1
2
0
-2
-4
-6
-8
-10
x10 -4
FIG 1B YINV2
25
23
21
19
17
15
13
11
9
x10 -2
FIG 1C YINV3
-20
-30
-40
-50
-60
-70
x10 -2
FIG 1D YINV4
-16
-20
-24
-28
-32
-36
x10 -2
FIG 1E YINV5
-23
-25
-27
-29
-31
-33
-35
-37
-39
x10 -2
1963
1967
1971
1975
1979
1983
1987

FIG 2A YGOV1



x10 $^{-2}$

FIG 2B YGOV2



x10 $^{-2}$

FIG 2C YGOV3

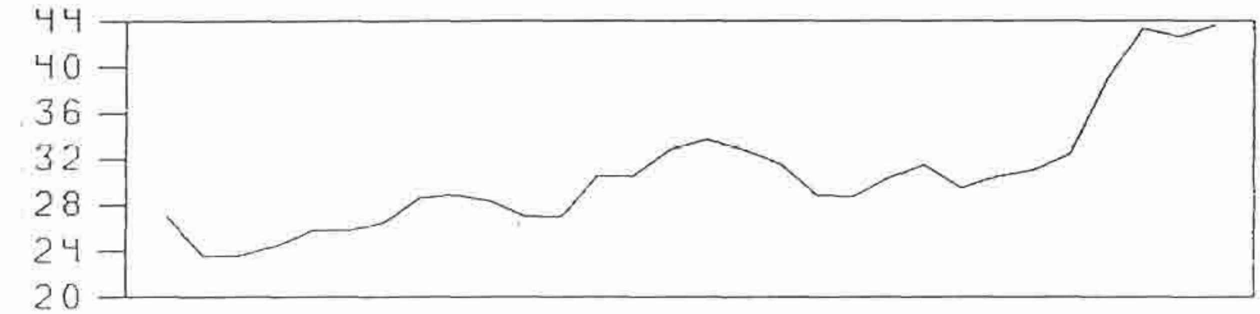


FIG 2D YGOV4

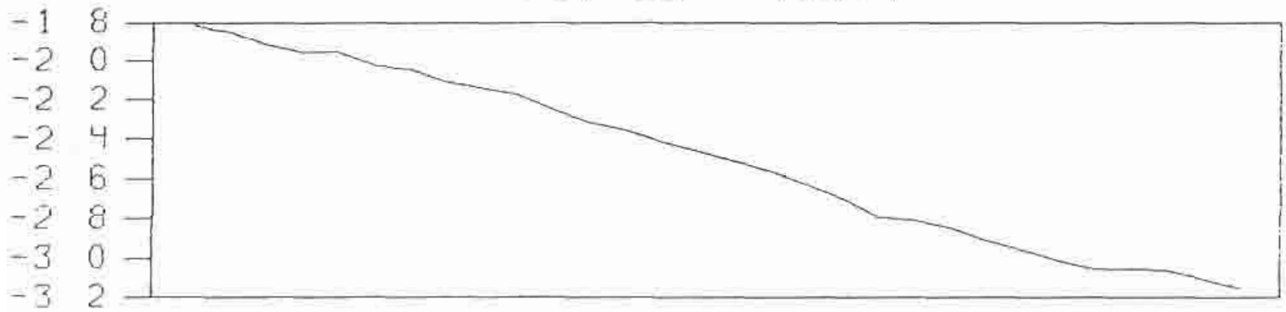
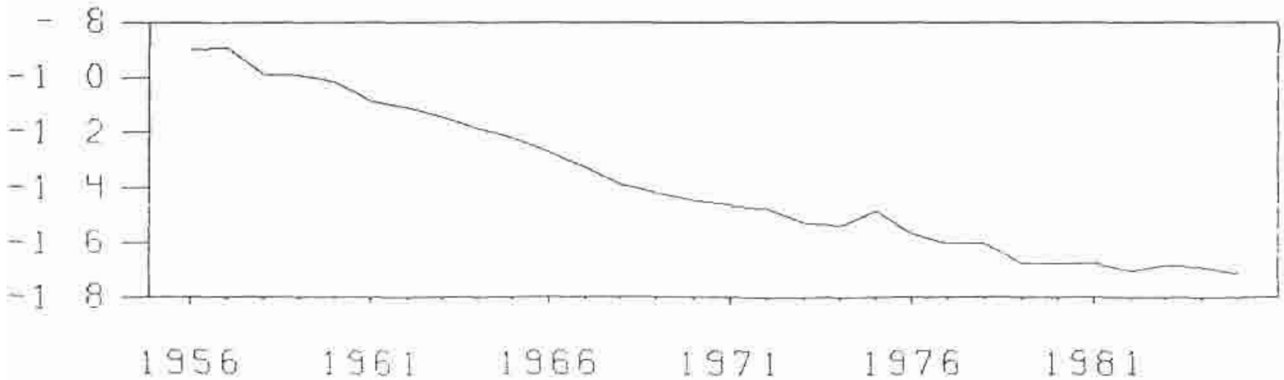


FIG 2E YGOV5



Data Appendix

Investment data, 1962-88

Time series in comparable prices were collected for investment in three branches of the national economy--agriculture, housing, and industry, the last broken down into ten sectors (electricity, coal, oil and gas, chemicals, ferrous metallurgy, machine-building and metal-working, construction materials, wood and paper, light industry, and food). The series begin in 1962 because the only available data for earlier years are based on a different demarcation of branches and industries.[10]

To construct the series in comparable prices it was necessary to splice together several series in prices of various years.[11] The longest series available were in 1973 prices, so it was expedient to convert the shorter series to a comparable basis. The calculations for each period and series are explained below.

Data in 1973 prices for agriculture and housing (1962-83), electricity, coal, oil and gas, chemicals, ferrous metallurgy, construction materials, and light industry (1965-83), and machine-building and metal-working, wood and paper, and food (1965-74, 1976-83) come from the *Soviet and East European Databank* (1988), pp. 7.3.2.1.2.1-2.2.4.[12]

Time series in 1962 prices for each industrial sector (1962-63) come from *Narodnoe khoziaistvo SSSR v 1963 g.*, p. 455. These series were converted to 1973 prices in two steps. First, they were converted to 1965 prices by use of branch and sectoral price indices of the form

$$\frac{1}{3}\left(\frac{I^{58}_{65}}{I^{58}_{62}} + \frac{I^{60}_{65}}{I^{60}_{62}} + \frac{I^{64}_{65}}{I^{64}_{62}}\right),$$

where I_k^j is investment in year j in prices of year k. There is one such index for each branch and sector. Data for I_k^j come from the *Narodnoe khoziaistvo SSSR* for 1964 (p. 516) and 1965 (p. 534). Second, the series in 1965 prices were converted to 1973 prices by use of branch and sectoral price indices of the form

$$\frac{I_{73}^{65}}{I_{65}^{65}}.$$

Data used in calculating indices of this form come from the *Narodnoe khoziaistvo SSSR* for 1965 (p. 534) and 1977 (p. 438).

Data in 1965 prices for 1964 investment in all industrial sectors come from *Narodnoe khoziaistvo SSSR v 1965 g.*, p. 534. They are converted to 1973 prices by use of the price indices defined at the end of the previous paragraph.

Data for 1975 investment in 1973 prices for machine-building and metal-working, wood and paper, and food come from *Narodnoe khoziaistvo SSSR v 1983 g.*, p. 361. (These data are minor revisions of those given in *Narodnoe khoziaistvo SSSR v 1977 g.* and reproduced in the *Soviet and East European Databank*.)

Data on investment in all branches and sectors in 1984 prices come from *PlanEcon Report*, Feb. 17, 1989, p. 21. To convert these data to 1973 prices, we multiply them by branch and sectoral price indices of the form

$$\frac{1}{4}\left(\frac{I_{73}^{80}}{I_{84}^{80}} + \frac{I_{73}^{81}}{I_{84}^{81}} + \frac{I_{73}^{82}}{I_{84}^{82}} + \frac{I_{73}^{83}}{I_{84}^{83}}\right).$$

(Data on I_{73}^j come from the *Soviet and East European Databank*, pp. 7.3.2.1.2.1-2.2.4; those on I_{84}^j come from *PlanEcon Report*, Feb. 17, 1989, p. 21.

Investments in the wood and paper, light industry, and food sectors were aggregated to form investment in total light industry.

The final series for investment are shown in Table A1.

Government expenditure data, 1955-85

Table A2 contains time series in current prices for 10 categories of government expenditure: industry and construction, transportation and communications, education, science, health and physical culture, social security, social insurance, aid to mothers, defense, and administration. Data sources for each period are indicated below.

Data for 1955 and 1960-65 come from *Gosudarstvennyi biudzhet SSSR ...* (1966), pp. 20-25.

Raw data for 1956-59 come from *Gosudarstvennyi biudzhet SSSR ...* (1962), pp. 18-23. The data for this period on science, education, and health needed adjustments to make them comparable to data for other years. The data for science were adjusted so as to exclude estimated expenditures on museums and exhibitions. (These expenditures amounted to 17.0 million post-1961 rubles in 1955 and 25.2 million in 1960. I interpolated these expenditures for 1956-59, assuming exponential growth.) For education, the adjustment involved adding estimated expenditures on museums and exhibitions and subtracting estimated expenditures for university health clinics. (The latter expenditures amounted to 18.2 million post-1961 rubles in 1955 and 17.3 million in 1960. I interpolated these expenditures for 1956-59, assuming exponential decline.) For health, the adjustment consisted of adding estimated expenditures on university clinics.

The data for 1966-70 come from *Gosudarstvennyi biudzhet SSSR ... 1966-1970 gg.*, pp. 25-29.

The raw data for 1971-75 come from CIA (1977), pp. 26-33. To make the data for science expenditures in these years comparable to those for other periods, I added estimated investment in scientific institutions. (Actual investments averaged 1.72% of other expenditures on science in 1970 and 1976. I added the same percentage to the raw data for 1971-75.)

The data for 1976-80 come from *Gosudarstvennyi biudzhet SSSR ... 1976-1980 gg.*, pp. 22-27; and those for 1981-85 come from *Gosudarstvennyi biudzhet SSSR ... 1981-85 gg.*, pp. 14-19.

Data on exogenous variables

Capital stocks in 1973 prices (CAPAGR, CAPHOU, CAPIND, CAPSER, CAPTOT, CAPTRAN) come from the *Soviet and East European Databank*, pp. 7.3.1.1.3.1 - 2 and *Narodnoe khoziaistvo SSSR v 1987* p. 53.

The price of gold in London, expressed in dollars per troy ounce, comes from *International Financial Statistics*. To obtain GOLDR, we divide that price by the U.S. producers' price index (1975 = 100), taken from *International Financial Statistics* and *Main Economic Indicators*.

Mid-year employment in the state sector (LABOR) in thousands comes from the *Soviet and East European Databank* p. 7.4.1.1 and *Narodnoe khoziaistvo SSSR v 1987* p. 364.

The nmp deflator NMPDEFL is obtained by dividing nominal net material product produced (in billions of rubles) by an index of real nmp produced (1970 = 100). The former series comes from the United Nations (1967, p. 598), the *Soviet and East European Databank*, p. 7.5.1.2.1, and *PlanEcon Report*, Feb. 17, 1989, p. 14. The latter series comes from the *Soviet and East European Databank*, p. 7.5.1.4.1, *Narodnoe khoziaistvo SSSR za 70 let* (1987, p. 1), and *Narodnoe khoziaistvo SSSR v 1987*, p. 15.

The price of Saudi (Ras Tanura) crude oil in dollars per barrel comes from *World Business Cycles* (1982, p. 166) and *International Financial Statistics*. This series ends in 1984 and is extended through 1987 by the price of Venezuelan crude oil (taken from *International Financial Statistics*) multiplied by the ratio of Saudi to Venezuelan prices in 1984. The price of oil is divided by the U.S. producers' price index to obtain OILR.

Population (POP) in thousands in January comes from the Clark and Matko (1983, pp. 3-4), *Narodnoe khoziaistvo SSSR v 1985*, p. 6. and *Narodnoe khoziaistvo SSSR v 1987*, p. 343.

The interest rate on three-month U.S. Treasury bills comes from *International Financial Statistics*. To derive RTBILL from this interest rate, we subtract the inflation rate calculated from the U.S. producers' price index. RTBILL is expressed in decimal form.

Inventories in retail trade at year end and retail sales, both in billions of rubles, come from *Narodnoe khoziaistvo SSSR*, various years. Their ratio is STOKSAL.

U.S. outlays on national defense (USDEF), in billions of 1982 dollars, come from U.S. Office of Management and Budget (1987, pp. 6.1(1)-(9)).

The price of Argentine wheat in dollars per bushel comes from *International Financial Statistics*. It is divided by the U.S. producers' price index to obtain WHEATR.

All the exogenous variables except RTBILL are used in logarithmic form.

