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A GLOBAL ECONOMIC MODEL

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PREFACE

There are appropriate occasions for large detailed models and for small simple models. In the context of the analysis of the world economy over long stretches of time, a good case can be made for the building of a small model--one that captures the essence of some aspect of growth and general economic environment that can serve a wide variety of problems. Many of these problems are going to be handled by scholars who are not economists--therefore, it is advantageous to construct a model that is not data-intensive, that is easy to manage, and easy to apply to a limited range of issues.

It is in response to the need for a model that meets such constraints that I have put together the simple system in this paper. There is much to be said in favor of learning to walk before learning to run. It is in this spirit that the present system is tentatively put forward.

The present study is only a first attempt. Many of the data and specifications need further work in a number of directions. It is hoped that it will generate discussion and provide a framework for moving to larger scale global systems that capture more of the detailed inter-relationships of the world economy. It is also hoped that the discussion can lead to suggestions for better data compilation and processing.

I wish to thank Bert Hickman of Stanford University for research collaboration on earlier versions of the present system, Mrs. Bijou Yeh for the enormous task of putting that data series together (this part was data intensive--the use and maintenance of the data are much less intensive) and Hans-Holger Rogner for programming assistance.

A GLOBAL ECONOMIC MODEL

By L. R. Klein - Data Preparation by Bijou Yeh
Programming by Hans-Holger Rogner

Motivation and Objectives

The predominant emphasis in macro econometric model building has been on short term national models, concerned with forecasting over an horizon of some one to three years (by months, quarters, years). Some of these models, especially those with large input-output components, have been regularly used in decade-long simulations. More recently, econometricians have become concerned with longer term prospects, notably because energy scenarios require at least two or three decades to deal with significant changes in the delivery and use of energy.

The few long term models that have been used for energy analysis or related problems of resource exhaustion and environmental protection have been relatively large systems. This is particularly true of input-output based systems. Models designed by Jorgenson and associates might be so compact that they have no more than 100 or so equations, while the models of Almon (IMFORUM), Wharton EFA (WEFA), and the Economic Council of Canada (CANDIDE) consist of some one thousand or more equations. These are large data-intensive systems. They are excellent but not readily manageable. Also, such models have been mainly confined to analysis of national economics. The Leontief model and some new proposals are trying to deal with the world economy at a detailed inter-industry level, but model management problems and data problems are severe. The project LINK models treat the entire world trading system at the individual country level with new research into capital flows/exchange rates, but that is a 5000-equation system (still expanding) and very complicated to manage, apart from being confined to a fairly short horizon - no more than a decade, at the present time.

After reviewing available systems and looking at perceived research needs, a system meeting the following conditions has been devised:

1. It should be global in scope - covering the whole world;
2. It should be global in concept - covering broad macro economic behavior or conditions;
3. It should be capable of interpreting some of the world's main problems of international economic relations;
4. It should be easily manageable and not data intensive;
5. It should be a general framework that readily admits improvement and elaboration;
6. It should be suitable for analysis of long term horizons.

During the early research phases of the Mesarovic-Pestel global modeling exercise, a general specification of an economic module meeting most of the above conditions was prepared jointly by B.G. Hickman and L.R. Klein.[1] The authors were not prepared to release the paper at that time because the model lacked price relationships, as well as an adequate data base. It is the intent of the present paper to carry through this work partially to completion.

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1. M. Mesarovic and E. Pestel, Mankind at the Turning Point, (N.Y.: E.P. Dutton (Reader's Digest Press, 1974), p.198. A complete specification was presented to the IIASA Conference on Global Modeling, March, 1974, Baden. The equations were published in Russian, A.A. Rivkin, I. Sh. Amirov, "Critical Analysis of Global Project 'Humanity in Front of Choice' Models," Economics and Mathematical Methods, XIII (May-June, 1977), 440-56.

Thanks are due to Dr. Hickman for critical observations on the present paper.

The data problem is not simple, but once a usable data base has been constructed, it is relatively easy to maintain it. The problem is to make an adequate inventory and analysis of data country-by-country and to combine them into meaningful aggregates for designated groupings of nations. There will always be knotty, unsolved data problems in this work, but once a set of procedures has been worked out, it should be possible to update and refine the basic data set with relative ease. It is in this sense that the model is not data-intensive.

The motivation, therefore, is to complete the economic model structure that was originally implemented for the Mesarovic-Pestel global model by adding a price system, building a usable data base, and using the system in long run simulations. Although the system is contemplated for background economic use in energy analysis, it is not a system with explicit energy sectors. It can, however, serve as a base into which to imbed or onto which to add an energy sector. Other sectors for which long run analysis is pertinent, such as agriculture, demography, or exhaustible resources, could also be studied in the same framework. The system is not energy specific, although the long run nature of the economic aspects of energy motivate the preparation of this model.

Model Specification

The present version of the model is not identical with that originally constructed for the Mesarovic-Pestel system, but it is designed in the same spirit. It is different partly because of some data/accounting issues, and it has been enhanced by the inclusion of a price system.

The global economy can be split into regions in various ways. From the viewpoint of economic structure, a useful set of groupings is:

The first world, consisting of the OECD countries plus South Africa. These might also be called the industrial democracies and will be denoted by subscript "D", standing for developed.

The second world, consisting of the centrally planned (CMEA) economies in Eastern Europe, the Soviet Union, Mainland China, VietNam, North Korea, Mongolian Peoples Republic, and Cuba. They will be denoted by subscript "C", standing for centrally planned.

The third world, consisting of the developing countries in Africa, Asia, Latin America, and the Middle East. South Africa is excluded from Africa; China and other centrally planned economies from Asia; and Cuba from Latin America. Island nations of the Far East are included in Asia. The developing countries will be denoted by subscript "L", standing for less developed countries.

Occasionally, the third world is split into two groups - oil producers in OPEC and those outside OPEC. The latter are sometimes referred to as the "fourth" world. It would be possible to make an OPEC/non-OPEC split and have four economic regions, but the present paper is based on three. For energy analysis, it is definitely going to be useful to subdivide the world into four groups. Mexico, as well as some developed countries are major oil producers; therefore, OPEC nations do not automatically encompass the global oil supply. From a practical point of view, however, it is probably simplest to deal with OPEC as an economic entity. Middle East, Persian Gulf or other groupings of oil producers would also be of some use in the analysis, but considering all aspects of the data and structural behavioral problems, it seems best to treat OPEC separately if a move from three to four groupings is to be undertaken.

The model is quite compact and can be laid out all at once.

D, Industrial Democracies

$sY = k(Y-Y_{-1})$

$s = 0.2 + E/Y$

$k = K/Y$

$K = L\exp\{0.62738 \ln \frac{(w/p)}{(i/p)} + 2.86975\}$

$w/p = 0.051862\ Y/L - 0.095046$

$L/N = 0.013014\ w/p + 0.118320$

$i/p = 0.06$

$X_{DD} = 0.095\ Y$

$X_{LD} = 0.020\ Y$

$X_{CD} = 0.004\ Y$

$E = X_D - \tau_D(X_{DD} + X_{LD} + X_{CD})$

$X_D = X_{DD} + X_{DL} + X_{DC}$

C, Centrally Planned Economies

$sY = k\ (Y - Y_{-1})$

$s = 0.097927\ \frac{\Delta Y/N}{(Y/N)_{-1}} + 0.263063$

$k = 40.0\ (X_{DC}/Y) + 3.08$

$K = kY$

$w/p = 0.001425\ t + 0.977865$

$L/N = 0.001052\ t + 0.066837$

$X_{DC} = X_{CD} + CR_{DC}$

$X_{LC} = X_{CL}$

$X_{CC} = 0.025\ Y$

$X_C = X_{CD} + X_{CL} + X_{CC}$

L, Less Developed Countries

$sY = k\ (Y - Y_{-1})$

$s = 1.510902\ E/Y + 0.241487\ \frac{\Delta Y/N}{(Y/N)_{-1}} + 0.171637$

$k = K/Y$

$K = L\exp\ \{0.329619\ \ln \frac{(w/p)}{(i/p)} + 1.149630\} + \sum_{i=24}^{t} (0.95)^{i} (T_{DL})_{-i} + T_{DL}$

$w/p = 0.094076\ Y/L + 0.652301$

$L/N = -0.000289\ t + 0.067781$

$i/p = 0.02$

$X_{DL} = X_{LD} + T_{DL}$

$X_{CL} = 0.013\ Y$

$X_{LL} = 0.035\ Y$

$E = X_L - \tau_L\ (X_{LL} + X_{DL} + X_{CL})$

$X_L = X_{LD} + X_{LL} + X_{LC}$

$T_{DL} = \alpha Y_D$

Variables of the Global Model

Y = real GDP in each area (Y_D, Y_L, Y_C)

s = savings rate (s_D, s_L, s_C)

k = capital-output ratio (k_D, k_L, K_C)

E = real trade balance (E_D, E_L)

$1/\tau$ = terms of trade (τ_D, τ_L)