TABLE A1. INVESTMENT IN BILLIONS OF RUBLES AT 1973 PRICES

DATE	IAGR	IHOU	IELE	ICOA	IOIL
1962	6.541	8.795	1.910	1.061	1.734
1963	7.215	8.776	2.059	1.116	1.906
1964	8.585	8.408	2.302	1.267	2.278
1965	9.477	9.589	2.456	1.389	2.655
1966	10.090	10.574	2.563	1.439	2.878
1967	10.769	11.395	2.668	1.470	2.949
1968	12.015	12.005	2.675	1.429	3.064
1969	12.517	12.351	2.702	1.398	3.115
1970	14.276	13.364	3.021	1.502	3.522
1971	16.430	14.028	3.312	1.582	3.831
1972	17.984	14.573	3.328	1.668	4.177
1973	19.856	15.078	3.356	1.696	4.504
1974	21.579	15.530	3.344	1.681	5.162
1975	23.293	16.265	3.649	1.710	5.579
1976	24.266	16.504	3.775	1.747	5.901
1977	24.908	17.013	3.596	1.848	6.534
1978	25.787	17.522	3.890	2.035	7.480
1979	26.344	17.332	3.940	2.020	7.880
1980	26.900	17.900	4.500	2.100	8.900
1981	27.600	19.000	4.500	2.000	10.100
1982	28.000	20.300	4.500	2.200	11.000
1983	29.000	21.900	4.600	2.300	11.800
1984	28.100	22.800	5.000	2.400	12.200
1985	28.500	23.800	5.700	2.400	14.100
1986	30.300	26.200	5.700	2.600	15.700
1987	31.100	28.400	5.800	2.900	17.800
1988	31.700	30.400	5.900	3.100	19.700

TABLE A1 (continued)

DATE	ICHE	IFER	IMBM	ICON	ILIT
1962	1.280	1.586	2.652	1.085	2.740
1963	1.612	1.627	2.701	1.111	2.844
1964	2.184	1.597	2.888	.992	3.362
1965	2.157	1.779	3.106	1.011	3.587
1966	2.078	1.689	3.393	1.061	3.793
1967	2.034	1.933	3.843	1.133	4.110
1968	2.141	2.197	4.312	1.377	4.349
1969	2.354	2.087	4.862	1.584	4.351
1970	2.400	2.021	5.958	1.671	4.834
1971	2.468	2.132	6.297	1.723	5.064
1972	2.742	2.297	6.786	1.932	5.479
1973	3.101	2.744	7.112	1.907	5.694
1974	3.528	2.931	7.820	1.876	5.854
1975	3.791	2.805	9.700	1.859	6.186
1976	3.972	2.907	10.053	1.664	6.206
1977	4.480	3.059	10.568	1.887	6.198
1978	5.320	3.030	11.110	1.800	6.220
1979	4.500	3.210	11.100	1.920	6.190
1980	4.000	2.800	11.900	1.900	6.700
1981	3.800	3.100	12.400	2.000	6.900
1982	4.000	3.200	12.500	1.800	7.000
1983	4.100	3.300	13.300	2.000	7.400
1984	4.300	3.000	13.600	2.000	7.500
1985	4.000	2.900	14.500	2.000	7.400
1986	4.000	3.400	16.300	2.000	7.900
1987	3.800	3.800	16.500	2.500	7.700
1988	3.800	4.200	16.700	2.200	8.100

Table A2. GOVERNMENT EXPENDITURE, BILLIONS OF CURRENT RUBLES

DATE	GIND	GTRN	GEDU	GSCI	GHEA
1955	10.9509	1.9464	6.0685	.8077	3.1322
1956	12.7534	2.1557	6.3451	1.0113	3.5843
1957	13.0772	2.2628	6.7284	1.3389	3.8510
1958	13.6739	2.4129	6.9287	1.6743	4.1320
1959	14.8817	2.6856	7.4314	1.9810	4.4816
1960	15.5875	2.8127	7.9917	2.3137	4.8410
1961	15.8136	2.6653	8.6763	2.6546	5.0056
1962	15.3636	2.7508	9.4526	2.9821	4.9446
1963	17.2919	2.7238	10.2632	3.4433	5.2566
1964	18.8678	2.7750	11.1541	3.9495	5.6622
1965	20.9895	2.8289	13.2454	4.2650	6.6686
1966	21.0559	2.6132	14.1195	4.6124	7.1002
1967	23.5298	2.6177	15.0432	5.0496	7.4508
1968	24.1503	2.6544	16.3255	5.5225	8.1385
1969	24.6814	2.8878	17.4247	5.8837	8.5517
1970	30.5319	3.1058	18.2260	6.5434	9.2842
1971	32.5300	3.1100	19.2613	7.0387	9.6200
1972	34.0500	3.4900	20.5248	7.4252	10.0300
1973	36.4500	3.5900	22.1813	7.6287	10.5000
1974	40.5900	4.1400	23.5345	8.0355	10.9700
1975	47.0100	4.9600	24.7646	8.0254	11.4700
1976	50.9815	5.6045	25.7593	8.0318	11.8529
1977	53.1762	5.7424	26.8005	8.3155	12.4639
1978	60.4972	5.7300	28.0259	8.9020	13.4921
1979	68.1852	6.5653	28.9275	9.4174	14.1350
1980	74.0993	7.9590	29.9069	10.0810	14.8210
1981	79.3403	7.4784	30.8098	10.8621	15.2432
1982	84.2885	7.6347	32.1450	11.7203	16.0350
1983	93.7619	7.5151	32.4326	12.7123	16.4549
1984	99.0875	8.2939	33.9806	13.2329	17.1491
1985	102.9124	8.1220	35.9776	13.6248	17.6106

TABLE A2 (continued).

DATE	GSEC	GINS	GMAT	GDEF	GADM
1955	2.5626	1.6554	.4908	10.7359	1.2494
1956	3.1505	1.8622	.5065	9.7322	1.2139
1957	5.2820	2.3454	.5229	9.1232	1.1953
1958	5.7283	2.4432	.5297	9.3630	1.1966
1959	6.0728	2.6694	.4999	9.3726	1.1151
1960	6.4830	2.8112	.4961	9.2987	1.0932
1961	7.1541	3.2099	.4864	11.5947	1.0823
1962	7.6708	3.4373	.4793	12.6448	1.0859
1963	8.1312	3.4062	.4661	13.8688	1.0947
1964	8.5776	3.5022	.4672	13.2801	1.1089
1965	9.0504	4.0366	.4616	12.7802	1.2801
1966	9.7449	4.3275	.4564	13.4033	1.4115
1967	10.3715	4.7174	.4486	14.5000	1.5123
1968	11.2560	5.4747	.4476	16.7000	1.6161
1969	12.0167	6.2860	.4384	17.7020	1.7164
1970	12.7378	7.3347	.4353	17.8540	1.6614
1971	13.6200	7.7800	.4300	17.8500	1.7800
1972	14.4500	8.3000	.4200	17.9000	1.8000
1973	15.1100	9.1200	.4100	17.8500	1.8500
1974	16.0800	9.8900	.4000	17.6500	1.9200
1975	18.1700	11.8500	.3900	17.4300	2.0100
1976	19.2128	12.7477	.3710	17.4300	2.0540
1977	20.1771	13.3298	.3548	17.2300	2.1513
1978	21.4103	13.9980	.3400	17.2300	2.2827
1979	22.6409	14.7475	.3248	17.2300	2.3613
1980	24.0088	15.9040	.3111	17.1240	2.5441
1981	25.6601	16.8912	.3047	17.0540	2.6382
1982	27.2808	18.0209	.5088	17.0540	2.7880
1983	28.0296	20.7714	.5446	17.0540	2.8566
1984	29.6237	22.2908	.5665	17.0540	2.8610
1985	31.8612	22.8372	.5916	19.0630	2.9822

FIG A1A IAGR

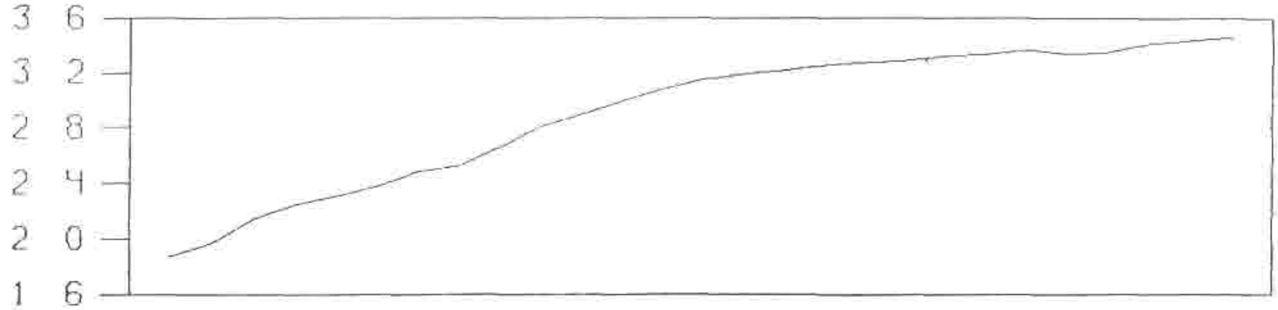


FIG A1B IHOU

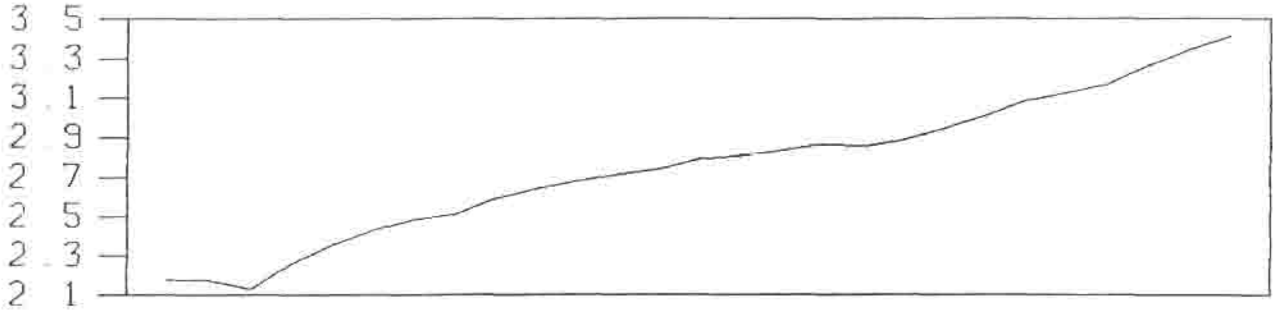


FIG A1C IELE

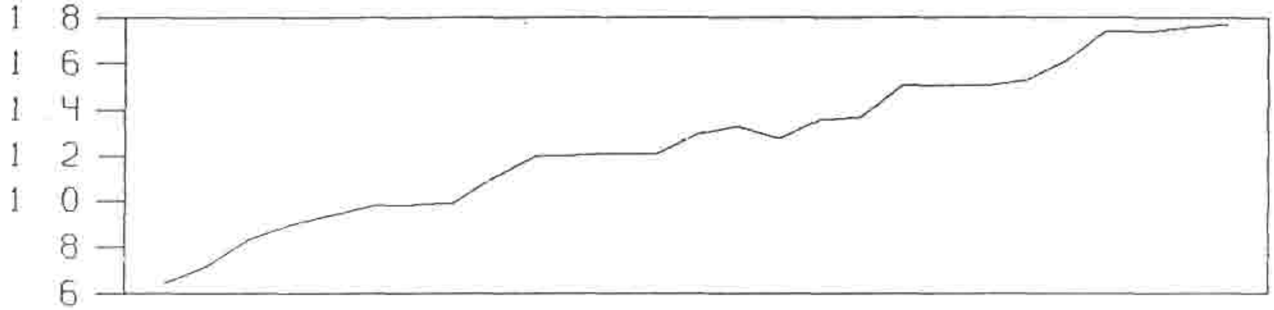


FIG A1D ICOA

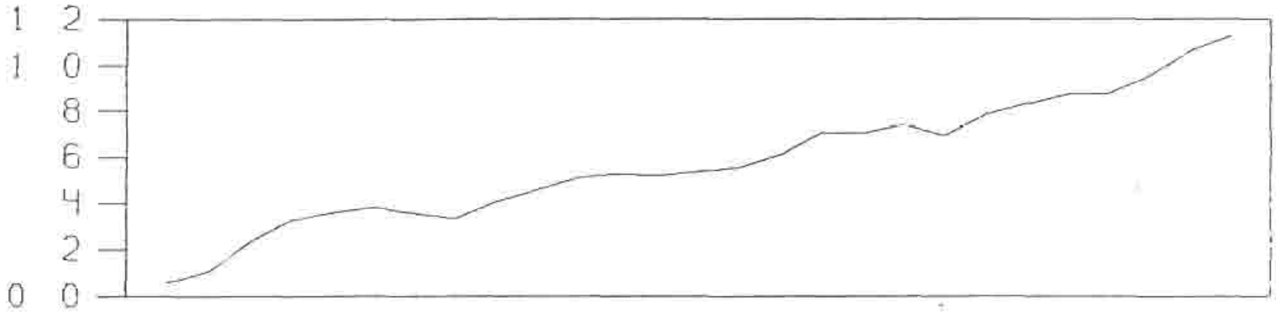


FIG A1E IOIL

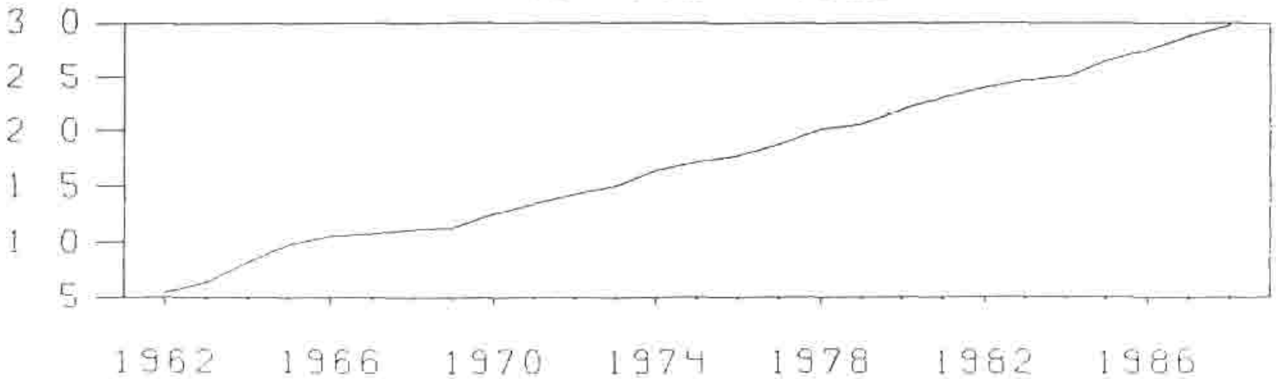


FIG A1F ICHE

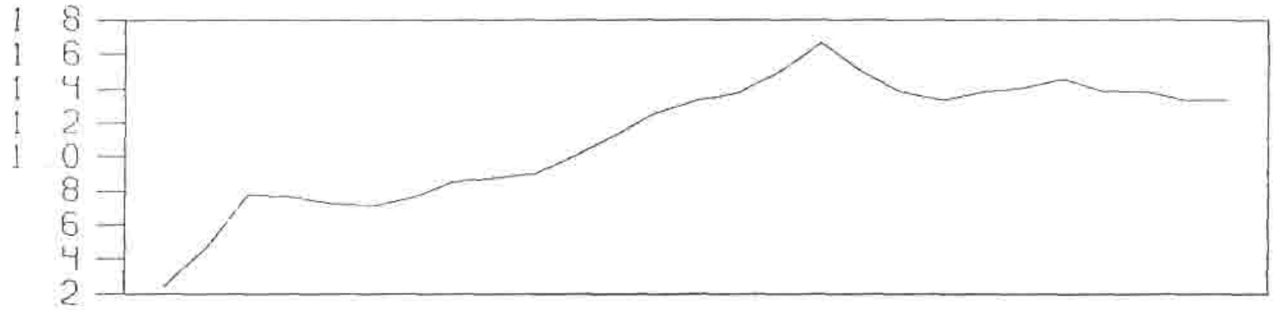


FIG. A1G IFER

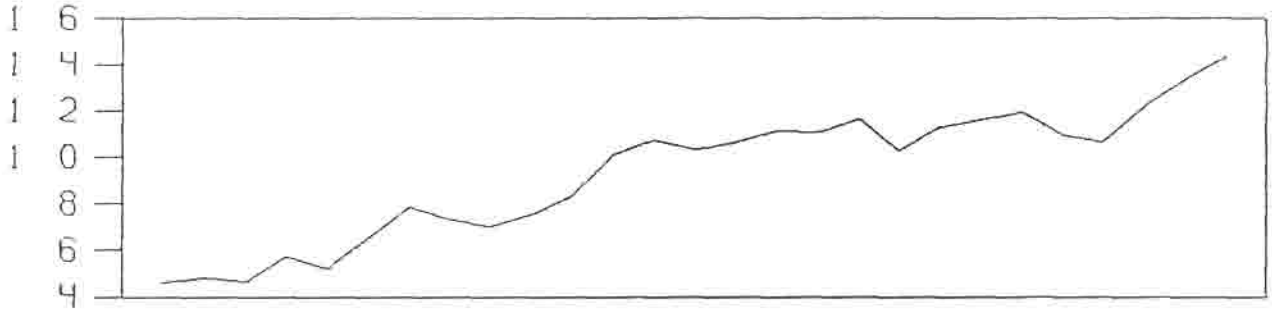


FIG. A1H IMBM

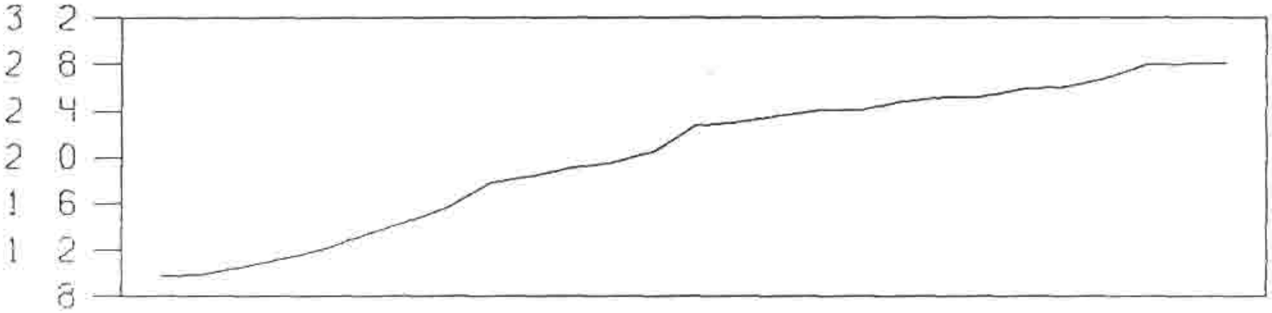


FIG. A1I ICON

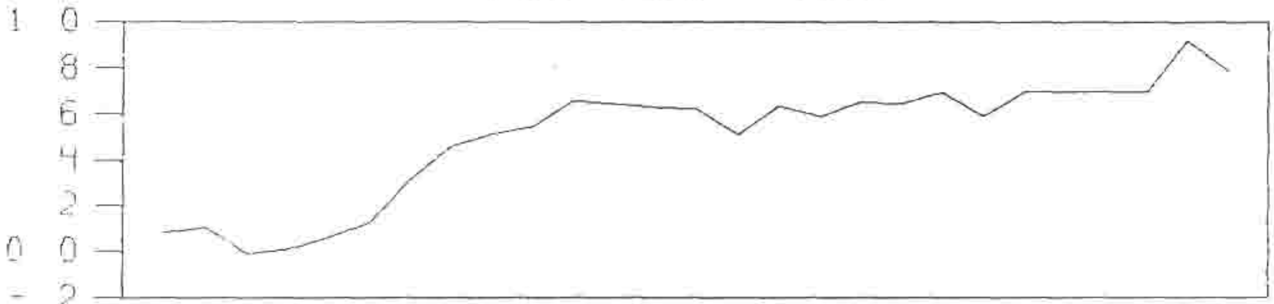


FIG A1J ILIT

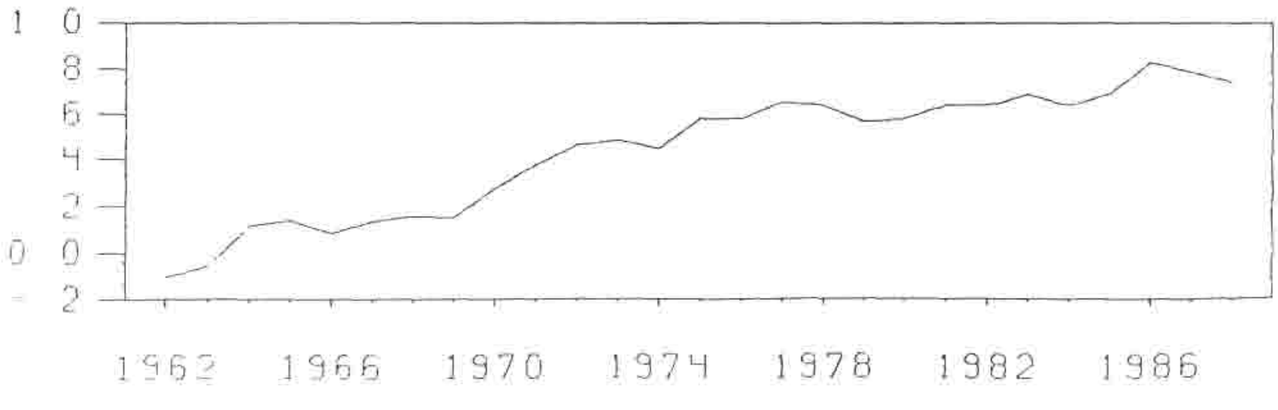


FIG A2A GIND

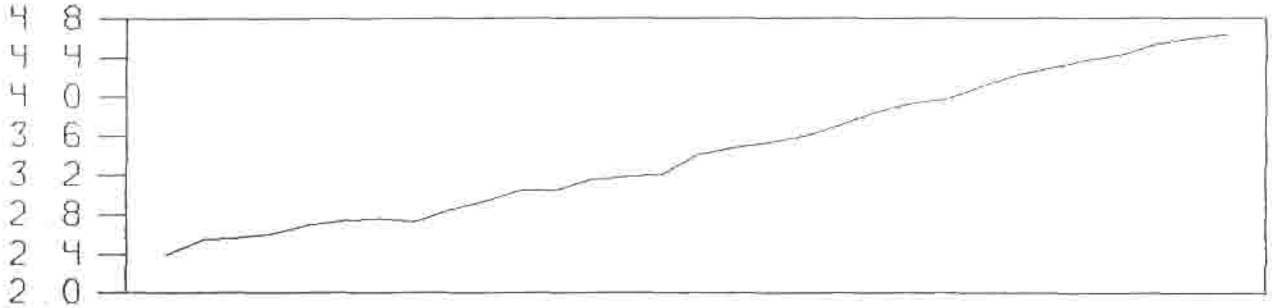


FIG. A2B GTRN

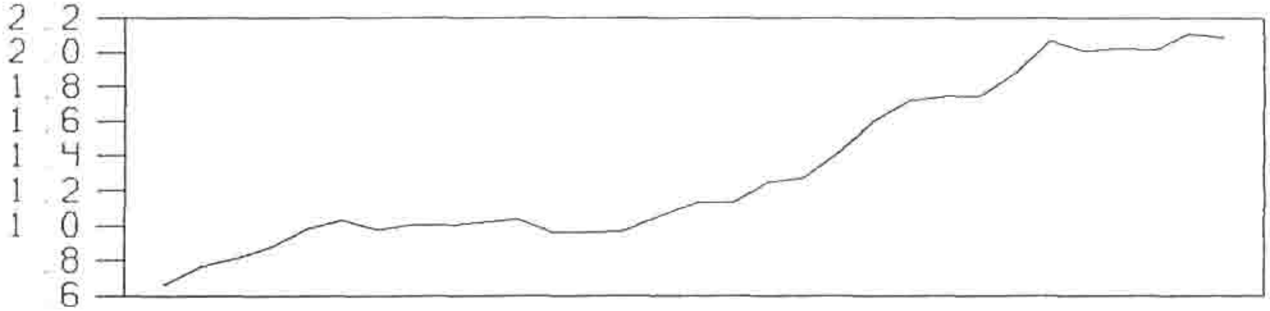


FIG. A2C GEDU

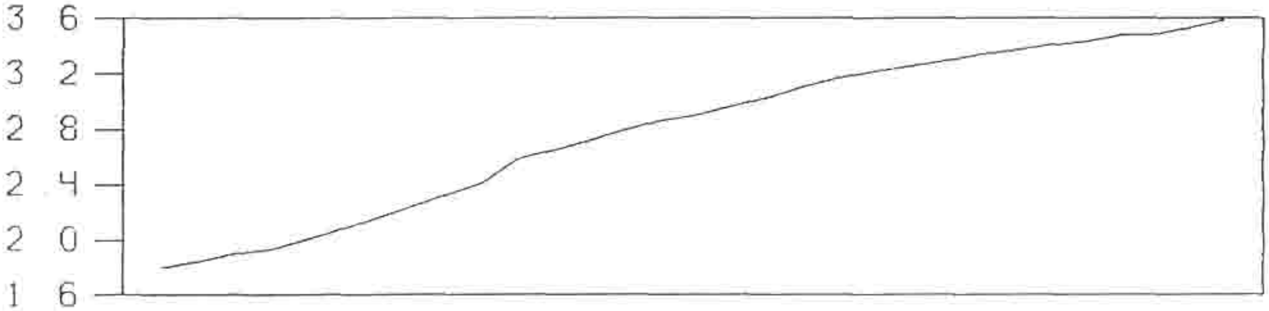


FIG A2D GSCI

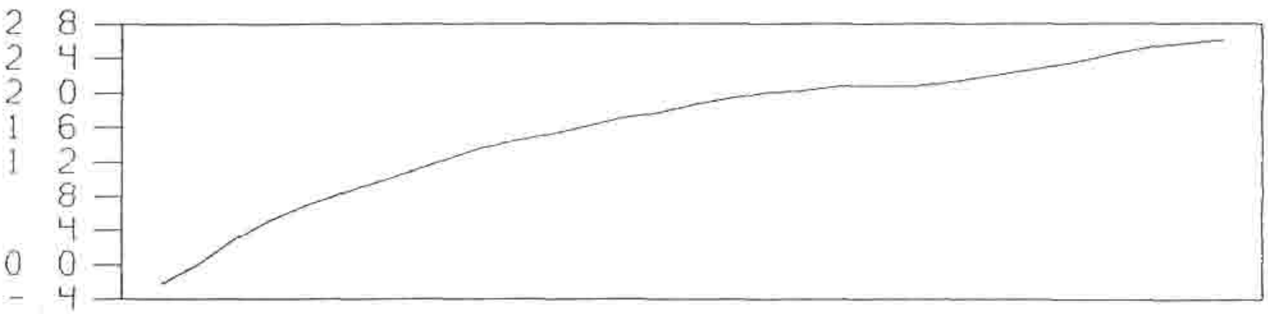


FIG A2E GHEA

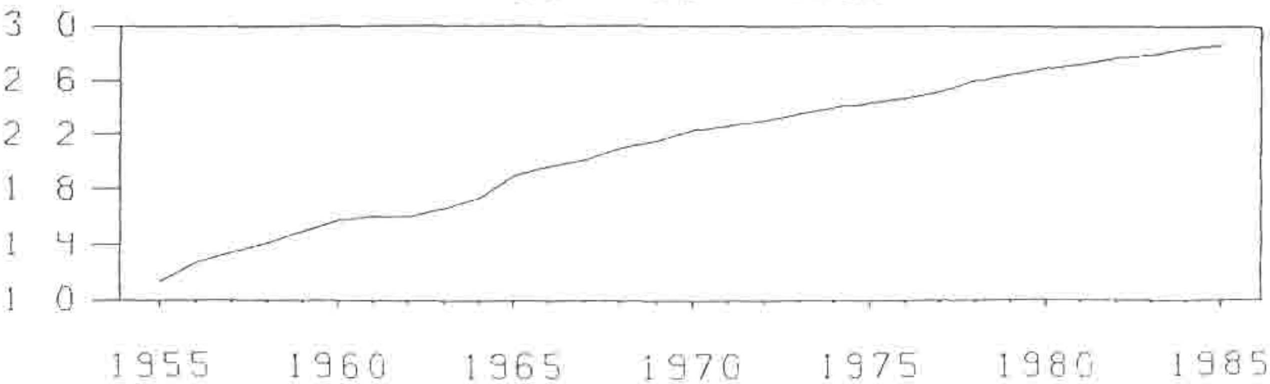


FIG A2F GSEC

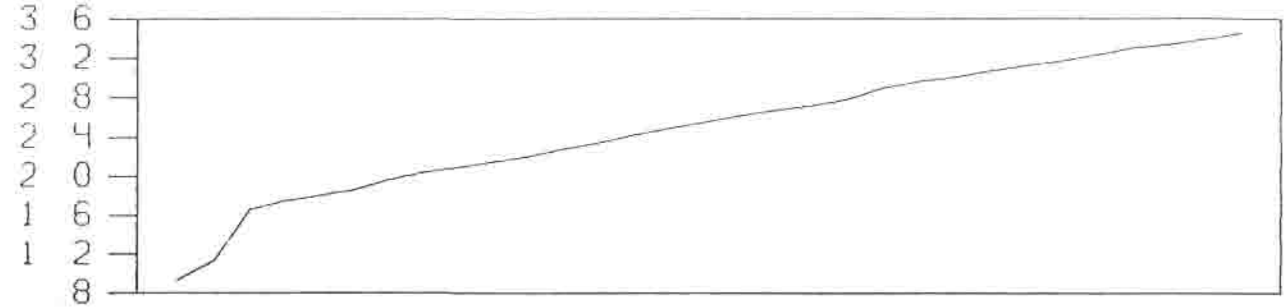


FIG. A2G GINS

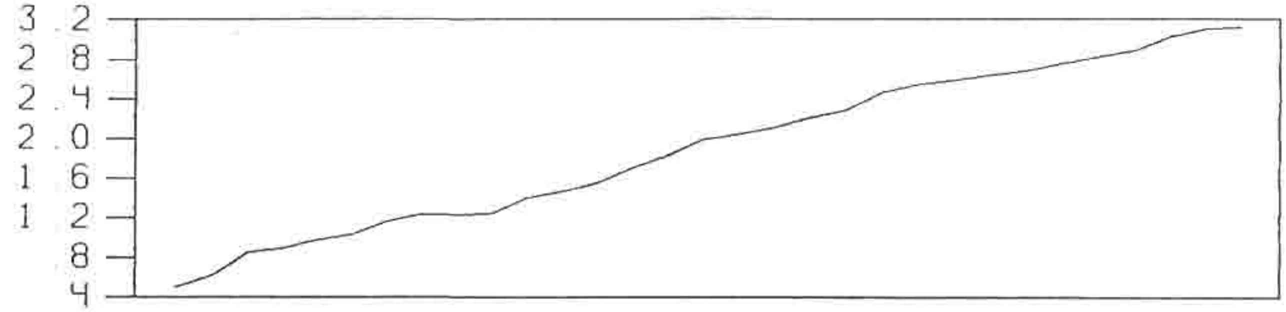


FIG. A2H GMAT

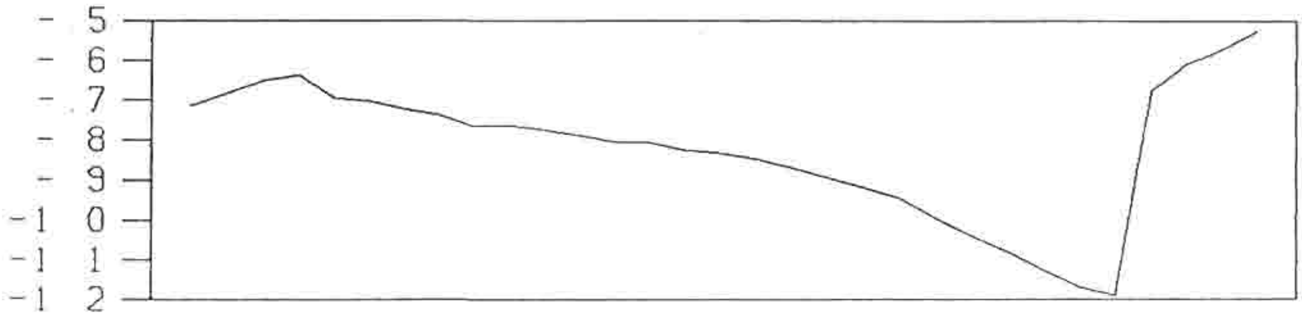


FIG A2I GDEF

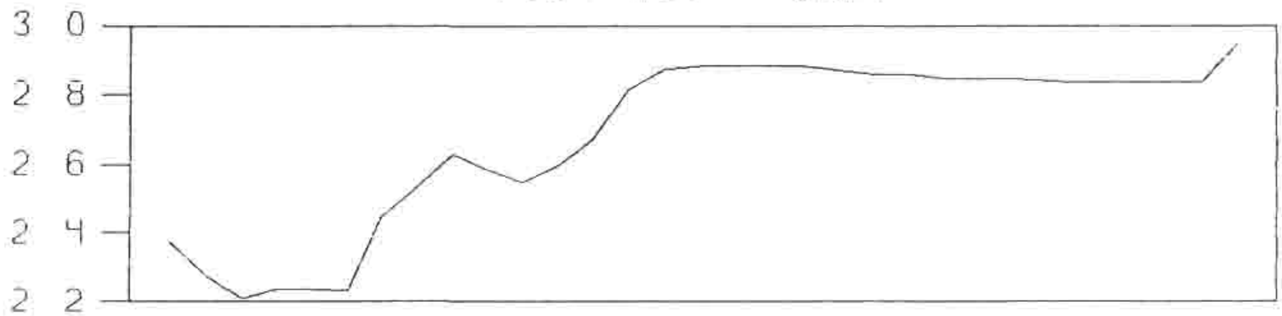
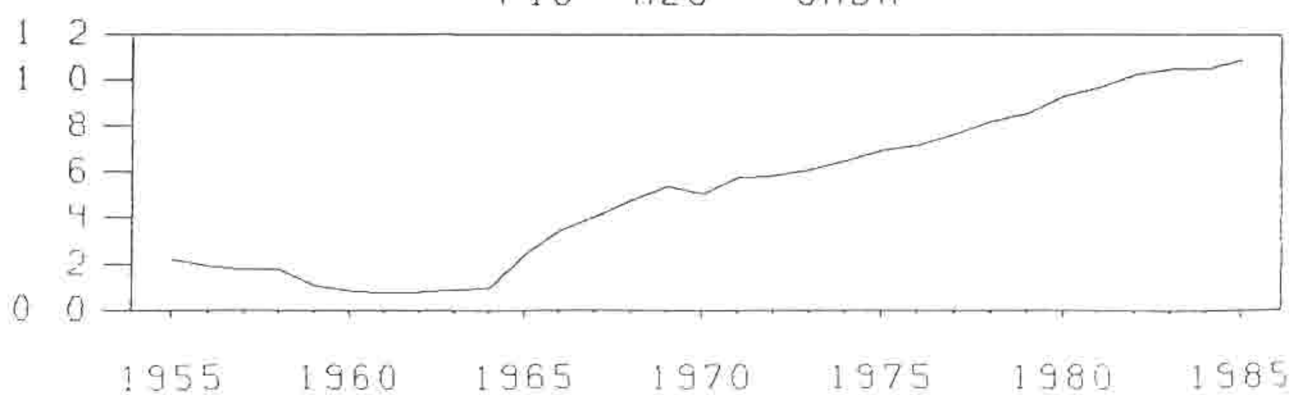


FIG A2J GADM



Footnotes

[1]I thank Josef Brada for helpful comments on an interim report, Janos Kornai for stimulating discussions, and Charles Retondo for splendid research assistance.

[2]If we could assume that the covariance matrix was diagonal, we could attribute any observed cross equation correlation of residuals to a disturbance to the latent variables. But since we do not have any good reason to suppose the matrix is diagonal, we could not identify the variance of any disturbance to the latent variables. Hence we do not bother to write a disturbance term in eq. (1).

[3]Government expenditure is a better policy indicator than employment, but expenditure data had not yet been assembled when the first stage of the investigation was carried out. In the second stage of the investigation employment data were replaced by expenditure data.

[4]The diagonality assumption is questionable, but relaxing it would leave us with pathetically few degrees of freedom.

[5]The ARIMA estimation was done using RATS version 3.0.

[6]All factor analysis was done in SAS version 5.

[7]The singular value decomposition theorem is more widely used by engineers than economists. I thank Petar Djuric for calling it to my attention.

[8]The distribution theory for both statistics presumes that we have maximum likelihood estimates of the covariance matrices. In fact, as noted earlier, the diagonality constraint on B prevents our OLS estimates from being fully efficient. An attempt was made to get SUR (seeming unrelated regression) estimates of the full series of models, but the larger models were numerically intractable. Hence the SC and LR criteria are only approximate as applied to our problem.

[9]In view of Wagner's "law" one might expect real NMP, together with NMPDEFL and POP, to be a basic determinant of government expenditures. However, real NMP turned out to be the least significant of all variables tried one at a time in the government expenditure VAR. The likelihood ratio test indicates that real NMP is not significant, even at the .25 level. Other evidence against this "law" is given by Pryor (1968).

[10]In SOVMOD, investments are treated as functions of defense expenditures, harvest size, gross profits, planned investment expenditures, and various dummy variables and time trends, although not all those variables are used as regressors for each investment category (Green 1977; Green and Higgins 1977). An obvious deficiency in these equations is that they attempt to explain one policy variable (investment) by another (defense expenditure) that lacks clear causal priority. A closely related econometric problem is that the defense expenditure is likely to be correlated with the disturbance terms, resulting in biased estimates. The exogeneity of current harvests and profits is also questionable. Planned investment expenditure is clearly predetermined in relationship to actual investment. However, explaining actual behavior by planned behavior does not get us very far: If plan targets are influential, we would like to know how they are determined. Likewise, the dummy variables and trends do not greatly advance our understanding of the determinants of

investment. We have avoided these problems by treating investments as functions of latent variables that summarize information available to policy-makers.

[11]Pryor (1968) regressed government expenditures, measured as fractions of national income, on income per capita. In the case of the Soviet Union, he obtained significant coefficients in the equations for welfare and education expenditures but not in the equation for health expenditures. Influenced by his work, but doubting the exogeneity of current national income, we included lagged national income and population among the regressors used in the exploratory stage of our research. We found that population is among the most significant influences on government expenditures, while national income is not. In our preferred model, population is one of ten predetermined variables driving the four factors that directly determine government expenditures. As previously noted, the most important factor behaves much like capital per capita. It may be that a correlation between national income and capital contributed to the significance of national income in some of Pryor's equations.