K = stock of capital (K_D, K_L, K_C)

w/p = real wage rate ($(w/p)_D$, $(w/p)_L$, $(w/p)_C$)

i/p = real interest rate ($(i/p)_D$, $(i/p)_L$)

L = employment (L_D, L_L, L_C)

N = population (N_D, N_L, N_C)

T_{DL} = real transfers from developed to developing areas

CR_{DC} = trade credits granted by developed to centrally planned economies

X_{ij} = real exports from area i to area j (i,j = D, L, C)

X_i = total real exports of area i (i = D, L, C)

World Trade Matrix

	Importing			
Exporting	D	L	C	Total Exports
D	X_{DD}	X_{DL}	X_{DC}	X_D
L	X_{LD}	X_{LL}	X_{LC}	X_L
C	X_{CD}	X_{CL}	X_{CC}	X_C

Row sums are total exports; column sums are total imports (not used explicitly in this model)

With identities and all, there are only 35 equations in this world model. With direct substitution of some identities, it could be made somewhat smaller, but this is a sufficiently compact description of the world economy that it can be programmed and manipulated with a great deal of ease. It remains to explain its logical structure in terms of bringing out the main characteristics of each world, of explaining the international trade/transfer relationships, and in generating the world growth process. Each world is structured so as to show some of its peculiar characteristics and the way present or contemplated world conditions would affect them.

There are three structural components in each of these three models:

(i) saving and investment behavior,

(ii) relative price formation,

(iii) international trade.

To explain the underlying assumptions in the model, it is convenient to deal with these components, in turn. First, however, it will be instructive to list the dependent (endogenous) and independent (exogenous) variables of the system.

The dependent variables are:

First World - $s_D \; Y_D \; E_D \; k_D \; K_D \; (\frac{w}{p})_D \; (\frac{i}{p})_D \; L_D$

$X_{DD} \; X_{CD} \; X_{LD} \; X_D$

Second World - $s_C \; Y_C \; k_C \; K_C \; (\frac{w}{p})_C \; L_C$

$X_{DC} \; X_{CC} \; X_{LC} \; X_C$

Third World - $s_L \; Y_L \; E_L \; k_L \; K_L \; (\frac{w}{p})_L \; (\frac{i}{p})_L \; L_L$

$X_{DL} \; X_{CL} \; X_{LL} \; X_L \; T_{DL}$

They are similar for each of the three cases. There is no interest rate or non-zero trade balance variable for the centrally planned economies. The capital transfer variable appears only in the equation system for the developing countries.

The independent variables are τ_D τ_L CR_{DC} N_D N_C N_L. The terms of trade and trade credit variables are assumed to be exogenous. To the extent that the terms of trade between regions are now controlled by the OPEC cartel, the assumption that τ_D or τ_L is exogenous has a great deal of plausibility. The arguments against this assumption are that all trade with the developing world is not oil trade and that the terms of trade, like exchange rates, should ultimately be explained by supply and demand balance. Even OPEC may not be able to defy the laws of economics indefinitely. They have succeeded in enforcing their price for 5 years and may continue to do so, but a long run model might well assume that the laws of economics eventually prevail. This notion will be introduced in later versions. At the present time, exogeneity of τ_D and τ_L are assumed.

Trade credits granted by industrial to centrally planned economies are always under discussion, in some form or other, and involve a number of noneconomic considerations. For the present analysis, however, this variable is kept in the exogenous category, subject to political determination.

The overall growth process is demonstrated in each case by the same mechanism, a Harrod-Domar or multiplier-accelerator mechanism that combines the productivity of capital with the provision of savings for investment purposes. It can be seen immediately that each world area is headed by the equation

$$sY = k(Y-Y_{-1})$$

The flow of savings is

$$S = sY$$

where Y = real output

s = savings rate (average propensity to save)

S = total real savings.

Total capital is related to output by

$$K = kY$$

k = capital-output ratio (inverse of average productivity of capital)

K = stock of capital

Investment is given by

$$K-K_{-1} = k(Y-Y_{-1}),$$

and the accounting equality between savings and investment gives us the dynamic relation to determine output

$$Y = \frac{k}{k-s} Y_{-1} = \frac{1}{1-\frac{s}{k}} Y_{-1}$$

The ratio s/k is crucial in interpreting the long run growth rate. The savings rate will generally be bounded

$$0 < s < 1,$$

empirically in the narrower range from 0.1 to 0.4. The capital output ratio will be generally a multiple of GDP,

$$k > 1;$$

so

$$(1 - \frac{s}{k})^{-1} = 1 + \frac{s}{k} + (\frac{s}{k})^2 + (\frac{s}{k})^3 + ---.$$

Define the growth rate as that value of r satisfying

$$1 + r = (1-\frac{s}{k})^{-1} = 1 + \frac{s}{k} + (\frac{s}{k})^2 + (\frac{s}{k})^3 + ---.$$

Then

$$r = \frac{\frac{s}{k}}{1-\frac{s}{k}}$$

This is all simple enough if s and k are constants. Then, only one equation would be needed for output determination in each world area. The fact is that s and k are not constant. They are ratios of variables that must be separately determined by distinctive processes in each area and affected by international economic relations.

The simple Harrod-Domar model with constant savings and accelerator coefficients are only indicative in the present context. We assume that a finite difference equation in Y that resembles the basic multiplier-accelerator equation holds, with variable coefficients This does not strictly equate savings and investment for three reasons:

1. Savings are reckoned "gross" in this model, while investment would need to have depreciation added to the change in capital stock. We would have to write

$$S = \Delta K + \delta K_{-1}$$

where the second term on the right denotes capital consumption.

2. With a variable capital-output ratio, net investment investment would be

$$\Delta K \simeq k\Delta Y + Y\Delta k$$

We have not used the second term on the right hand side.[1]

3. Our accounting is not complete in this model because only merchandise trade is explicitly accounted for. We did not model trade in invisibles that would be needed for the savings-investment identity. See p 21 below. In a later, extended version of this model, some of these different treatments of the savings - investment identity are being measured and modeled differently.

The historical statistics indicate remarkable stability in the savings ratio, s, for the industrial democracies at about 0.2. Constancy of the savings ratio has long been observed in individual developed countries, but has not been studied widely for the first world as a whole. There are well known cyclical fluctuations in the savings rate, and it is not strictly a constant. Something new has come on the horizon, however, in connection with new pricing of energy, namely a transfer of resources from the developed to

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1. We did not use the incremental (ICOR) ratio $v = \Delta K/\Delta Y$ because it tends to be unstable in annual statistical series.

the developing countries, including OPEC in the latter. Nominal trade has generally been in overall balance for the developed countries in the first world,

$$(PX)_D \, X_D - (PM)_D \, (X_{DD} + X_{LD} + X_{CD}) = 0$$

If we divide both sides by PX_D, we get

$$X_D - \frac{(PM_D)}{(PX_D)} (X_{DD} + X_{LD} + X_{CD}) = 0$$

After the re-pricing of oil by OPEC, in 1974, this magnitude turned strongly unfavorable for the developed countries. The reciprocal of the terms of trade will be denoted by τ_D, and the quantity

$$E = X_D - \tau_D \, (X_{DD} + X_{LD} + X_{CD})$$

will be strongly negative as long as τ_D is significantly greater than unity. It is indicative of the real loss of resources through unfavorable terms of trade. It measures exports less cost of imports, reckoned in export pricing units.

The behavioral assumption is made that savings in the first world will depend on the size of E. With relatively high energy prices, E will generally be negative, and savings will fall. Expressing E as a fraction of output, we assume that the previous long term stable rate of 0.2 will be brought down by the unfavorable terms of trade. That is why we write

$$s = 0.2 + E/Y$$

There are not enough data to determine this relation through a statistically estimated regression; therefore, a simple additive relation has been assumed as a first approximation. As the terms of trade become more unfavorable, cet. par., s will fall, and the resulting growth rate of output will also fall; both numerator and denominator of

$$r = \frac{s/k}{1-s/k}$$

will tend to fall, if k is unchanged.

The capital-output ratio, however, is not a constant and cannot be assumed generally, to be unchanged. If this ratio and the labor productivity ratio are not assumed to be constant, then there is implicit substitution possible between labor and capital. The production functions are not explicitly introduced into the models, but relations derived from them are. In the models there is separate determination of K and Y; the capital-output ratio is simply the ratio of these two endogenous variables. Similarly, employment and output are separately determined and the labor productivity ratio is simply the ratio of these two endogenous variables. Both ratios move from one time period to the next; this is the essence of the assumption that production takes place with the possibility of substitution. In the D and L models, it is assumed that factors of production are used efficiently. Cost minimization would require that

$$\frac{\partial x/\partial L}{\partial x/\partial K} = \frac{w}{i} ;$$

in other words that the ratios of marginal productivities equal the ratios of unit factor rewards. For a general class of production functions - the CES class - we may write

$$\ln \frac{K}{L} = \sigma_0 + \sigma \ln \left(\frac{w}{i}\right),$$

where σ is the elasticity of substitution between capital and labor. The estimated version of this equation with est σ = 0.62738

is normalized on K, as

$$\frac{K}{L} = \exp\ \{\ \sigma_o + \sigma \ln \frac{w}{i}\}$$

$$K = L \exp\ \{\sigma_o + \sigma \ln \frac{w}{i}\}$$

in the D area model. The L area case will be discussed later.