[12]We conjecture that a common set of factors influence all policies of the central government. We have subjected investments and government expenditures to separate analyses without meaning to suggest that different factors are involved. The justification for the separation is purely pragmatic: As the number of dependent variables approaches the number of observations, the correlation matrix approaches singularity and technical difficulties multiply.

[13]The redefinition of branches and industries, beginning with data for 1962 (recorded in *Narodnoe khoziaistvo v 1963 g.*), involved shifting investment in facilities for transport of oil and gas from the oil and gas industry to the transportation branch; shifting investment in construction from the construction materials industry to the construction branch; and a mysterious fall in investment in light industry. The changes in categories are mentioned by Bahry (1980, p. 278) and *Istoriia sotsialisticheskoi ekonomiki SSSR* (1980, vol. VII, p. 224). An attempt to work around the redefinition of industries was made by the CIA (1982), which took Soviet data on investments in 1960 as a fraction of investments in 1965 and interpolated figures for 1961-64, assuming constant growth rates. (These CIA interpolations are reproduced in the *Soviet and East European Databank*.) While such interpolations may be reasonable guesstimates, they are misleading as a basis for econometric work and hence are not used in this paper.

[14]Soviet data on investment in purportedly constant prices probably contain some hidden inflation. The extent of this inflation is discussed by Kontorovich (1989) and works cited therein.

[15]The *Soviet and East European Databank* records investment in "millions" (p. 7.3.2.1.2.4) of 1973 rubles that are actually billions. The error is corrected in this paper.

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FINAL REPORT TO
NATIONAL COUNCIL FOR SOVIET AND EAST EUROPEAN RESEARCH

TITLE: The Soviet Economy to the Year 2000:
Paper 5 of 12
"Energy in the USSR to the Year 2000

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COUNCIL CONTRACT NUMBER: 622-2

DATE: November 16, 1981

The work leading to this report was supported in whole or in part from funds provided by the National Council for Soviet and East European Research.

THE SOVIET ECONOMY TO THE YEAR 2000

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SUMMARY

Energy in the USSR to the Year 2000

Robert Campbell

The USSR is at a turning point in the way energy supply interacts with economic growth, and this paper attempts to analyze how tighter energy supply conditions in the final two decades of the century will affect investment and foreign trade and through them, growth. It is not expected that under the conditions of the Soviet economic system it will be possible to bring the GNP elasticity of energy demand much below the value of 1 characteristic the last two decades. On the other hand, reduced rates of economic growth to the year 2000 induced by considerations other than energy supply will keep the rate of growth of domestic energy demand well below the 4.6 percent per year of the 60's and 70's. Drawing on a variety of Soviet forecasts regarding the future structure of energy demand, and on forecasts and estimates of feasible growth rates for some individual elements, possible energy balances for 1990 and 2000 are developed. The implications of these balances and trajectories for investment requirements, for energy exports, and for interregional energy shipments are considered and their feasibility discussed. In general it concluded that the USSR can probably expand domestic energy output fast enough to keep up with growth of domestic demand. It is much more difficult to rationalize the feasibility of output levels that will permit significant energy exports however. One conclusion of the paper is that exports both to Eastern Europe and to other countries will disappear, making it difficult to continue the current emphasis on imports of technologically advanced equipment to stimulate productivity growth. There is also likely to be a significant increase in the share of energy branches in total investment

and a diversion of investment away from growth inducing directions. These two effects will strongly reinforce the growth decelerating effects of other adverse changes such as low labor force growth, and slow growth in total factor productivity.

ENERGY IN THE USSR TO THE YEAR 2000

Introduction

The beginning of the eighties is an appropriate time to look forward to ask how problems of energy supply will influence the growth of the Soviet economy between now and the end of the century. The USSR is currently at a turning point in energy policy, and at a turning point in the way energy supply interacts with economic growth. The two decades ahead are likely to provide a sharp contrast in this respect with the two decades just finished. It is, therefore, useful to review briefly the relationship between energy production and economic growth in the recent period as a way of posing the problems of energy supply that will emerge over the next two decades.

In the sixties and seventies output and energy consumption in the Soviet economy grew at the rates indicated in Table 1. The estimates of GNP growth rates are those produced by the CIA. We might argue with them for various reasons, but they are more useful as a measure of growth than official Soviet data. They reflect the generally accepted interpretation that Soviet growth has decelerated as the economy has matured. If GNP grew in the immediate postwar period at approximately six percent per year, in the sixties it grew at only about five percent per year and in the seventies at less than four percent per year. Growth at these rates has required rapidly increasing supplies of energy, as shown by the rates of growth of energy consumption in the second column of the table. Taking the two decades as a whole, growth of GNP has been associated with an equally rapid growth of energy consumption -- indeed for the two decades taken together the GNP elasticity of energy consumption (the ratio of the percentage growth of energy consumption to the percentage growth of GNP) has been somewhat over 1. Between 1965 and 1975 the elasticity fell appreciably below 1, probably because of the sharp gains in energy efficiency associated

Table 1. Rates of Growth of GNP and Energy Consumption
(average annual rates, percent)

Period	GNP	Gross Energy Consumption*
1960/1950	5.8	6.4
1965/1960	4.9	5.9
1970/1965	5.3	4.9
1975/1970	4.1	4.0
1976/1975	4.3	NA
1977/1976	3.4	NA
1978/1977	3.2	NA
1979/1978	0.7	NA
1980/1979	3.0	NA
1980/1975	3.0	3.8

Sources: GNP growth rates are taken from CIA, Handbook 1979, p. 26, with the following exceptions: 1950-1960 is from Greenslade, 1976, p. 271; 1979 and 1980 are from CIA, The Soviet Economy in 1978-79, and Prospects for 1980, pp. 19, 25.

Data for growth of energy consumption are from Campbell, 1978, and from Table 2 in this paper for 1980.

*Energy consumption can be conceptualized in numerous ways and at various levels of grossness. I find it most useful to operate with a concept of energy consumption that is essentially delivery of energy forms to final users. This is a concept difficult to follow consistently, and the departures from it forced by expediency will be clear from careful study of the energy balances cited later. For example, I treat expenditure of energy in pipeline transportation as own use, and hence not as energy consumption, but energy consumption in other forms of energy transport (e.g., railroad haulage of coal) is treated as final consumption and counted as final demand.

Electric power generation from fossil fuel can be considered either a form of final demand or as a transformation within the energy sector. In this paper I use "gross energy consumption," to refer to the former, "net energy consumption" to mean the latter. In the latter case conversion losses in electric power stations and losses in transmission and distribution are a form of own use within the energy sector. But even when I treat electric power stations as part of the energy sector rather than as a demand sector, I am inconsistent in failing to treat consumption of electric power in other energy branches (say use of electric power on pipelines) as a form of own use within the energy sector.

Much of Soviet energy analysis operates with a consumption concept based on "useful energy," i.e., the work produced by energy-using equipment and continuation of notes to Table 1.

processes. The rationale is that this concept bears a more stable relationship to output than does my concept of energy supplied to energy-using equipment and processes. This is probably true, though I don't believe that "useful energy" is ever really measured, being rather derived by applying some estimate of utilization efficiency. But such Soviet data as there are on "useful energy" can usually be exploited for my estimates, since they can be reconciled with my concept through a coefficient of energy use efficiency.

Given the concept I am using, the measures of consumption in this paper must be adjusted upwards for nonfuel use and for own use to arrive at figures for apparent consumption, and then for net trade to arrive at production.

There are data available based on other concepts of energy consumption, such as the series that appears in Nar Khoz SSSR in the table on the "fuel and energy balance." This is the series Marshall Goldman has used in commenting on the measures of elasticity in this table. The Nar Khoz SSSR series involves some conceptual peculiarities that make me prefer my own. For example, it includes hydropower at its theoretical energy content rather than at the amount of fossil fuel saved, includes a significant, unexplained "other" category, and does not mention nuclear power. And various anomalies in that series -- such as no growth in consumption in 1971 -- make me distrust it.

with the shift away from solid fuel to the more efficiently used hydrocarbons. (It is a little puzzling that there was no similar gain in the first half of the sixties, when the shift in energy composition was well underway.) The most striking feature of the table is that elasticity has again risen above 1 in the second half of the seventies, at a time when the government has pursued a vigorous campaign to encourage energy saving and reduce waste.

The task of providing the energy increments for growth in the sixties and the seventies was greatly simplified by the fact that output expansion was accompanied by a shift from solid fuel to hydrocarbons. At the end of the fifties, 65 percent of Soviet consumption of primary energy was covered by solid fuel-- coal, shale, peat, and firewood. In the 20 years after 1959, however, during which consumption more than doubled, 80 percent of the incremental consumption has been met by expanding oil and gas production.* Output of solid fuels stagnated or grew very slightly. By the end of the seventies the share of solid fuel in total primary energy consumption had fallen to 34 percent.

In retrospect, it seems quite clear that this shift to oil and gas greatly eased the cost of providing the energy required for growth. It permitted huge resource savings in production compared to providing the same amount of energy in the form of solid fuel. The hydrocarbons make it possible to save fuel itself, since they are utilized more efficiently than solid fuels. It takes many fewer calories to haul a ton of freight a mile in a train pulled by a diesel locomotive, for example, than in one pulled by a coalburning steam locomotive. Hydrocarbon fuels also permit large savings of other resources at the consumption stage. A gas-fired power station, for example, can do away with the elaborate and costly facilities necessary to store and handle the

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*Oil and gas accounted for an even larger share of the increment in production--about 85 percent.

fuel used in a coalburning station and to prepare it for combustion.

Furthermore, these increments of oil and gas output were won cheaply enough to make these fuels attractive as exports as well as for domestic use and the Soviet Union used energy exports, especially oil, both to support the strategy of technology transfer, and to keep growth going in Eastern Europe in the face of that region's crucial energy deficit. Net energy exports grew during these two decades at almost 10 percent per year (compared to 4.4 percent for domestic energy consumption) and by 1980 accounted for about 42 percent of all export earnings and about half of hard currency earnings from export.

It is probably a valid generalization to say that this growth of oil and gas output was obtained without imposing particularly rigorous technological demands on the economy. The hydrocarbons were found in relatively easily accessible formations, and the wells to find and produce them were drilled with a novel but relatively simple technology -- the turbodrill. This technology was adequate to the geological situations the industry encountered and permitted a dramatic end run around the low productivity the Soviet oil industry achieved in standard rotary drilling technology, which the USSR found it very difficult to improve. Moreover, most of the oil was in the kind of reservoirs where it was possible to apply effectively the new science of reservoir engineering, an innovation that speeded up extraction and saved on investment and operating costs by combining sparse well-spacing patterns with pressure maintenance through water injection. The gas was brought to market relatively cheaply under conditions that were not especially demanding technologically -- the Russians used large investments of metal in the form of very large diameter pipe to substitute for the more sophisticated technology and quality levels that are generally characteristic of pipelines in other countries. In addition, crucial elements of pipeline technology could be and were imported on a large scale. The technological and investment demands associated with processing hydrocarbon fuels were sidestepped -- in the case of oil by refining it only lightly and using it to a very large extent in the form of residual fuel oil for boiler and furnace purposes, and in the case of gas, simply by doing minimal processing. Only a small fraction of the valuable liquid and liquifiable byproducts of gas production were extracted and devoted to their higher-value uses.

All in all, meeting the energy requirements of a growing economy during the sixties and seventies imposed a relatively modest burden on Soviet investment resources and on Soviet technological sophistication. Indeed, the fact that energy supply expansion was so easy as to permit exports made the growth of energy output not so much a burden on growth as a special contributor to it through foreign exchange earnings and the technology imports these earnings supported.

This impression of relative ease in energy expansion during the sixties and seventies is strengthened by extending our retrospective look to the late forties and the fifties. Energy supply grew rapidly in the first fifteen years after World War II, but these increments required very large investments in solid fuel production and expensive experiments in fuel processing. Whereas in the sixties and early seventies the energy sector was taking only 28-29 percent of industrial investment, during the Fifth Five-Year-Plan (1951-55) the energy branches had absorbed 37.2 percent of all industrial investment to cope with the output expansion required. In the Sixth Five-Year-Plan (1956-60) when the transition to hydrocarbons had already started, the energy branches took 32.7 percent. (TsSU, Nar Khoz SSSR, various years).

As the Russians look ahead to the remaining two decades of the century, however, the hydrocarbon energy bonanza shows signs of disappearing. It is predicted that the USSR will be lucky to keep oil output near its present level, let alone achieve its expansion. The CIA, in fact, forecasts a large decline in petroleum output during the eighties, perhaps to as low as two-thirds of the 1980 output of 603 MTnat. For gas, reserves are clearly adequate to support an expansion of output well above the 1980 level, but under adverse changes in location that will lead to very significant increases in the cost of producing and transporting it. The effects of a decline in hydrocarbon potential are exacerbated by the fact that coal, which has continued to supplement hydrocarbon supplies, will undergo very significant adverse changes in quality and location, as reserves give out and production costs rise in the European USSR.

Energy Supply and Economic Growth

One approach to exploring the impact these energy difficulties will have on Soviet economic growth would be via an econometric model. The CIA has used this approach in its short term forecasts (CIA, Simulations, 1979). A formal model seems less appropriate to a long range projection over two decades, however, and in any case, that is not my style. My analysis is much looser than that of a formal model, and instead of an explicit quantitative forecast, I offer consideration of possible alternatives and the structural changes which the energy policymakers will need to deal with.

It will be useful to start by explaining how I envisage the relationship of the energy sector to economic growth over the next twenty years. From the demand side, I see growth of GNP, and an associated level of energy final demand, as essentially exogenous to energy policy. This aggregate energy demand also has a structure, which includes a regional dimension, a type-of-use dimension (e.g., boiler and furnace use versus internal combustion engine use) and a sector-of-demand dimension. This structure, also, presents itself to energy planners as fairly autonomous. The major exceptions would be the extent to which energy policymakers can influence the choice of technologies by final energy consumers to alter the type of energy demanded (e.g., direct fuel furnaces versus electric furnaces) or to improve the efficiency of energy use (e.g., insulating buildings or raising the efficiency of internal combustion engines).

On the supply side, the natural resource base does not completely rule out choice, but still imposes serious constraints on planners' choices regarding both the kinds of energy sources to be used and their location. For example Soviet energy planners will probably find it impossible to meet motor fuel demand within the European USSR from oil sources located within the region.

These respective structures on the demand and supply side are mediated by the various transport and transformation activities, and choices in this area constitute some of the major source variables with which energy policy makers will be concerned. To meet an electric power need in the Ukraine, for example, the planners have, among other alternatives: Ekibastuz coal → minemouth generation → high voltage transmission; Ekibastuz coal → slurry pipeline → Ukrainian generating plant; Ukrainian nuclear power station. It is in the reconciliation of these two sides that most of the energy policy issues will be found.

The reconciliation may be possible in part by influencing the demand and supply structures, but much of the decision making in these areas is outside the reach of the energy policy makers. They can probably do very little to influence the regional distribution of demand. A lot of the production choices are made by the energy suppliers on the basis of internal considerations and other pressures -- e.g., the respective role of breeders and standard fission reactors. The primary task of energy policy is to stand above all these actors to make certain that their actions get co-ordinated. The energy policy makers have to make sure that if oil is going to cease to be allocated to the electric power industry, that the power industry be given coal to make up for it, and that power industry policies and plans get modified accordingly.

Finally, the most important reverse linkage in my view of energy-GNP interactions is the investment demands and cost levels that grow out of these constraints and choices, which will divert investment funds and current inputs from the activities that would otherwise be generating energy demands. Some other modelers, particularly the CIA in its short term modeling, treat potential shortfalls in energy supply as a direct constraint on output. That may happen-- indeed it is very likely to within short periods. But in thinking about economic expansion over a relatively lengthy period it seems more appropriate to assume that short-term disproportions can be overcome, and that enough energy will be produced to meet demand.

My goal in this paper is not so much to make a concrete forecast of what the energy situation will be in the year 2000 as it is to examine how energy problems will affect growth in the intervening period. The best way to get at this, however, will be to project some current trends to the year 2000 and then examine the resulting scenario for contradictions and implications that may raise problems that will prevent the USSR's actually arriving there.

The next two sections describe the current energy supply and demand situation, and develop a possible scenario for the year 2000. This will set the stage for a discussion in the last part of the paper of what problems must be solved to get from here to there.

Current Supply and Demand

The first step is to sketch the current demand-supply situation. In an earlier work, I have provided energy balances for 1950-1975, (Campbell, 1978) but it would be preferable to describe the 1980 situation as the starting point.

At this point actual 1980 data for many elements in the fuel and energy balance are still unavailable. Still, it is possible to produce for 1980 a simplified but reasonably accurate version of the fuel balance table in the form published earlier and this is presented in Table 2.

I would like to draw attention to several distinctive features of the Soviet energy balance that are important to keep in mind in thinking about possible futures.

1) Despite the talk about the tightening of energy supply, the Soviet Union was still exporting heavily in 1980. Indeed energy exports apparently grew faster than consumption in 1975-1980 and increased their share in total production. A pronounced shift in export composition toward gas is taking place, and the domestic difficulties of the coal industry appear to be forcing a reduction in solid fuel exports. This export surplus is an important cushion for meeting future domestic demand growth, though giving up energy exports will impose its own constraints on growth.

2) Electric power stations account for a very large share of all primary energy consumption -- 590.5 MTst out of the 1481 MTst available for domestic consumption in energy uses, or almost 40 percent. This is somewhat above the analogous share in the U.S. and Western Europe.

3) Industry is the dominant final consumer, accounting for 58 percent of net consumption, and indeed has continued to increase its share since 1975.

4) The greatest novelty of Soviet energy policy compared to other countries' experience has been the employment of co-generation on a large scale. In 1980 the Soviet electric power industry captured and utilized more of the energy of the fuels it burned in the form of by-product heat than in the form of electric power, and was able largely by that means to achieve an efficiency in the conversion of fuel to electric power higher than the U.S. power industry does.