K cannot be determined unless L is determined, and the wage rate must be determined in order to determine L. This is the basic idea of simultaneity or interdependence in the D system. It is assumed that the real wage follows labor productivity in the long run and that the participation rate, L/N, is an increasing function of the real wage rate. These are straightforward trend ideas, but no basic distinction is made between labor force and employment; i.e., the cyclical phenomenon of unemployment is ignored. It is not that full employment is assumed. It is simply that the average long run rate of unemployment is accepted as a norm for this system. Unemployment will fluctuate a great deal in the short run, but cyclical dynamics are being left out of this trend system.

The next equation fixes the deflated interest rate at a constant value, 0.06 in the present case. An accepted concept of the real rate of interest is

$$i - \text{expected}\ \frac{\Delta p}{p}$$

Even if we simplify by making the expected rate of inflation the same as the rate observed in the long run, we would seriously complicate the system by trying to explain both i and $\frac{\Delta p}{p}$ as separate variables. In a long run analysis, where interest focuses on the next century, it is not meaningful to try to outguess the monetary authorities and set up a framework for jointly estimating i and $\frac{\Delta p}{p}$. The inflation rate is used to correct nominal values of i in order to get at real values. An alternative correction is to divide i by p, where p is an index on a fixed base. This is formally different from subtracting the inflation rate, but achieves a similar correction of movement in i. An interesting concept in the economics literature, known as the Gibson Paradox or the Gibson Effect provides an empirical justification for using $\frac{i}{p}$ as the real rate.[1] A. H. Gibson noted that there is a strong correlation between the nominal interest rate and an index of the price level. This correlation has been observed over long periods of time and in different industrial countries. It also stands up well in up-dating to the present era, looking back as far as the turn of this century. The data that we shall describe in a later section indicate that not only is i a linear function of p, for the first world as a whole, but it is practically proportional. That enables us to write $\frac{i}{p}$ as a constant, and greatly simplifies the presentation. This is why we have

$$\frac{i}{p} = 0.06$$

in the D area model.

The equations for the D area are rounded out by writing import requirement functions as proportions of GDP. There is one proportion for each area from which imports are drawn, including the D area itself. With a definition of X_D in terms of bilateral exports,

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1. See J. M. Keynes, A Treatise on Money (London: Macmillan, 1930). Keynes remarked that Gibson's finding "...is one of the most completely established empirical facts within the whole field of quantitative economics ..."

we complete the equations for the first world, D.

We next turn to an explanation of the equations for the third world, L. The basic income generating equation for growth determination is the same as in the D case, but the equations explaining s and k (K) are different. In the third world, E is now positive because the terms of trade, τ_L, have moved strongly in their favor, mainly because of high petroleum prices but partly because of relatively high prices for other basic materials. The effect of $\frac{E}{Y}$ on s has been very tentatively estimated because few observations at the new favorable values of τ_L are available. The historical pattern of s is quite different from that in the previous case. It has not at all been steady but has gradually risen as growth in the developing world has taken place; therefore, per capita growth in real GDP is another variable influencing the savings rate. For a great part of the period since 1960, s has been low for the developing countries and has reached about 0.20 only in recent years.

The capital-output ratio is much lower in the L region than in the D region, but also the elasticity of substitution between labor and capital is much smaller; it is only one-half as large. To a large extent, capital is the limiting factor, and the abundant labor force is drawn upon to work with the scarce capital factor to the extent to which the latter is available. Capital imports for the developing world come not only from the working of the market process but also through grants and loans made by the other sectors, mainly the developed sector. Trade between the developed and developing sectors is assumed to be unbalanced to the extent to which real resources are transferred from the former to the latter. These real resources are then added to K to augment the process of capital expansion. These real resources are depreciated at the standard rate of 5% per annum assumed for all capital in the L area.

It is interesting to note that in current prices X_{DL} falls far short of X_{LD}. This is largely the petrol deficit. In real terms, however, i.e. in 1970 prices, at 1970 exchange rates, X_{DL} is greater than X_{LD}. This is the resource transfer that shows how much in real terms the developing countries can buy from the developed countries with their surplus. The variable T_{DL} is, therefore, a significant policy variable that drives the system, showing how much extra input into capital expansion the developing countries can obtain.

T_{DL} does not consist entirely of purchases from the petrol fund. It also represents aid that developed countries have traditionally made. A goal has always been to have this aid at one or two percent of the GDP of developed countries. Actual aid has fallen short of that goal by significant amounts, but a policy parameter α is introduced in the L area model to show that T_{DL} depends on Y_D

$$T_{DL} = \alpha Y_D$$

This gives a significant linkage across models.

To complete the wage-rate/labor sector of the L area model, we introduced a wage equation that depends on productivity, as in the D area model, and a simple trend for the participation rate. There is little point, in the developing world area, in considering the distinction between labor force and employment, as there are no meaningful statistics of unemployment. It is also not as sensible to think of labor force participation as being responsive to real wage changes; therefore, the participation rate is a simple trend relation, that is apparently drifting downwards at a very slow pace.

The Gibson Effect should prevail for the developing countries in much the same way that it is present in the developed countries, but the factor of proportionality is much lower. It is also not as constant. We have simply used the value toward the end of the sample span as an estimate of the ratio between i and p.

Apart from the special balance of imports and exports with the developed countries through the policy transfer variable T_{DL}, it is assumed that imports either from the C or L areas are proportional to area GDP.

Modeling of the centrally planned economies is much less developed than for the other two areas. In particular, the process of factor substitution between labor and capital as a function of relative real rewards cannot be implemented. In the first place, there are no available data for the area as a whole on capital charges. There are some data on wage rate and price level, but the resulting estimates of real wage trends are suspect. It appears that real wages grow very slowly, certainly not as fast as productivity. The same real income generating process is used, but the equations for determination of the fundamental coefficients s and k are different. The s coefficient is made a function of the growth of per capita real income. This is sensible and straightforward enough. The savings rate has risen markedly in the C area. The capital-output ratio is a technological variable and should be given priority for expansion at the present stage of development by the central planning officials. It is growing and should continue to grow, by plan. But there is a deliberate effort to import high technology goods from the D area. The exports from D to C are, therefore, introduced, as a ratio to Y, in the explanation of k. There are few time points for the use of this variable, as the policy of opening up for capital imports has just begun.

Rather than introduce interacting relationships between real wage and employment, we have simply used trend relations for w/p and L/N. As in the developing area model, no distinction is made between labor force and employment. In the case of the centrally planned economies, it is assumed that there is an effective commitment to full employment.

By and large, centrally planned economies have sought to maintain balanced trade, both overall and bilaterally. We have imposed strict bilateral balance with the developing world but allowed for a real resource transfer from the developed to the centrally planned world. This transfer is the counterpart of credits that have been granted from official and banking sources to the centrally planned economies to permit them to finance high technology imports and adjustment to short run harvest disturbances. The variable CR_{DC} is another trade policy variable that has an effect on X_{DC}, which, in turn, influences the capital-output ratio. The C area model is closed by making internal trade, X_{CC}, proportional to GDP.

The trade variables in all three models are merchandise flows. This gives rise to an an accounting issue in the basic GDP identity:

$$GDP = C + I + (X-M)$$

C = real consumer expenditures

I = real investment expenditures

X = real exports

M = real imports

X-M = real trade balance.

This balance includes goods and services. Savings are defined as GDP that is not consumed.

$$S = GDP-C;$$

therefore exogenous movements in X-M could be driving forces of GDP in the usual sense of export/import multipliers. That effect does not show up in our models because we have implicitly let net service exports or imports serve as a residual buffer. The trade influences work indirectly in the system through their effects on s and k(K). In each of the area models, these effects have been spelled out through E_D, E_L, τ_D, τ_L, T_{DL}, X_{DC}, and CR_{DC}. Estimation of a world trade matrix of invisibles and fuller integration of the GDP account structure is one way of proceeding to handle this issue.

A TRIAL SIMULATION

A base line simulation to the year 2000 has been worked out to examine the model's properties and possibly to gain some insight about substantive results. In order to simulate the model from 1973 to 2000, it is necessary to supply inputs in the form of initial conditions, exogenous (policy) variables, and selected equation adjustments. The system starts on a correct path, as from 1973.

Assumptions are listed in Table I. Results of the solution are in Table II.