Table 7. USSR FUEL AND ENERGY BALANCE, 1980

Unit	Primary Sources and Energy Products	Output	Losses and Internal Consumption	Net Trade	Intrasector Transfers: Inflow	Intrasector Transfers: Outflow	Available for Distribution	Consumption Sectors: Non-fuel	Electric Power	Industry	Household and Municipal	Agri-culture	Trans-portation	Con-struction
	Primary Energy Outputs													
BKWH	Hydropower	181.3	—	—	—	—	—	—	—	—	—	—	—	—
MTst		56.9	—	—	—	—	56.9	—	56.9	—	—	—	—	—
BKWH	Nuclear Power	73	—	—	—	—	...	—	—	—	—	—	—	—
MTst		23.7	—	—	—	—	23.7	—	23.7	—	—	—	—	—
bm^3	Natural Gas	453.5	64.2	52.0	.5	5.4	327.4	21.5	104.2	349.6	45.1	2.6	1.4	3.0
MTst		536.1	76.2	61.9	.6	6.5	391.9	28.0	124.0	178.1	53.4	3.1	1.7	3.6
MTst	Liquified Gases	—	—	.5	15.3	—	14.6	5.9	—	.9	7.7	—	.1	—
MTst	Manufactured Gas	—	.8	—	1.2	.4	—	—	—	—	—	—	—	—
MTnat	Crude Petroleum	603	31.7	110.0	—	461.1	—							
MTst		862.3	45.6	157.3	—	659.4	—							
MTnat	Petroleum Products	—	29.5	40	461.1	6.0	385.6	26.6	101.0	88.0	9.9	51.9	88.2	18.0
MTst		—	42.2	57.2	659.4	8.6	551.4	38.1	144.4	125.8	14.2	77.1	126.1	25.7
MTnat	Coal	716	99.4	9.2	—	1.0	517.4	—	339	211.1	30	7.7	11.5	17.9
MTst		487	25.1	9.2	—	.7	447	—	222	172	23.7	6.1	5.1	14.1
MTst	Peat	16.8	1.6	—	—	—	15.2	—	13.6	.8	.8	—	—	—
MTst	Oil Shale	12	—	—	—	.5	11.5	1.2	7.4	2.9	—	—	—	—
MTst	Firewood	24	—	—	—	—	24	—	.5	12	9.5	1	1	—
MTst	"Decentralized" Fuel	20	—	—	—	—	20	—	—	—	20	—	—	—
MTst	Total Primary Output	2031.8	191.5	286.1	—	—	1554.2	73.2	590.5	492.5	129.3	87.3	138	43.4
	Secondary Allocations													
BKWH	Electric Energy	—	212.4	12	1295	—	1071	—	—	690.8	177.3	76.6	100.0	26.5
MTst		—	26.1	1.5	159.1	—	131.5	—	—	84.8	21.7	9.4	12.3	3.3
MGK	Heat from TETsy	—	23.0	—	1150.0	—	1127	—	—	897.0	210.0	—	—	—
MTst		—	3.3	—	164.3	—	161	—	—	128.1	32.9	—	—	—
MTst	Other Sources	—	10.0	—	50.4	—	40.4	—	—	40.4	—	—	—	—
MTst	Total Secondary Allocations									253.3	54.6	9.4	12.3	3.3
MTst	Total Primary and Secondary Allocation						1296.6*	73.2	—	745.8	183.9	96.7	150.3	46.7

*Available primary less expenditures in power stations plus available secondary.

This table was revised in February 1981, and absorbs information available to the author at that date. The methodology underlying the construction of this balance is explained in Campbell, 1978. A detailed explanation of the data services and estimates of 1980 magnitudes is given in an appendix available on request to the author.

5) Gas, too, is used in a very different way in the USSR than in other countries, i.e., it is heavily dedicated to boiler use, including extensive use in power stations, rather than to the high value uses such as household use that mark the pattern of other countries. In the U.S. we use about 40 percent of gas in the residential and commercial markets and 18 percent in electric power stations, (DOE Energy Data Reports. Natural Gas Production and Consumption: 1978) whereas the corresponding figures for the USSR are 13 percent for the housing and municipal sector and 32 percent in power stations, i.e., the proportions are essentially reversed.*

6) The Soviet economy faces a petroleum stringency only in a very special sense. The USSR produces a larger petroleum output than any other country in the world. But with total output of crude petroleum and condensate at 603 MTnat for 1980, domestic consumption of petroleum products was only about 386 MTnat, of which 166 MTnat was burned in boilers and furnaces. The requirements of the Soviet economy in 1980 for the high value, non substitutable uses of petroleum such as motor fuel, petrochemicals, and so on, was less than 200 MTnat, compared to the U.S. consumption of over 700 MTnat. The Soviet Union has a large room for maneuver in dealing with a tightening oil supply situation by improving the way it uses oil -- getting a higher quality mix out of its oil to cover motor fuel and petrochemical needs, and replacing residual fuel oil with other boiler and furnace fuels.

7) The USSR has never gone as far as the U.S. and Western Europe in pushing solid fuel out of the fuel balance. In the USSR at the end of the seventies,

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*The contrast is not quite so strong as these figures suggest, since some of the gas burned in Soviet power stations produces co-generated heat that is used for urban space heating. But allowance for this would shift no more than about 2 percentage points from power stations to households (Ryps, pp. 13-14, Campbell, 1979, pp. 26, 29).

solid fuel covered about a third of primary energy consumption, in the U.S. less than 20 percent. At the same time the Soviet economic planners have kept its share this high only by forcing themselves to accept very low quality in solid fuel. The heat content of shale is only 32 percent of that of good hard coal, of peat only 34 percent. And the average heat value of Soviet coal itself is only about 67 percent of the kind of good hard coal that is usually taken as a standard.

As Soviet planners let coal gradually increase its share once again, or even maintain its present share, the two main sources they plan to use have quality characteristics that are drastically inferior to the current average. Ekibastuz coal has such a high ash and rock content that what is loaded and shipped to consumers is scarcely distinguishable from what is dumped on the spoil banks. When Kansk-Achinsk coal is shipped, half the mass transported is water and ash rather than anything combustible. The technological problems of processing this low quality fuel are among the most pressing ones energy planners face, and the costs and energy losses associated with this beneficiation will be very great.

8) The evidence is mounting that energy is used very wastefully in the USSR. As indicated earlier in Campbell, 1978, energy consumption in industry and agriculture seem disproportionately large compared to U.S. consumption, given the relative size of the two countries' output in these sectors. The divergence in the two countries' experience with GNP elasticity of energy demand since 1975 dramatizes the point still further. As shown in Table 1, for every percentage point increase in Soviet GNP between 1975 and 1980, energy consumption has grown 1.26 percent. The corresponding elasticity for the U.S. in the same period was .6 (DOE, Monthly Energy Review, June 1980, p. 12). The Russians are now busy searching for ways to cut energy consumption, and in the

process are documenting the many alarming ways in which energy is wasted. They are still wasting enough oil-well gas (15.5 Bm^3 per year) to cover the total energy needs of a small country, e.g., Portugal or Greece. There are huge evaporative losses of liquid fuels in tank farms and transport. Tremendous amounts of coal are lost in transit, by wastage during storage and by use in unsuitable equipment. Gas, electricity, hot water and steam are often supplied to users without metering or control and are used very wastefully. There would thus seem to exist a considerable potential for conservation as an alternative to supply expansion, though conservation efforts would need to be directed at different targets than those we consider most important in the U.S. Whether Soviet energy policymakers have the instruments to mobilize these potentials is a subject we will discuss more fully at the end of the paper.

A Possible Scenario for the Year 2000

It is probably unrealistic to try to develop an elaborate projection of energy supply and demand to the end of the century. There are simply too many uncertainties to allow one to have much faith in the results. But it will be instructive to try to sketch a basic quantitative framework that can be used to examine the major issues of energy policy over the next two decades.

Level and Structure of Aggregate Demand. The first step is to estimate a plausible level of aggregate demand for the year 2000. In doing so I will make heavy use of a fairly extensive Soviet literature directed toward the same goal. Two recent books (Makarov and Vigdorchik, 1979, Beschinskii and Kogan, 1976) provide rather comprehensive descriptions of the current status and trends in the Soviet fuel and energy balance based, I believe, on the most extensive and authoritative work of this kind in the USSR. I have also been able to use three papers prepared by various combinations of these authors and other Soviet energy forecasting specialists for a U.S.-Soviet seminar on energy forecasting (Makarov and Melent'ev, 1979; Styrikovich and Cherniavskii, 1979; Beschinskii and Vigdorchik, 1979) and much of what follows is based on those papers. Those papers have been especially useful for my purposes since they are more specific than much of the other published output of these authors in giving dates, and in their greater conscientiousness in covering all the important variables. The data in these sources are reasonably well echoed in a set of energy forecasts submitted by the USSR to the Economic Commission for Europe showing in rather aggregated form the energy balances forecast for 1990 and 2000. It is thus probably fair to say that these projections constitute a semi-official view of the Soviet energy future. One could not call them operational forecasts; they represent rather the views held by a kind of energy forecasting "establishment" at the research level of energy policy making. Melent'ev and Styrikovich are Academicians, the others appear to work in various R and D organizations in the Academy system or the energy sector.

Most Western observers expect the Soviet rate of GNP growth through the 'eighties to remain at the relatively low levels experienced in the last several years. In the 'nineties the adverse labor force prospects that are an important factor in that forecast will ease, but other adverse influences may well keep the growth rates from recovering even then. I consider that projection of growth at 2.5-3.0 percent per year for the 20-year period as a whole is moderately optimistic. I further believe that it will prove impossible for the Soviet system to bring the GNP elasticity of energy demand below 1 over the next two decades. There is certainly room for conservation, but the record so far has shown very little success in reducing the elasticity of demand below 1, even in the most recent five year period when there has been a vigorous campaign to that end. The question of conservation is a complicated subject to which we will return in the concluding section, but for the moment I will operate on the assumption that the GNP elasticity of energy demand will be in the range of .9 to 1.

The effect of differing assumptions regarding growth rates and GNP elasticities is shown in the following tabulation of possible energy consumption in the year 2000, starting from the 1980 gross consumption figure of 1481 MTst, figured in Table 2, i.e., 1554.2 MTst "available for distribution" less 73.2 MTst of non-fuel use.

		Elasticity	
		1	.9
GNP Growth Rate	2.5	2427	2311
	3.0	2678	2523

It will be much easier to proceed with this exercise if we pick a single aggregate demand figure -- I suggest 2500 MTst as a plausible projection. For some perspective on the magnitude of this task, the absolute increment (1019 MTst) is somewhat larger than that experienced in the preceding two decades (907.2 MTst) but the rate of growth is much smaller.

Soviet forecasts generally envisage a demand larger than 2500 MTst, based on a more rapid rate of growth of the total output of the economy than I would be willing to accept, somewhat offset by more optimistic expectations regarding energy conservation. Styrikovich and Cherniavskii (1979, p. 17) assume a 3.7 percent/year rate of growth for net material product (NMP) for

1975-2000 but an elasticity of .76 - .86, to give a figure for energy consumption in 2000 of 2615-2823 MTst. The forecast reported to the ECE shows consumption in the year 2000 as 2735-3285 MTst. If 2500 MTst seems too high or low, one can easily trace through the kind of alterations needed in the following analysis and will find that the changes don't much affect the nature of the problems, but only their acuity.

In thinking about the composition of this demand, let us first figure the demand for conversion to electric power. There is a great deal of contradictory evidence on the likely share of electric power in gross consumption of primary energy at the end of the century. Makarov and Vigdorchik say (p. 202) that electric stations will in the future take 40 percent of the energy resources consumed in the country, and let us suppose that the year they have in mind is 2000. But only part of that consumption will be charged to electric power, since some will be captured as by-product heat. Styrikovich and Cherniavskii (1979, p. 19) forecast that the amount charged to power will be 30-33 percent of all primary consumption by 2000, while the forecast submitted to the UN suggests a share of only 27.4-29.6 percent. If we accept 40 percent as the share consumed in power stations, and 30 percent as the amount charged to power, the amount of primary energy consumed in power stations would be 1,000 MTst, the amount charged to power would be 750 MTst, and the amount captured as co-generated heat 205 MTst, i.e., the remaining fuel corrected for boiler efficiency. The tables submitted to the ECE forecast a conversion efficiency of 41.7 percent in the year 2000, so that the amount of energy embodied in the electric power produced is 313 MTst. The resulting ratio of co-generated heat captured or the energy in the form of power (250 MTst/313 MTst) is a smaller ratio than that at present, but that makes sense in the light of the fact that power generation is likely to undergo regional shifts that reduce the potential for co-generation -- i.e., to minemouth stations in the East. Since there are 8,140 KWH per tons of standard fuel, the electric power produced would be 2548 BKWH, and since 1980 output was 1295 BKWH, the annual average rate of growth would be 3.4 percent.

There are several possible indications of the share that might be met by nuclear power stations. Styrikovich and Cherniavskii say that by the end of the century nuclear power might account for 8-10 percent of total primary energy supply (p. 20). The forecast submitted to the ECE shows 9.4 percent and using that figure implies a contribution of 235 MTst which would produce 798 BKWH at the conversion efficiency of .417 which I am assuming for fossil-fired plants.* On the reasonable assumption of 5,000 hours utilization, they would require 160 GW of nuclear capacity. Capacity at the end of 1980 is about 18 GW, so capacity would have to grow at 11.5 percent per year and annual average additions would be 7.1 GW per year. That seems at the outer limits of feasibility. The forecast given to the ECE shows the nuclear contribution in 2000 as 300-400 MTst, but that seems to me quite impossible to achieve. For present purposes, I will accept that the output of electric power from nuclear plants in 2000 could be 798 BKWH.

It is also intended to continue development of hydroelectric power -- what might hydropower output be by 2000? According to Nekrasov and Pervukhin, 1977, Chapter 7, studies performed by Gidroproekt in recent years show that it would be possible to add capacity <u>in the European part</u> of the USSR totalling 11 million KW, with a long term average output of 27 BKWH. Added to 1975 capacity and potential, that would bring the total to 31.5 MKW and 110

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*Throughout this analysis, I treat the contribution of nuclear and hydropower to primary energy production as the heat content of the fuel they replace at the contemporary heat rate in fossil-fired stations rather than the energy content of the nuclear and hydro-generated power itself.

BKWH. It seems to me unlikely that all this capacity would be added by 1990, just because of the lead times involved, but I will assume that the 110 BKWH can be considered a target for 2000. The additionally developable potential in the Asian part of the USSR is much greater, and the authors say that completions in 1975-1980, plus new projects to be started in the same period will aggregate 39.0 million KW. Added to capacity in operation at the end of 1976, this would bring the total to 58.4 million KW, which at 3500 hours utilization would provide 204.4 BKWH. Let us suppose that by the end of the century, enough capacity will have been added to bring the Asiatic total to 200 BKWH. The total for the USSR in 2000 would thus be 310 BKWH. The forecast submitted to the ECE is 288-339 BKWH, so 310 BKWH is reasonably in line with Soviet expectations.

Any electric power provided by solar, tidal, and geothermal sources by 2000 would be very small, so approximately 1440 BKWH would be left to be covered by fossil-fired generation, requiring 424 MTst of fossil fuel.

Styrikovich and Cherniavskii (1979, p. 20) have a three-way breakdown in which energy is used as electric power, steam and hot water (teploenergiia), or directly in equipment such as engines and furnaces. I am not using their electric power figure, but using their 30-40 split between teploenergiia and direct use, teploenergiia would be 750 MTst, and direct use 1000 MTst. They further suggest that about 43 percent of direct fuel use will consist of liquid fuel (that would be 430 MTst). Some part of that will be residual fuel oil (mazut) or distillate fuel oils burned as furnace fuel, but by the end of the century most direct use of liquid fuel will surely be as motor fuel -- let us say 80 percent -- which would be 344 MTst, or about 241 MTnat of light fractions from petroleum refining suitable as fuel for internal combustion engines. The other 86 MTst (60 MTnat) of liquid fuel will be essentially fuel oil fractions burned in boilers and furnaces.

As for the primary energy consumption devoted to producing steam and hot water (teploenergiia) which will amount to 750 MTst, a significant fraction will be supplied as co-generated heat from electric power stations which we figured above as 205 MTst. Remember that in figuring the fossil-fuel requirements to generate electric power we have allowed only for the fuel to be charged to power.* This would leave 545 MTst to be accounted for by steam and hot water produced in conventional boilers.

Adding the fossil fuel consumption for power estimated above as 424 MTst, and that charged to heat in co-generation plants (250 MTst) we get a total of 674 MTst of fossil fuel burned in power stations. What might be the composition of the fuel burned in power stations by 2000? Makarov and Melent'ev say (pp. 13-14) that studies have shown that it is possible to replace one-half to three-fourths of the current uses of residual fuel oil (mazut) with coal and gas. Power stations, which we estimated earlier to be burning about 100 MTnat of liquid fuel in 1980, probably have even better replacement potential than other mazut-burning equipment, so let's say that power stations may still be burning maybe as much as 30 MTnat (43 Mtst) of liquid fuel for power, or 6.4 percent of total fossil fuel consumption in power stations. Subtracting 43 MTst of liquid fuel and about the same amount of minor solid fuels as in 1980 (25 MTst) leaves 600 MTst to be covered by coal and gas in the year 2000. In 1980 the coal/gas ratio in fossil fuel consumption in power stations was 1.7 but the report submitted to the UN fore-

*The Soviet heat rate in power generation is figured by dividing fuel consumption, less the captured co-generated heat (converted for boiler efficiency), by the power output. I have used a projection of the heat rate so conceptualized to translate electric power output into fuel consumed for power. The current heat rate is about 340 grams of standard fuel per KWh, which implies a conversion efficiency of about .36, and I have assumed this would rise to .417 by 2000.

cast a ratio of over 2.5 by 2000. That seems to me a bit overambitious and I will assume a coal/gas ratio in power stations of 2. On the basis of the foregoing calculations, the overall consumption balance is as shown in Table 3.

Table 3. Energy Consumption in 2000 by Primary Source and Energy Form (MTst)

	Primary Source				
Energy Form	Total	Liquid	Gas	Solid	Nuclear and Hydro
Power generation	750	43	202	429**	326
Co-Generated heat (steam and hot water)	250 (205)*				---
Other heat (steam and hot water)	545	NA	NA	NA	---
Direct Use	1,000	NA	NA	NA	---
Total	2,500	NA	NA	NA	326

*250 MTst is the fuel charged to co-generated heat, but corrected for boiler efficiency the amount delivered is only 205 MTst.

**This figure consists of 404 MTst of coal and 25 MTst of minor solid fuel.

Production Structure

How might the total of 2500 MTst be supplied? Let us assume that non-fuel use and own consumption will be at least as large in relation to final energy consumption in 2000 as in 1980, i.e., 17.7 percent. That means the energy sector would have to produce 2942 MTst to cover the final energy consumption we have analyzed. Styrikovich and Cherniavskii (p. 19) forecast an energy production structure for 2000 as shown in column 1 of Table 4 below. Column 2 shows the structure in the ECE forecast already mentioned.

In the third column I have made adjustments to these forecasts that a) make the total equal 100; b) reflect my view that both these forecasts are over-optimistic on oil; c) use the amounts for hydro and nuclear estimated earlier in the paper; and d) accept what I take as more recent Soviet thinking underlying the forecast for the ECE that the role of gas will be greater and that of coal smaller than was earlier thought.

Table 4. Possible Energy Supply Structure in 2000

	Cherniavskii and Styrikovich (1) (percent)	Forecast for ECE (2) (percent)	Adjusted by Author (3) (percent)	(4) (MTst)*	(5) Natural Units
Oil	25-30	25-27	21	631	441 MTnat
Gas	25-30	33-36	35	1053	887 BM^3
Coal	26-29	23-28	28	842	745 MTnat (K-A + E**) 614 MTnat (Other)
Nuclear	8-10	9-10	9.4	235	---
Hydro	2-3	2-3	3.6	91	---
Other	2-3	2-3	3	90	---
Total	88-105	94-107	100	2942	---

*Neither of the Soviet forecasts makes any allowance for losses and own consumption within the energy industries or non-fuel use, which must be allowed for in my approach. Given the way hydro and nuclear energy are figured, they do not involve losses and own consumption, so I load the allowance for such losses and non-fuel use fully onto the other four sources.

**Based on assumptions that the heating value comes half from Kansk-Achinsk and Ekibastuz coal, (with equal weights) whose heat contents are 3570 and 4340 Gkal/T respectively (Nekrasov et al. 1974, pp. 81-82) and half from other sources with heat value maintained at the 1978 average of 4,796 Gkal/T (1978 Nar Khoz and the fact that K-A output 1978 = 32 MTnat -- Shabad 1980 -- and Ekibastuz output 1978 = 50.3 MTnat -- Elektricheskie stantsii, 1979:10, p. 8).

How plausible is it that these amounts can be produced? First consider oil. One view of Soviet oil prospects holds that considering the prospective area and the relatively light degree of exploration so far, output can be sustained at more or less the present level for many years to come. But the opposing view, even accepting the reality of this potential, holds that low exploration effectiveness, missing infrastructure and the lead times required for new technologies will make for slow realization of this potential. My own view is that the 441 MTnat of crude oil and condensate used in this paper is an optimistic forecast, as can be seen if we think about the amounts of oil it implies must be found and explored to the production stage in the next two decades. I do not want to get involved in a discussion of reserve concepts and estimates, but consider the following simple analysis. If output falls steadily to about 400 MT in 1990, as the CIA suggests it may, but then rises smoothly after 1990 to 441 MT by 2000 as in Table 4, cumulative production 1981 through 2000 would be 9.1 billion tons. With falling production, the working inventory of reserves can be smaller in 2000 than in 1980, but the total discoveries would still have to be 7.5 billion tons.* The largest fields ever found in the USSR -- Samotlor and Romashkino -- are said to have contained about 2 billion tons of recoverable reserves each (Dienes, p. 58, CIA, 1977, p. 3). Given that no giant field of this kind has been discovered in the last 15 years (since Samotlor in 1965) it is difficult to convince oneself that the problem will be easily solved by finding a few such fields in the next 15 years. Given the adverse trends in exploratory effectiveness experienced in recent years discovering this much oil seems a formidable task.

If it can be achieved, however, an output of 441 MT of oil in the year 2000 certainly seems adequate to domestic needs. With 5 percent field losses, 4 percent refinery losses, and 10 percent of refinery runs in the form of non-fuel items -- such as feedstocks for petro-chemicals and asphalt -- such an

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*Assume that on the average the working inventory of recoverable contents in fields being produced is ten times the annual output. The suggested production profile could thus be compatible with a reserve drawdown of 1.6 billion tons.

output would provide 382 MTnat of refinery products for energy use. That is more than adequate to meet the liquid fuel needs we have outlined -- i.e., 241 MTnat of light fractions for motor fuel use, 30 MTnat for electric power, and 60 MTnat for other furnace uses. It would involve a refinery mix significantly different from the present one, however -- 241 MTnat of light fractions is about 73 percent of the listed total of uses, compared to a ratio of less than 50 percent today.

In translating the coal requirements into actual sources, I assume that by the year 2000, half of the heat value of coal output would come from the low quality strip-mined coals of the East, with an average heating value of 3955 Gkal/T and that the average heating value of coal from other sources will have been maintained at the 1979 level. To maintain that heating value, it will have to undergo more processing than at present, with large losses. The implication that coal output from the traditional basins can be kept as high as 614 MTnat, i.e., about the 1980 level, is probably over-optimistic. The figure of 745 MTnat for Ekibastuz and Kansk-Achinsk coal may thus be an underestimate of how much those basins would have to supply. But even at the forecast level the costs of developing the technology for, and financing the investments in, producing, processing, and transporting this coal or energy forms derived from it are going to be formidable. The technologies for using the Ekibastuz coal are reasonably well established, but for the Kansk-Achinsk coal there are three large steps -- burning it in large power generating units, processing it into some kind of transportable fuel, and shipping it by pipeline -- the technologies for which are still quite undeveloped at the moment. When the power transmission technology is added to this list, there can be no doubt that getting Eastern coal to make the contribution suggested is subject to terrible hazards. And it is clear that much of this coal will have to be processed by some technique less certain than combustion in power plants. Even the most ambitious projections discussed for the Ekibastuz and Kansk-Achinsk mine-mouth power complexes imply that they would not consume more than 150 MTst of these coals,* and even allowing for considerable additional amounts to be consumed in the Ural, and at moderate distances from Kansk-Achinsk, the 421 MTst forecast for these basins implies huge amounts to be processed for long distance shipment with very large energy losses in the process.

The estimated volumes of gas would come to a very large extent from Siberia, where reserves to support these output levels do exist. The question will be whether the capacity to transport it can be built -- a point on which at least some commentators are pessimistic. If we assume that the average transmission distance does not rise above 2000 km, the transport work would be 2,106,000 Bm^3km (about 2.5 times the 1980 level), and would itself consume perhaps as much as 75 Bm^3 with total own use on pipelines as much as 100 Bm^3.**

One of the greatest uncertainties, and the most controversial issue in any forecast of the energy situation in the next two decades will be the competition between gas and coal, each with its distinctive potential bottleneck. Soviet studies show that gas currently has a significant cost advantage over coal, even in such uses as raising steam in power stations. The advantage is said to be between 4 and 5 rubles per ton of standard fuel in most regions of the USSR (Il'ina, 1978, pp. 138-139), and compared to the Soviet

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*The Ekibastuz complex is to consist of four stations of 4 GW each, and the Kansk-Achinsk complex is talked about in terms of 30, 50, or 70 GW. (Shelest' pp. 226-229, 239-249). Assuming average utilization of 5,000 hours and a heat rate of 340 g/KWH, 34 GW would consume about 80 MTst per year; 74 GW would consume 146 MTst. They may well succeed in getting the stations above 5,000 hours -- Shelest' implies an expectation of 6,250 hours.

**In 1976, when gas pipelines did $405 \times 10^{12} m^3 km$ of transport work, they consumed about 15 billion cubic meters of gas themselves, and in addition, had losses of about 5.5 billion cubic meters. In 1976 only 71 percent of the compressor capacity on gas pipelines used gas turbines as prime movers, and this share is likely to increase considerably over the next two decades. (Campbell,1981 and Ekonomika gazovoi promyshlennosti, 1977:11, p. 27).

estimate of the marginal cost of coal (the so-called zamykaiushchie zatraty which are discussed more fully below) of about 20-22 rubles per ton of standard fuel, that is a significant saving. My guess is that the discrepancy will increase significantly as coal quality and location deteriorate. But there is a big offsetting obstacle in the way of a victory for gas, i.e., the demands it puts on the steel industry. As Makarov and Vigdorchik say (p. 195) one cannot assume that enough pipe can be gotten either by domestic production or by import to fully utilize the potential contribution of gas.

The amounts shown for nuclear and hydro power are, as already suggested, at the upper end of what might be considered feasible. The amount for "other" is probably attainable. Oil, shale, peat, and firewood are unlikely to grow from their 1980 level of 73 MTst, and little can be expected from tidal, geothermal, and solar. The best bet is better utilization of secondary sources, poorly exploited at present. Combustible by-products (such as coke-oven gas) are already fairly heavily utilized, but it is estimated that large amounts of secondary heat resources go unutilized in the major energy intensive branches. It was planned that total secondary energy resources in industry in 1980 would be about 83 MTst, of which a little over 20 MTst would be unutilized. (Sushon, p. 265). With growth, and serious efforts to capture these resources, it would be possible to reach the 94 MTst shown in Table 3.