Table I

	1973	74-77	78-87		88-2000
τ_D	1.0142	1.200	(steps of 0.02 per year to max. 1.4)		1.4
	1973	74-77	78-82		83-2000
τ_L	.936	.646	(steps of .02 per year to max. .746)		.746
	1973	1974	1975	76-81	82-2000
α	0	.0025	.005	(steps of 005 per yr. to max. .02)	.02
	1973	1974	75-83		84-2000
CR_{DC}	4.0	1.0	(steps of 1.0 per yr. to max. 10.0)		10.0
	1973-2000				
Adjust $(w/p)_L$	+0.2				
	1974	75-85	1986	87-97	98-2000
Adjust k_C	0.3	0.1 per yr. to max. 1.4	1.3	-0.1 per yr. to min. 0.0	0.0

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SIMDAT FILE WAS OPENED WITH FOLLOWING PARAMETERS
NED NEX NXS  JL  IY  IP  IR TYPE OF DATA
 34   5   0   1  73   1   1     ACTUAL
MAX
 50
 NUM TY  LABEL      LAG KSET NUM TY  LABEL      LAG KSET NUM TY  LABEL      LAG KSET NUM TY  LABEL      LAG KSET NUM TY  LABEL      LAG KSET
   1 E   D-GDP$70    1   1    9 E   D-I/P       0   14   17 E   L-K/O       1   24   25 E   XCL         0   36   33 E   C-W/P       0   48
   2 E   D-K$70      0   2   10 E   XDD         0   15   18 E   L-S/GDP     0   25   26 E   XLL         0   37   34 E   C-EMPL      0   51
   3 E   D-K/O       0   4   11 E   XLD         0   16   19 E   L-W/P       1   28   27 E   XL          0   38   35 X   C-POP       1   52
   4 E   D-S/GDP     0   5   12 E   XCD         0   17   20 E   L-EMPL      1   31   28 E   TDL         1   39   36 E   XDC         0   53
   5 E   D-W/P       0   8   13 E   XD          0   18   21 X   L-POP       1   32   29 X   TIME        0   19   37 E   XLC         0   54
   6 E   D-EMPL      0  11   14 X   TIME        0   19   22 E   L-E         0   33   30 E   C-GDP$70    1   41   38 E   XCC         0   55
   7 X   D-POP       0  12   15 E   L-GDP$70    1   21   23 E   L-I/P       0   34   31 E   C-K/O       0   44   39 E   XC          0   56
   8 E   D-E         0  13   16 E   L-K$70      1   22   24 E   XDL         0   35   32 E   C-S/GDP     0   45
REGRESSION COEFFICIENTS
   1    0.627380    2    2.869750    3    0.051862    4   -0.095046    5    0.013014    6    0.118320    7    0.095000
   8    0.720000    9    0.004000   10    1.014200   11    0.000000   12    0.000000   13    0.000000   14    0.000000
  15    0.300000   16    0.035000   17    0.025000   18    1.200000   19    0.646000   20    0.329619   21    1.149630
  22    1.510902   23    0.241487   24    0.171637   25    0.094076   26    0.200000   27    0.652301   28   -0.000289
  29    0.067781   30    0.013900   31    0.936000   32    0.000000   33    0.000000   34    0.000000   35    0.000000
  36    0.000000   37    0.000000   38    0.750000   39    1.000000   40    3.000000   41   40.000000   42    0.001425
  43    0.977865   44    0.001052   45    0.066837   46    0.097927   47    0.263063   48    0.020000   49    0.000000
  50    0.060000
SIM LIS NGR ERR NIT NCOL WS NS
 0 101   0   0   3    0   0  0
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DYNAMIC SIMULATION

SOLUTION VALUES FOR A DYNAMIC SIMULATION FOR POTENTIAL GNP MODEL
FOR

		1	2	3	4	5	6	7	8	9	10	11	12
		E	E	E	E	E	E	X	E	E	E	E	E
		D-GDP$70	D-K$70	D-K/O	D-S/GDP	D-W/P	D-EMPL	D-POP	D-E	D-I/P	XDD	XLD	XCD
1973	1	2423.352	11459.364	4.729	0.200	1.114	103.981	782.900	0.914	0.060	230.218	48.467	9.693
1974	1	2521.010	11817.758	4.688	0.182	1.147	105.265	790.000	-46.394	0.060	239.496	50.420	10.084
1975	1	2625.158	12205.539	4.649	0.184	1.179	106.854	799.417	-40.790	0.060	249.390	52.503	10.501
1976	1	2736.324	12614.779	4.610	0.187	1.213	108.486	808.947	-34.761	0.060	259.951	54.726	10.945
1977	1	2855.093	13046.964	4.570	0.190	1.249	110.162	818.590	-28.262	0.060	271.234	57.102	11.420
1978	1	2980.453	13498.424	4.529	0.190	1.287	111.880	828.348	-28.321	0.060	283.143	59.609	11.922
1979	1	3112.834	13970.157	4.488	0.191	1.326	113.639	838.222	-28.427	0.060	295.719	62.257	12.451
1980	1	3252.705	14463.308	4.447	0.191	1.366	115.442	848.214	-28.583	0.060	309.007	65.054	13.011
1981	1	3398.520	14972.677	4.406	0.189	1.408	117.282	858.325	-37.267	0.060	322.859	67.970	13.594
1982	1	3550.479	15498.637	4.365	0.187	1.450	119.160	868.557	-46.741	0.060	337.295	71.010	14.202
1983	1	3708.776	16041.571	4.325	0.185	1.494	121.077	878.910	-57.054	0.060	352.334	74.176	14.835
1984	1	3873.369	16601.098	4.286	0.182	1.538	123.031	889.387	-69.248	0.060	367.969	77.467	15.493
1985	1	4044.410	17177.574	4.247	0.180	1.583	125.024	899.989	-82.373	0.060	384.219	80.888	16.178
1986	1	4222.100	17771.320	4.209	0.177	1.628	127.056	910.717	-96.480	0.060	401.099	84.442	16.888
1987	1	4406.603	18382.648	4.172	0.175	1.675	129.127	921.573	-111.621	0.060	418.627	88.132	17.626
1988	1	4600.886	19020.078	4.134	0.175	1.723	131.251	932.559	-116.984	0.060	437.084	92.018	18.404
1989	1	4805.573	19605.023	4.096	0.174	1.773	133.428	943.675	-122.633	0.060	456.529	96.111	19.222
1990	1	5021.332	20378.961	4.058	0.174	1.825	135.662	954.924	-128.588	0.060	477.027	100.427	20.085
1991	1	5248.882	21103.525	4.021	0.174	1.878	137.954	966.308	-134.868	0.060	498.644	104.978	20.996
1992	1	5488.997	21860.352	3.983	0.174	1.934	140.306	977.826	-141.495	0.060	521.455	109.780	21.956
1993	1	5742.510	22651.316	3.944	0.174	1.992	142.723	989.483	-148.492	0.060	545.538	114.850	22.970
1994	1	6010.318	23478.309	3.906	0.174	2.052	145.206	1001.278	-155.884	0.060	570.980	120.206	24.041
1995	1	6293.391	24343.418	3.868	0.174	2.114	147.758	1013.213	-163.697	0.060	597.872	125.868	25.174
1996	1	6592.771	25240.863	3.830	0.174	2.179	150.383	1025.291	-171.960	0.060	626.313	131.855	26.371
1997	1	6909.508	26197.025	3.791	0.174	2.246	153.083	1037.513	-180.704	0.060	656.411	138.192	27.638
1998	1	7245.062	27190.398	3.753	0.174	2.316	155.863	1049.881	-189.963	0.060	688.281	144.901	28.980
1999	1	7600.508	28231.742	3.714	0.174	2.388	158.726	1062.396	-199.774	0.060	722.048	152.010	30.402
2000	1	7977.357	29323.971	3.676	0.174	2.464	161.675	1075.060	-210.175	0.060	757.849	159.547	31.909

SOLUTION VALUES FOR A DYNAMIC SIMULATION FOR POTENTIAL GNP MODEL
FOR

	13	14	15	16	17	18	19	20	21	22	23	24
	E	X	E	E	E	E	E	E	X	E	E	E
	XD	TIME	L-GDPS70	L-KS70	L-K/O	L-S/GDP	L-W/P	L-EMPL	L-POP	L-E	L-I/P	XDL
1973 1	293.379	24.000	417.414	1357.363	3.252	0.274	1.205	111.357	1748.000	24.248	0.020	48.467
1974 1	313.605	25.000	454.450	1361.974	2.997	0.244	1.242	109.589	1793.200	17.432	0.020	63.025
1975 1	334.083	26.000	493.522	1429.387	2.896	0.229	1.264	112.829	1838.963	14.255	0.020	72.192
1976 1	355.986	27.000	534.400	1504.787	2.816	0.216	1.285	116.112	1885.893	10.779	0.020	82.090
1977 1	379.445	28.000	576.776	1588.411	2.754	0.202	1.307	119.440	1934.022	6.962	0.020	92.791
1978 1	404.381	29.000	618.329	1679.942	2.717	0.183	1.326	122.813	1983.379	0.053	0.020	104.316
1979 1	430.902	30.000	657.825	1779.439	2.705	0.162	1.343	126.231	2033.995	-7.900	0.020	116.731
1980 1	459.126	31.000	693.917	1886.990	2.719	0.141	1.356	129.697	2085.903	-17.003	0.020	130.108
1981 1	480.394	32.000	729.624	1995.444	2.735	0.134	1.368	133.210	2139.135	-21.123	0.020	135.941
1982 1	502.517	33.000	764.688	2104.459	2.752	0.126	1.378	136.771	2193.727	-25.610	0.020	142.019
1983 1	525.520	34.000	801.309	2214.799	2.764	0.126	1.389	140.382	2249.711	-26.723	0.020	148.351
1984 1	548.397	35.000	839.884	2315.537	2.757	0.127	1.405	143.043	2307.124	-27.872	0.020	154.934
1985 1	572.173	36.000	880.612	2417.981	2.746	0.127	1.421	145.754	2366.002	-29.059	0.020	161.776
1986 1	596.872	37.000	923.717	2522.308	2.731	0.128	1.437	148.517	2426.383	-30.282	0.020	168.884
1987 1	622.518	38.000	969.458	2628.697	2.712	0.128	1.455	151.333	2488.305	-31.540	0.020	176.264
1988 1	649.523	39.000	1018.109	2737.382	2.689	0.129	1.473	154.203	2551.807	-32.858	0.020	184.035
1989 1	677.975	40.000	1069.982	2848.620	2.662	0.129	1.493	157.126	2616.929	-34.240	0.020	192.223
1990 1	707.965	41.000	1125.437	2962.677	2.632	0.130	1.514	160.106	2683.714	-35.687	0.020	200.853
1991 1	739.595	42.000	1184.888	3079.837	2.599	0.131	1.536	163.141	2752.203	-37.201	0.020	209.955
1992 1	772.971	43.000	1248.815	3200.407	2.563	0.131	1.559	166.233	2822.440	-38.784	0.020	219.560
1993 1	808.209	44.000	1317.784	3324.718	2.523	0.132	1.584	169.384	2894.469	-40.438	0.020	229.700
1994 1	845.434	45.000	1394.237	3391.326	2.432	0.134	1.612	172.594	2968.337	-42.142	0.020	240.413
1995 1	884.781	46.000	1479.607	3461.329	2.339	0.135	1.644	175.863	3044.089	-43.887	0.020	251.736
1996 1	926.395	47.000	1575.740	3535.178	2.244	0.137	1.680	179.194	3121.775	-45.661	0.020	263.711
1997 1	970.433	48.000	1685.067	3613.438	2.144	0.139	1.721	182.587	3201.443	-47.446	0.020	276.384
1998 1	1017.064	49.000	1810.869	3696.844	2.041	0.142	1.768	186.042	3283.145	-49.215	0.020	289.802
1999 1	1066.471	50.000	1957.700	3786.368	1.934	0.145	1.824	189.562	3366.931	-50.925	0.020	304.020
2000 1	1118.853	51.000	2132.106	3883.351	1.821	0.149	1.891	193.146	3452.856	-52.512	0.020	319.094

(25)

SOLUTION VALUES FOR A DYNAMIC SIMULATION FOR POTENTIAL GNP MODEL
FOR

	25 F XCL	26 E XLL	27 E XL	28 E TDL	29 X TIME	30 E C-GDP$70	31 E C-K/O	32 E C-S/GDP	33 E C-W/P	34 E C-EMPL	35 X C-POP	36 E XDC
1973 1	5.426	14.609	68.503	0.000	24.000	1014.315	3.759	0.269	1.012	107.353	1165.000	14.693
1974 1	5.908	15.906	72.234	12.605	25.000	1091.873	3.786	0.269	1.013	110.274	1184.000	11.084
1975 1	6.416	17.273	76.192	19.689	26.000	1172.504	3.906	0.269	1.015	113.304	1202.940	12.501
1976 1	6.947	18.704	80.378	27.363	27.000	1256.302	4.024	0.268	1.016	116.402	1222.183	13.945
1977 1	7.498	20.187	84.787	35.689	28.000	1343.345	4.139	0.268	1.018	119.570	1241.733	15.420
1978 1	8.038	21.642	89.289	44.707	29.000	1433.710	4.252	0.268	1.019	122.810	1261.596	16.922
1979 1	8.552	23.024	93.832	54.475	30.000	1527.471	4.363	0.268	1.021	126.123	1281.777	18.451
1980 1	9.021	24.287	98.362	65.054	31.000	1624.697	4.473	0.268	1.022	129.511	1302.281	20.011
1981 1	9.485	25.537	102.992	67.970	32.000	1725.462	4.581	0.267	1.023	132.974	1323.113	21.594
1982 1	9.941	26.764	107.715	71.010	33.000	1829.833	4.687	0.267	1.025	136.515	1344.278	23.202
1983 1	10.417	28.046	112.638	74.176	34.000	1937.880	4.793	0.267	1.026	140.136	1365.782	24.835
1984 1	10.918	29.396	117.782	77.467	35.000	2050.155	4.877	0.267	1.028	143.838	1387.630	25.493
1985 1	11.448	30.821	123.158	80.888	36.000	2166.715	4.963	0.267	1.029	147.622	1409.827	26.178
1986 1	12.008	32.330	128.780	84.442	37.000	2293.042	4.849	0.267	1.031	151.490	1432.379	26.888
1987 1	12.603	33.931	134.666	88.132	38.000	2430.236	4.735	0.267	1.032	155.444	1455.292	27.626
1988 1	13.235	35.634	140.807	92.018	39.000	2579.547	4.620	0.267	1.033	159.486	1478.572	28.404
1989 1	13.910	37.449	147.471	96.111	40.000	2742.408	4.506	0.268	1.035	163.618	1502.224	29.222
1990 1	14.631	39.390	154.448	100.427	41.000	2920.466	4.392	0.268	1.036	167.841	1526.254	30.085
1991 1	15.404	41.471	161.852	104.978	42.000	3115.624	4.278	0.268	1.038	172.157	1550.668	30.996
1992 1	16.235	43.709	169.723	109.780	43.000	3330.085	4.164	0.268	1.039	176.568	1575.474	31.956
1993 1	17.131	46.122	178.104	114.850	44.000	3566.417	4.050	0.268	1.041	181.076	1600.676	32.970
1994 1	18.125	48.798	187.130	120.206	45.000	3827.620	3.936	0.269	1.042	185.684	1626.281	34.041
1995 1	19.235	51.786	196.889	125.868	46.000	4117.219	3.822	0.269	1.043	190.392	1652.296	35.174
1996 1	20.485	55.151	207.491	131.855	47.000	4439.379	3.708	0.269	1.045	195.204	1678.726	36.371
1997 1	21.906	58.977	219.075	138.192	48.000	4799.043	3.594	0.269	1.046	200.121	1705.580	37.638
1998 1	23.541	63.380	231.823	144.901	49.000	5202.116	3.480	0.270	1.048	205.145	1732.863	38.980
1999 1	25.450	68.520	245.980	152.010	50.000	5655.691	3.366	0.270	1.049	210.279	1760.583	40.402
2000 1	27.717	74.624	261.888	159.547	51.000	6151.000	3.353	0.270	1.051	215.524	1788.746	41.909

SOLUTION VALUES FOR A DYNAMIC SIMULATION FOR POTENTIAL GNP MODEL
FOR

	37	38	39
	F	E	E
	XLC	XCC	XC
1973 1	5.426	25.358	40.478
1974 1	5.938	27.297	43.289
1975 1	6.415	29.313	46.229
1976 1	6.947	31.408	49.300
1977 1	7.498	33.584	52.502
1978 1	8.038	35.843	55.803
1979 1	8.552	38.187	59.190
1980 1	9.021	40.617	62.649
1981 1	9.485	43.137	66.216
1982 1	9.941	45.746	69.889
1983 1	10.417	48.447	73.699
1984 1	10.918	51.254	77.666
1985 1	11.443	54.168	81.793
1986 1	12.008	57.326	86.223
1987 1	12.603	60.756	90.985
1988 1	13.235	64.489	96.128
1989 1	13.914	68.560	101.692
1990 1	14.631	73.012	107.728
1991 1	15.404	77.891	114.290
1992 1	16.235	83.252	121.443
1993 1	17.131	89.160	129.262
1994 1	18.125	95.690	137.857
1995 1	19.235	102.930	147.339
1996 1	20.485	110.984	157.840
1997 1	21.936	119.976	169.520
1998 1	23.541	130.053	182.574
1999 1	25.450	141.392	197.244
2000 1	27.717	153.775	213.402

This is, in fact a base line scenario; therefore, the script writers' choices for inputs need explanation. The estimate of τ_D and τ_L for 1973/74 are from observed data, as well as these can be estimated. They reflect the large increase in oil prices in 1974, following a general rise in basic commodity prices, against the developed countries, in 1973. The 1973 rises were on a modest scale. After 1974, there have been some further increases in oil prices, but not enough to protect OPEC (and developing countries, as a whole) against dollar depreciation, with inflation in the D area. We, therefore, bring up τ_L gradually after 1974 to show that the developing countries have not held to their maximum gains on terms of trade. The relative prices τ_D and τ_L should not be pure reciprocals of each other because this is a 3-area world, but they should bear approximate resemblance to a reciprocal relationship; therefore, τ_D is moved up to be closer to $1/\tau_L$.