The East-West Transport Problem. Finally, what does all this mean about the European-Asiatic split? Styrikovich and Cherniavskii (1979, p. 11) predict that even by the end of the century, the share of the European part of the USSR in total energy demand will still be 65-70 percent. Taking the midpoint of this range implies 1,986 MTst to be made available in the European USSR. What levels might be expected for the output of coal, oil, and gas in the European USSR by the year 2000? I suggest the amounts shown in the first column in Table 5 as optimistic estimates, on the following arguments:

Table 5. The East-West Split in
Soviet Energy Production in 2000 (MTst)

	Europe	Asia	Total
Hydro	32	59	91
Nuclear	235	negl.	235
Oil	286	345	631
Gas	119	904	1023
Coal	137	735	872
Other	60	80	90
Total	869	2073	2942

European output of coal in 1980 was about 330 MTnat, which represented a decline from 1975. Many of the mines are being exhausted, and are being replaced only partially by new mines. When specialists look at individual basin and mine capacities they see European output as barely holding its own or falling further by 1985. The Russians will continue to develop some new capacity here, even at high cost, because they need the coking coal. But total output must continue to decline, just because the investment cost is so high that Soviet planners will prefer to replace exhausted capacity with new mines in the East, rather than here.

Petroleum output in the European SSSR has fallen by about 40 MTnat in the Tenth FYP. Its still substantial production of about 350 MTnat in 1980 will continue to fall sharply in the '80s as the big fields in major producing regions are exhausted. Development of new small fields in the traditional producing areas will continue, but the industry is already doing that on a large scale, without stopping the slide in output. On the other hand some of the best long-range prospects for additional oil production are in the European areas -- at great depths in the Pri-Caspian depression, offshore in the Caspian, Baltic, and Black Seas, and in the far north. The postulated 200 MTnat allows for extensive new discoveries offshore and at deeper horizons.

Output of gas in the European SSSR has stayed about constant in the Tenth FYP, and stands in 1980 at slightly over 150 billion cubic meters. It has managed to keep this position only because development of new areas -- especially the growth of output from the Orenburg field -- offset declines in older fields. To expect 100 Bm^3 in 2000 is optimistic, and assumes that a great deal more gas will be found as a concomitant of the intensive search for oil in the European areas.

The regional split on hydro power has already been indicated earlier. Nuclear will be almost exclusively in the West, as will most (let us say 80 percent) of "other."

The implication is that 1117 MTst will have to flow from the East to the West in the form of coal, oil, gas, and to some extent in the form of electric power generated in the East. This is somewhat overstated, since much of the own use within the energy sector that differentiates production and final consumption will occur in the East and along the transport routes. On the other hand, these are probably overoptimistic projections for what is feasible in the European areas. The nuclear contribution is estimated generously, and the European prospect for coal and oil are probably also on the high side. Overall, these calculations suggest a transport problem more serious than Makarov and Vigdorchik (p. 201) are willing to admit -- they see a 2.5 fold increase in the East-West flow between 1975 when it was 360 MTst, and the end of the century, which implies a movement in 2000 of about 900 MTst compared to the 1117 calculated above.

Conservation. Before concluding, we should consider a bit more fully the possibilities of conservation. How strong a case could one make for a radically different vision in which growth was accommodated to a considerable extent by conservation rather than by supply increases? If elasticity could be cut fairly sharply, say from the assumed value of 1 to a value of .6, GNP growth at 2.5 percent per year would require an energy supply 432 MTst less in the year 2000 than I have projected. Looked at another way, with elasticity at .6, and assuming that other constraints are not binding, the 2500 MTst of consumption I think could be produced in the year 2000 would be consistent with much more dynamic economic growth or with a significant growth of exports. Whether the GNP elasticity can indeed be brought down significantly is a very complicated question, and one that will merit continued assessment as the Soviet efforts along these lines unfold. Depending on how the system evolves, significant energy conservation might be possible, though I am dubious that the USSR can achieve a reduction in the elasticity of energy demand to anything like .6, and it is worth spelling out the reasoning behind this position in more detail.

As indicated in the previous section, the peculiarities of the Soviet demand structure mean potential energy savings are much more heavily concentrated in industry, agriculture, and other "productive" sectors than in the household and municipal sectors where conservation efforts are focussed in the U.S. The other side of this difference in demand structure is the relative unimportance of energy use in the household sector at the present time. These are uses with high personal income elasticity, and over a twenty year period of growth at 2.5-3 percent, if consumers are allowed to participate reasonably evenly in economic growth, we should expect sharply rising household demand.

In the production sectors, where conservation efforts must now focus, the problem in the Soviet institutional setting is to find policy instruments that will induce "rational" energy savings that do not reduce production. One possibility is price increases. Heretofore, as in the U.S., energy has seemed cheap and abundant to Soviet decisionmakers, partly because it has been priced well below its social cost. The evidence for this assertion is developed in another paper, (Campbell, 1981) and only a sketch of the argument can be included here. Energy represents a unique case in Soviet price-policy because an attempt has been made to evade the irrationalities of Soviet pricing and to develop measures of the real opportunity cost of energy in the form of zamykaiushchie zatraty or ZZ. These can be thought of as marginal cost-based prices, or as the shadow prices associated with an optimizing program for producing and allocating energy. They are mandated as the official indices of energy cost in project making decisions about what energy source or what technologies to use. There are two difficulties however: a) for a large range of decisions about energy use (i.e., enterprise-level, current-operating decisions) it is transactions prices rather than the ZZ that control decisions, and transactions prices are well below the ZZ for most energy forms; b) the ZZ themselves are probably well below the true opportunity costs.

New ZZ's, higher than those used in the 'seventies, have now been promulgated (Makarov and Vigdorchik, 1979, p. 240) but they are still below real costs, especially since they do not reflect the opportunity cost of foregoing energy exports. New, higher transactions prices for energy are also to be introduced as part of a general price reform. The fact that the new prices will not be introduced until January 1, 1982, however, suggests something less than full appreciation of the urgency of the matter. And it seems that the new prices, on petroleum products at least, are to be kept well below marginal cost by squeezing out rent in the pricing of crude oil. The overall level of crude oil prices is to be raised by 2.3 times. But that will not be high enough to cover the marginal cost of oil from sources that will have to be used to meet the output goals of the eleventh Five-Year-Plan, and for deciding on the extensive and intensive margin of extraction, there will also be introduced a notional price five times higher than the old level of oil prices. (Ekonomika neftianoi promyshlennosti, 1980:8, pp. 2-4).

A related question is how significant price rises will be in discouraging consumption in the Soviet institutional setting. Given the present incentive system controlling managerial behavior, I doubt the price increases will be very effective in inducing conservation, though we should not rule out the possibility that over the twenty year period contemplated here there may be significant systemic changes that will increase sensitivity of decisionmakers to prices as signals of scarcity.

Soviet writers are fairly optimistic about conservation. According to Makarov and Vigdorchik (p. 25) the coefficients for useful work in relation to energy consumed for various fuels and uses could change over the next two decades as shown in the first two columns of Table 6. If we apply these efficiency gains to the major end use categories described in the 2000 scenario, the savings would be as shown in the last column of the table.

Table 6. Energy Conservation from Improved Utilization

	Efficiency in Energy Use (percent)		Consumption Forecast (MTst)	Corrected for Efficiency Gain (MTst)	Savings (MTst)
	1980	2000			
Steam and hot water (teplovaia energiia)	.825	.85	795	772	23
Furnaces*	.50	.62	400	323	77
Electricity	.39	.45	750	650	100
Engines	.31	.47	347	229	118
Other fuels (peat, firewood, shale)	Constant		---	---	---
Total					318

*Direct use other than internal combustion engines was calculated as 653 MTst, but I believe that Makarov's efficiency gain for furnaces must refer to a much smaller universe than the 653 MTst.

This is an extremely crude calculation, but the implication is that efficiency increases in end use could make a very significant contributor to solving the energy problem -- 318 MTst is a good fraction of the 400 MTst saving mentioned above as associated with a drop in elasticity to .6. But here again how seriously one takes these possibilities depends on one's view of the ability of the Soviet system to innovate. These putative gains depend on an extraordinary variety of R and D efforts, commercialization, and diffusion of equipment innovations. Imagine, for example the kind of redesign of equipment, changes in fuel quality, service, etc. that will be required to raise internal combustion engine efficiency from 31 to 47 percent! This kind of flexibility and innovational drive is conspicuous by its absence in the Soviet system, and I just don't see these kinds of changes taking place in two decades.

There is one notable example of such a rapid change -- the heat rate in power generation has been cut by almost one-third in the last two decades, from 468 grams of standard fuel per net KWH in 1960 to 330 grams in 1980. But I see this achievement as dependent on a very special situation. It could be achieved by focussing innovational efforts on a few strategic variables in a relatively small number of facilities. In other sectors a much broader, diffuse, heterogeneous set of changes is likely to be required, calling for much greater low level initiative and co-ordination.

Over a third of primary energy consumption takes place in electric power stations, and we might well ask about possible additional improvements in efficiency for this large component of total demand. Fuel expenditures per unit of output was reduced here by heavy use of co-generation and by a technological policy that has emphasized large units using steam at supercritical parameters. I doubt that much further improvement along these lines is possible in the future. Indeed, the heat rate may well rise, as the share of co-generation falls. The major innovation that might help is the introduction of MHD (magnetohydrodynamic) generation but it is difficult to predict when MHD will become a working innovation and for any reasonable estimate of timing and magnitude, its impact on overall fuel expenditure per unit of output will not be great. Even supposing that MHD could account for 20 percent of fossil-fired generation by the year 2000 its differential efficiency of 50 percent versus the 41.7 percent we have been using for conventional power generation would raise average efficiency only to 43 percent and result in savings of 13 MTst of fossil fuel. Soviet energy planners themselves may be having doubts as to the feasibility of much improvement in the heat rate. In contrast to the .45 efficiency forecast by Styrikovich and Cherniavskii and used in Table 6, the forecast supplied to the ECE showed an efficiency rising to only 40.3 percent by 1990 and to 41.7 percent by 2000.

Conclusion. I hope I have avoided the trap of leading readers to believe that the foregoing quantitative sketch is my considered conclusion as to what the Soviet energy future looks like in the year 2000. Each major building block in the argument really warrants an in-depth study in itself, and I have sacrificed detailed justification of individual elements to focus instead on the interrelations of major separate elements in the situation. Thus the most appropriate form for some concluding remarks is probably some questions about whether or not the overall view developed seems plausible, in terms of consistency both internally, and with some major aspects of the environment within which energy policy will develop. I would like to speak to that from three points of view.

a) I believe the energy scenario described is feasible in terms of technical and energy resource constraints. The coal and gas resources it requires have already been discovered. It may be perhaps a bit optimistic in relation to the amount of oil resources it requires the Soviet oil industry to discover over the period, but as suggested above, the economy could probably get by with somewhat less oil than forecast here. The USSR possesses a working nuclear power technology, and has made a good start on commercializing the breeder technology that will overcome possible limitations in resources of fissionable material. In the major technological areas the issues are not so much whether a given job, such as gas transport, can be performed, but whether technological progress can proceed fast enough to avoid the crippling resource inputs that present technological levels imply. Even in cases where one could not say that a working technology has been mastered in the Soviet economy as in offshore work or in slurry transport, the technological problems have been solved abroad and the technology can probably be imported.

b) The path outlined will be costly in terms of investment requirements. It would be an exceedingly ambitious and uncertain task to attempt to quantify those requirements in detail, but we can think about the problem in terms of the basic proportions of the Soviet economy in the recent period. With investment at 22 percent of GNP, industrial investment at 35 percent of all investment and investment in the fuels and power industries at about 28 percent of all industrial investment, energy investment takes about 2.2 percent of GNP (CIA, Handbook of Economic Statistics). As I understand the way the Soviet statistics work, that includes investment in energy transport insofar as oil and gas pipelines and power transmission are concerned, but not in other forms of energy transport. It does not seem unrealistic to suppose that the share of the fuels and power sector in all industrial investment should rise again to the 40 percent of all industrial investment it required in the pre-hydrocarbon period. If one assumed that the share of industrial investment in GNP could not be raised, that is equivalent to diverting to the energy sector to compensate for the rising capital intensity 12 percent of the flow that normally goes into growth-inducing projects. Some of the sacrifice might be in non-industrial investments, and as an alternative measure of the pressure on the economy, to keep the fraction of GNP going to growth-inducing investments of all kinds from falling, almost 1 percent of GNP would have to be diverted from some other end use such as consumption or defense to compensate for the rising relative capital intensity of energy expansion. This is not a dramatic diversion, but is certainly large enough a change from recent experience that over an extended period it would have a palpable independent effect on growth. The energy expansion path this paper has described seems feasible in part because of the relatively modest role of economic growth assumed, but the investment demands of that expansion path seem sufficiently heavy to validate the original pessimism about economic growth.

c) It will not have escaped notice that this sketch of a possible energy situation in 2000 envisages neither exports nor imports of energy. Is that plausible? The analysis suggests to me that it is realistic to expect that Soviet domestic energy demand at the end of the century can be met from domestic energy sources. It also seems quite clear to me that the USSR is going to be unable to export any significant amounts of energy to the non-socialist world (there may be small exceptions in the form of some gas and some coking coal, especially from Siberia). Without such exports, it seems obvious that it will not be possible to continue the present policy of large scale importation of technology in the coming years, and I see that as another force that will keep Soviet economic growth down to 2.5-3 percent per year. What <u>is</u> implausible about the picture presented is the implication that the USSR will be able to get out from under the burden of energy exports to Eastern Europe, and I believe that all during the next two decades it will be exporting amounts to Eastern Europe that will rise from the present level to something on the order of a couple of hundred million tons of standard fuel in various forms. I believe the USSR could produce this much of an increase above the magnitudes already described, especially if it were in the form of gas. Nor does the addition of this extra demand seem incompatible with growth at the postulated rates, in part because the USSR would make sure that much of the associated investment burden is borne by the Eastern European importers, rather than by itself.

This exercise should end with heavy emphasis on a reminder that this is a highly tentative and unfinished analysis. There are too many uncertainties at this point to be very dogmatic about how the problem of provisioning the economy with energy is going to interact with its overall growth over the two decades ahead. Each of the elements treated as feasible could run into insoluble problems -- the nuclear contribution could be blocked by a serious nuclear accident, technologies for processing Kansk-Achinsk coal may be delayed for a decade or two. There may be breakthroughs on possibilities I have ruled out -- the discovery of fabulous oil fields or significant success in conservation. But the author will consider this paper a success if it has succeeded in establishing a framework that will be productive in focussing attention and defining issues for continuing research on this important question.

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