The share of developed countries' GDP transferred to developing countries have rarely satisfied the latter's targets. In 1973, the bilateral accounts were in near balance; therefore, we gradually increased aid to a target of 2.0%. In 1977-78, it falls well below 2%, but that level is a maximum that OPEC pricing plus North-South dialogue seem capable of extracting. That governs our choice of 2.0 as an upper limit.

In 1973, the Soviet grain failure (of 1972) led to a large credit in trade with the D area. This was cut back to a more normal level of 1.0 billion (1970 dollars) and then increased in a gradual trend to a maximum of $10 billion.

Two equations appeared to need adjustment in order to set the solution off in the right neighborhood. The real wage rate in developing countries was estimated from a loose-fitting equation and started from a low value that did not pick up the jump in wages as OPEC funds flowed into the L area. We, therefore, added 0.2 to the index value of w/p. The scenario results for k_C showed a steady decline of the capital-output ratio. This is contrary to central planners' targets. We adjusted the equation upwards to reach a maximum of 5.0 by 1985, assuming that direct planning could achieve that add-on. This keeps the centrally planned economies on a plausible growth path with capital expansion.

The estimated expansion rate for the D area's GDP is 4.5%. This compares with an estimate of 4.6% in the whole period 1950-74. Starting from 1960, eliminating the period of reconstruction in Japan and Western Europe, the rate to 1974 was 4.8%; therefore, a significant slowdown is projected as compared with the period of fast growth, but the rate is projected to return to a longer run normal rate - not necessarily a reduced rate.

Much interest attaches to the growth rate estimate because it is generally felt that expensive energy, limits of exhaustible resources, and environmental problems may lead to a slow growth pattern for OECD countries, much below historical averages. This model simulation does not come near a rate as low as 4.0% for the rest of the century; it does indicate a slower rate for the post-embargo decade, 1973-83, at 4.3%, picking up slightly in the next decade.

The determinants of growth are the strategic ratios s and k. The former is limited in this model by E/Y. The terms of trade favoring OPEC vs. the OECD make s smaller than its long run average rate of about 0.20 and restrains growth, especially in this decade. Working against the lower value of s is a lower value of k, indicative of technical progress. A falling value of k makes for faster growth. Going further into the model we notice that a relatively high wage/capital rate would make for a larger value of k and slower growth. The falling value of k in the sample period 1950-74 amounted to a drop of 1.1 points. In the 24 years after 1974, the corresponding drop is not quite one full point.

The real resource transfer, shown by the variable E, is strongly negative for the entire simulation period. The terms of trade could reverse through political or economic developments. If so, the value of E could even change sign and bring up the savings rate to 0.2 or more. This would put the OECD area on a faster growth track again.

GDP in the L area expands by 6.2% in this scenario to the year 2000. This is a target of the United Nations and may seem to be quite favorable; however, their target refers specifically to the non-OPEC part of the developing world. OPEC nations are included in the L group and are expected to grow at a rate significantly in excess of 6%; therefore, the rate indicated here is slightly below target for the whole developing world. Historically they grew at 5.5% from 1960 up to the time of the high commodity prices and oil embargo of 1973. If we extend the historical period through 1974, the overall rate is about 6%. All in all, the scenario projection is modest for the less developed countries.

Their saving rate had been growing strongly in the 1960's and early 70's. It remains well above 0.20 in the scenario until 1977 and then falls fairly steadily through the 1980's, reviving a bit in the 1990's. The fall is induced by a decline in their E/Y value. The OPEC nations have already turned out to have a prodigious appetite for imports and are expected to continue buying abroad. Even though the terms of trade was estimated to remain in their favor, imports rise faster than exports at a rate that brings down E and the savings rate. This restrains growth.

The capital-output ratio falls, and this helps to maintain their growth rate. This rate rose in the 1960's and early 70's. The usual pattern, expected for the L area, would be an increasing k ratio as infrastructure investment is built up. It would then fall with technical progress after the initial build-up is completed. This pattern would induce slower growth, followed by faster growth. Our model pattern works out differently in the scenario. The estimated value of k falls by more than one full point in the 27 year period following 1973.

There is good growth in the real wage rate but much less than in the D group of countries.

The centrally planned economies are estimated to grow at 6.9%, somewhat higher than their historical performance since 1955, at about 5.55%. In the C area, the Eastern European countries in CMEA have consistently grown, as a group, at a rate above the Soviet Union's. Strong future growth of the CMEA group should help to maintain a fairly high growth rate for the whole C area, but it is necessary to consider the position of China, as well, in judging the overall plausibility of the area's growth rate. China had some years of very slow growth, thus holding down the historical rate, but there is every reason to believe that the China rate, now on a path above 7%, will continue to exhibit firm growth. For these reasons, we can accept the estimated results from the base case scenario as plausible.

Over the historical sample period, the savings ratio grew for the centrally planned economies; this promotes growth. There is a slight tendency for this ratio to grow in the scenario after the mid 1980's, but it sags up to that point. By and large, however, the ratio is nearly constant. The other key ratio, capital/output, would show a falling tendency, steadily over the scenario period were it not for the exogenous imposition of some early increases. The falling tendency is indicative of technical progress, but, as in the LDC case, we would first expect a rise prior to a fall. The rise would represent a continuing process of building up an infrastructure.

A marginal calculus of capital requirements does not seem to be appropriate for the model of the C area. We have used this calculus for specifying capital-labor substitution in the O and L areas. Instead of relying on the marginal calculus, we infused some arbitrary increments that would be typical of the central planning authority's goals for capital expansion. These were superimposed on the relation that made the capital/output ratio a function of shipments from the developed to the centrally planned areas. A significant part of their shipments will consist of capital goods flows. The other relationships in this model are largely trends in real wage rate and labor force participation. Neither of these plays a key role in the C model. The statistics on real wage in the centrally planned group are suspect as intuitive insight would suggest that historical gains in the real wage rate were higher than estimated.

Trade flows of the C area countries are heavily oriented toward the main developed area markets and developing country markets, too. We are assuming here that an attempt is made to keep bilateral flows in balance, but some slippage occurs as the USSR (and others) try to secure credits to import beyond the amounts determined by bilateral balance.

A strategic variable in the D area model is the rate of return on capital i (nominal) or i/p (real). For the scenario, following the Gibson Paradox, we made i/p fixed at 0.06. The sensitivity of the system to changes in i/p are shown by consideration of a drop to 0.055. In this case, GDP is a great deal lower by 2000. It is only $7365.1 billion compared with $7977.4 billion in the base case. The growth rate falls to 4.2%; this is significantly below the historical rate of 4.6%. It is through less manifest technical progress, i.e., a drop in the capital-output ratio, that the growth slowdown occurs.

GDP values in the L and C areas are greater by 2000 in this alternative case. In the developing countries, the capital output ratio is lower and the savings rate higher. These make for faster growth, reaching a final figure that is higher by 10%. Centrally planned GDP is also higher, but only slightly so.

If employment is adjusted somewhat higher in the D area in order to make the 1973-74 values line up better with observations, and if these adjustments are retained for the remainder of the horizon, there is more capital investment, a higher capital-output ratio, and a smaller GDP value for the D area. The developing country GDP value is slightly higher, but the C area value is practically unchanged.

Enhancement of the System

This has admittedly been a first attempt at building a self-contained global economic model with simulation capabilities to the end of the century. This aspect of the present study has already been noted in the opening pages. What are the next steps in making the system better suited to this end? A number of studies are already underway and others are contemplated.

The first study for system improvement is to re-evaluate the area totals, i.e., the developed, centrally planned, and less developed area aggregates of GDP, investment, trade, and related variables. The re-evaluation will be to substitute price conversion factors, drawn from the pioneering study of I. B. Kravis and associates,[1] for official exchange rates in making up cross-country aggregates in a common unit of measurement. In many respects, the

1. I. B. Kravis, A. Heston and R. Summers, International Comparisons of Real Product and Purchasing Power, (Baltimore: John Hopkins University Press, 1978).

Kravis factors are superior as descriptive measures, and it remains to be seen what effect their use has on econometric system properties.

Any long run model ought to treat population and associated demographic variables as endogenous. In the near future, equations for N_D, N_C, N_L will be introduced, together with other demographic variables that are needed in order to close the system. Interaction between demographic and economic variables will be introduced.

If the system is to be used for energy analysis, it is important to introduce energy trade explicitly in the world trade matrices. At the same time, area energy requirements and supplies should be modeled explicitly. It is quite possible that a separate OPEC grouping, as a component of the less developed area, will be needed. In any event, some energy modeling is called for.

It was shown above that estimates of trade in invisibles was implied, on a net basis, as a residual for each major area, by virtue of the standard national accounting identity. Direct estimation of invisible flows, preferably on a bilateral basis, would be a better approach for these items. The first thing to do would be to prepare a trade matrix of invisibles. Some data are available for this purpose, but it is certain that some heroic assumptions will have to be made in order to determine complete matrices of these trade items. Aspects of debt service will be included in the flows of invisibles, and this is an important process to analyze in long term simulations.

At the moment, it appears that energy trade is of crucial importance. It surely is, and will probably remain so for years to come; nevertheless, other primary commodities should also be given explicit attention. Primary products of agriculture and mines are particularly significant; therefore, trade matrices and associated bilateral flows of basic commodities, with market determined prices, should be introduced on both supply and demand sides. In keeping with the global nature of this system, it would seem best to start with trade in agricultural commodities and in mineral commodities.

The sample data used in this study extend through 1974. It took more than one year to prepare them, estimate and simulate the system. By now, new data are available. The underlying series should be revised and up-dated. Then the whole system should be re-estimated. As an alternative to the elementary time series estimation used for determining the numerical parameter values in the present study, it is sensible to experiment with another method of estimation, namely cross-section estimation. Within an area, say the D area, it would be possible to estimate the underlying relationships from cross-country variations. These should then be compared with the estimates obtained from time series variation. Or it would be possible to pool time series of cross sections in larger samples. At any rate, there is much scope for consideration of alternatives in estimation methodology.

At the same time the data are extended to more recent years, they can be reorganized for a more careful attempt to include all the elements of the savings-investment identity. A more faithful modeling of this identity to allow for depreciation and variation of k in computing net investment will be considered.

Finally, the convenient assumption that the terms of trade are exogenous - determined largely by OPEC decisions now - is not legitimate. In the long run, the variables τ_D, τ_L should respond to market prices. This is particularly true in non-energy markets. As the trade matrix is disaggregated, separate determination of terms of trade becomes more pressing.

The system was kept compact, partly for expositional reasons and partly for experimental reasons. An "explanation" of the world economy in just 35 equations is overdoing compactness. All the suggestions for elaboration, revision, and improvement of the system would add equations and make it larger. They would not, however, put the system beyond simplified analytical reach. Instead of being a very simple system, it would become a moderately small system of fewer than 100 equations. The programming and computer use would remain essentially minimal, nothing like the 5,000 equation LINK system in complexity of structure or difficulty of management.

(I) The Variables

The three region model is composed of three separate econometric models, one for each region, linked together via trade relationships. The structure of the model for each region is rather simple - a multiplier accelerator (or Harrod-Domar) model with trading relations.

The aggregate variables used satisfy the basic GDP definition as follows:

GDP = PC + GC + I + (X-M)

= C + I + (X-M)

= C + S

GDP = gross domestic product

PC = private consumption

GC = government consumption

I = gross investment or gross capital formation

X = export (goods/services)

M = import (goods/services)

C = consumption (equal to PC plus GC)

S = savings

The separation of government spending into consumption and investment was not always possible. This problem occurred most frequently in the case of developing countries.

The aggregate production function requires use of other variables of the regional economy, capital stock and employment or labor-force. If employment data are not available or not reliable, labor force data can be used.

Data of employment for some less developed countries are scanty. In order to maintain consistency in aggregation over countries, the working population is, in some cases, a preferable substitute for employment. This statistic is usually available.

Corresponding to the output and factor services supplied in the economy, there are three highly aggregate prices, namely, (1) the general price level of the economy which is estimated by the GDP deflator; (2) the wage rate and (3) the interest rate to show the return on capital.

The last variable in the list is the exchange rate. It is expressed in terms of local currency vs. the U.S. dollar. Using exchange rates to obtain internationally comparable data is subject to established arguments in the literature about purchasing power parity. However, the argument is not wholly applicable in our case, since only the base year's exchange rate is employed. Thus the problem boils down to a choice of which year is one of equilibrium for all countries. It is possible that a single year's base is not appropriate.

II. Data Sources

We restrict ourselves to some specific data sources in order to obtain maximum comparability and consistency.

The data are mainly from publications of the United Nations (UN); the World Bank (WB), the International Monetary Fund (IMF) and the International Labor Office (ILO). In addition to these, the data for centrally planned economies are taken from publications of U.S. government agencies and supplemented by works of individual research scholars.

Countries or areas are classified, in principle, according to the U.N. Statistical Yearbook (1976) for the purpose of foreign trade statistics, so that we can manipulate the international trade matrices easily without much adjustment due to misclassification of country. The composition of major areas and regions in the world are shown in Table 1, which combines economic, together with geographical classification, criteria. The number of countries or areas in each region for the present study's purposes is indicated separately in Table 2.

Data for the variables concerned are collected in the first step, country by country, from the stated sources. These are shown in Table 3.

Here it should be noted that, for the centrally planned economies, the market adjustment mechanism works differently. Therefore a kind of material product system which is apparently different from that in market economies is employed as their national accounting system. In that system, net material product used as an indicator of total output in the CPE, excludes most services, for example, a substantial portion of transportation, communication and government services. These services are thought to be non-productive, while in the national account statistics of the individual market economies, these are part of GNP or GDP. Furthermore, defense expenditures are located in accumulation and consumption accounts, for instance, in the USSR.

Because of these differences in the material product system prevalent in CPE's, different sources of data are employed so as to give rise to a set of roughly comparable data across regions.

The main sources for the CPE area are listed below:

(1) USSR - Wharton Economic Forecasting Associates, "SOVMOD III" (7/15/77)

(2) Eastern Europe - T.P. Alton "Economic Structure and Growth in Eastern Europe"; "Comparative Structure and Growth of Economic Activity in Eastern Europe" in the Joint Economic Committee's "East European Economies Post-Helsinki" (8/25/77) U.S. Congress

(3) China, People's Republic of - L. J. Lau, W.W.F. Choa, W.L. Lim and J.D. Shea "An Econometric Model of China" (Jan. 1978); CIA: "China: Economic Indicators" (Oct. 1977)

(4) Cuba - CIA - "The Cuban Economy, A Statistical Review, 1968-76"

The detailed source for each variable is indicated in Table 3 for CPE.

III. Aggregation and Aggregates

As our final interest is to set up a world model by integrating the separate macro models of each region through trade interrelationships, the raw material obtained from the various sources for each country has to be aggregated over constituent countries in each region to get the regional figures.

Before making the aggregation, we must note two major issues:

(1) Comparability and consistency of the data and of the calculation method

(2) The internal characteristic of individual countries in each region.

The source of difficulty in achieving strict comparability and consistency of the data base varies. It might be due to a different accounting system from which the data are generated. For example, for national income and product statistics, three basic systems are currently used. They are the U.N. System of National Accounts (SNA), the French System and the Material Product System (MPS). It might be due to different statistical bases on which data are collected. Three types of statistics are used among countries to construct employment data, according to ILO's Yearbook of Labor Statistics (1976), namely, statistics of compulsory social insurance, labor force sample surveys, and statistics of establishments. These are only examples of heterogeneity. The comparability of data is made worse by the differences between countries, and even within a country, as regards details of definition used, and methods of collection and tabulation.

Internal characteristics of each country can vary fundamentally. Some countries are industry-centered, others are agriculture-centered. Some are well endowed with resources,while others are poor. There are also differences in social cultural backgrounds.

To cope with the problems raised by the above differences, several rules of thumb are followed:

(1) We adhere to the same data source as closely as possible. We assume that each given source, to some extent, is consistent in the way it manipulates the data.

(2) If the consistency of data is questionable, then an index rather than the absolute figure for the variable concerned is calculated. The cases of wage and employment in indexes are two good examples.

(3) A proportional splicing method usually is used to get around the inconsistency due to changes of versions regarding the same data.

If time series of some specific variable have different figures resulting from changes of base coverage or concept, each version might end up with a different year as its base year. In this case, the following formula is applied to obtain a set of consistent series.

$$\frac{I_i^c}{I_i^p} \times I_j^p = I_j^c \qquad \begin{array}{l} i \neq j \\ i,j = 1, \ldots, t \end{array}$$

Where I^p denotes an index from the previous version, while I^c stands for the current version; and i and j denote different time periods. Specifically, j is the bridge year.

(4) The weighted average method is a handy way to take into account some of the internal characteristics of the individual country. The weight can be real GDP share, for instance, for calculating regional GDP deflators; or population share for wage indexes.[1]

By following these rules of thumb, we can hopefully obtain data with minimal distortions. Let us describe the regional aggregates.

In dealing with international data, exchange rates must come into play. We are mainly interested in economic relationships in real terms. The variation of exchange rates resulting from speculation in the foreign exchange market, or from domestic economic conditions should accordingly be factored out, as well as changes resulting from inflationary fluctuations in the world economy.

Therefore, all the macro variables are converted from current values in terms of local currency into constant priced values in terms of U.S. dollars. Here, two steps are involved in conversion:

(1) 1970 is the base year for our calculations, and the 1970 exchange rate is used. Since the base year should reflect a normal situation in the international economy, and the sample periods span 1950 - 74 for the D region, 1960 - 74 for L region and 1955 - 74 for the C region, 1970 is selected because it is well within the period and also widely used as a base year for U.N. statistics.

(2) The aggregate figures derived from 1970 exchange rates at current prices in U.S. dollars are deflated then by each country's own GDP deflator on a 1970 base to get the corresponding figures at constant prices in 1970 U.S. dollars.

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1. Population rather than employment share is chosen mainly because the availability of data is more frequent for the former than the latter; meanwhile, we assume that the labor participation rate stays fairly constant over time.

Figures of the regional aggregative variables, such as GDP, C, I, S, etc., for market economies are simply the summations of the corresponding figure over member countries of the same region.

The regional price indexes for these economies are derived in a specific way. All of them are the weighted average of the corresponding figures of individual countries. The only variation occurs in the weights used. The weights for regional GDP and wage rates are real GDP and population shares, respectively. Note that the weights vary over time. In deriving the regional interest rate, the weight is the real GDP of 1970 for all years of the sample period.

A particularly difficult aggregate to construct was capital stock. They were all calculated from the recursive formula.

$$K_t = K_{t-1} + I_t - D_t$$

The implementation of this formula required two parameters - the initial value of capital, K_o, and the rate of depreciation

$$D_t = \delta K_{t-1}$$

The initial value of K was computed for each region from an independent external estimate of the capital/output (incremental capital output ratio (ICOR)) ratio, given an associated value of GDP for the initial time period. It strains reliability to use the ICOR ratio for the capital output ratio becuase this proxy measure can sometimes be erratic. Its use results in rather high average values for the ratio. The depreciation rates were judgmentally set as follows:

δ = 0.10, D area

δ = 0.05, L area

δ = 0.07, C area

As noted above, data sources for the CPE are different from those for market economies; the aggregation procedure, therefore, is different. They are as follows:

(1) Since only indexes of GNP for given sources are collected, the regional GNP for CPE is derived in two steps. First, the weighted average of the corresponding GNP indexes of each CMEA country with 1970 real GNP as weight is calculated. We then used the CIA's estimates of real GNP for total CPE to convert them into absolute figures.[1]

(2) Except for the regional wage rate for CPE which is derived in the same way as for market economies, the other regional aggregates, such as S/GNP, I/GNP and the GNP deflator are the weighted average of the corresponding figure of each member country of CPE with 1970's real GNP shares as fixed weights.

The data on real wage rate for CPE show no growth from 1955 to 1974. In the middle of this series, there is a small decline and and recovery. One may well be suspicious of this time series pattern, but the average for the area comes from published U.N. series on industrial wage rates. These rates produce the (surprising) no-growth result. This is clearly a data problem of concern that merits additional research investigation.

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1. It is judged, after detailed comparison between Alton, CIA and World Bank estimates of real GNP for individual CPE countries, that CIA's estimates are most reliable on the grounds that (1) they are calculated on the basis of purchasing power parity, and that (2) the estimate for Hungary is much closer to what is shown in the International Comparison Project by Kravis, Heston & Summers. Hungary was one of the participating countries in this sample.

Table 1. ECONOMIC/GEOGRAPHIC COMPOSITION OF THE WORLD *

Developed Market Economies

Africa: South Africa

Northern America: Canada, United States; Bermuda, Greenland, St. Pierre & Miquelon

Asia: Israel, Japan, Turkey

Europe:

- EEC: Belgium, Denmark, France, Federal Republic of Germany, Ireland, Italy, Luxembourg, Netherlands, United Kingdom
- EFTA: Austria, Faeroe Islands, Finland, Iceland, Norway, Portugal, Sweden, Switzerland
- Other: Leichtenstein, Monaco; Andorra, Gibraltar, Greece, Holy See, Malta, San Marino, Spain, Yugoslavia; Channel Islands, Isle of Man, Svalbard & Jan Mayen Islands

Oceania: Australia, New Zealand

Less Developed Market Economies

Africa:

- Northern Africa: Algeria, Egypt, Libyan Arab Republic, Morocco, Sudan, Tunisia, Western Sahara
- Western Africa: Bernin, Cape Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, St. Helena, Senegal, Sierra Leone, Togo, Upper Volta
- Eastern Africa: British Indian Ocean Territory, Burundi, Comoros, Ethiopia, French Territory of the Afars & the Issas, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Reunion, Rwanda, Seychelles, Somalia, Southern Rhodesia, Uganda, United Republic of Tanzania, Zambia.
- Middle and Southern Africa: Angola, Central African Republic, Chad, Congo, Equatorial Guinea, Gabon, Sao Tome & Principe, United Republic of Cameroon, Zaire; Botswana, Lesotho, Namibia, Swaziland, French Southern & Antarctic Territories.

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*Countries without underlines are included in the data bank; while countries with one underline are those that are not included in the data bank though their GNP in U.S. dollars can be obtained from the World Bank Atlas; and countries with two underlines are all others.

EEC: European Economic Community
EFTA: European Free Trade Association
LAFTA: Latin American Free Trade Association
CACM: Central American Common Market

Source: "1976 Statistical Yearbook," United Nations, p. 9.

Table 1. (cont.)

America:

LAFTA: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay, Venezuela
CACM: Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua,
Caribbean America: Antigua, Bahama, Barbados, British Virgin Islands, Cayman Islands, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Netherlands Antilles, Puerto Rico, St. Kitts-Nevis-Anquilla, St. Lucia, St. Vincent, Trinidad & Tobago, Turks & Caicos Islands, United States Virgin Islands
Other Southern & Middle America: French Guiana, Guyana, Surinam; Belize, Canal Zone, Panama; British Antarctic Territory; Falkland Islands (Malvinas)

Asia:

Asian Middle East: Bahrain, Cyprus, Democratic Yemen, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Neutral Zone, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates, Yemen
Eastern Asia: Hong Kong, Macau, Republic of China, Republic of Korea
Southern Asia: Afghanistan, Bangladesh, Bhutan, India, Maldivers, Nepal, Pakistan, Sri-Lanka; Brunei, Burma, Democratic Kampuchea, East Timor, Indonesia, Lao People's Democratic Republic, Malaysia, Philippines, Singapore, Thailand; Palestine (Gaza Strip), Kymer Republic

Oceania:

Melanesia: New Caledonia, New Hebrides, Norfold Island, Papua New Guinea, Solomon Islands
Polynesia & Micronesia: American Samoa, Canton & Enderbury Islands, Christmas Islands, Cocas (Keeling) Islands, Cook Islands, Fiji, French Polynesia, Gilbert Islands, Guam, Johnston Island, Midway Islands, Nauru, Niue Island, Pacific Islands, Pitcairn Island, Tokelau Islands, Tonga, Tuvalu, Wake Island, Wallis & Futuna Islands, Western Samoa

Centrally Planned Economies

America: Cuba
Asia: Democratic People's Republic of Korea, Mongolia, People's Republic of China, Socialist Republic of Viet-Nam
Europe: Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, Union of Soviet Socialist Republics

Table 2. COMPOSITION OF DATA BANK AND THE WORLD

Developed Market Economies	Data Bank	The World
Africa	1	1
America	2	5
Asia	3	3
Europe	20	30
Oceania	2	2
Sub-Total	28	41
Less Developed Market Economies		
Africa	40	56
America	23	45
Asia	22	39
Oceania	2	26
Sub-Total	87	166
Centrally Planned Economies		
America	1	1
Asia	1	4
Europe & USSR	7	8
Sub-Total	9	13
Total	124	220

Table 3. REFERENCES FOR DATA

Variable	Observation Period	Title of Publication	Publisher	Reference Issue
GDP, GDP Deflator Private Consumption, Government Consumption & Gross Investment	1950-56	Yearbook of National Accounts Statistics	UN	"1957-58"
	1957-64	YNAS	UN	1965-66
	1965-74	YNAS	UN	1975
Imports & Exports*	1950-59	Statistical Yearbook	UN	1960
	1960-66	SY	UN	1968
	1967-75	SY	UN	1975
Exchange Rate	1950-60	Statistical Yearbook	UN	1960
	1961-67	SY	UN	1968
	1968-75	SY	UN	1975
Wage Rate	1950-57	Statistical Yearbook	UN	1958
	1958-65	SY	UN	1967
	1966-75	SY	UN	1975
Interest Rate	1950-57	Statistical Yearbook	UN	1958
	1958-62	SY	UN	1962
	1963-68	SY	UN	1968
	1969-75	SY	UN	1975
Population	1950-63	Demographic Yearbook	UN	1966
	1964-73	DY	UN	1973
	1974-75	DY	UN	1974-75
Employment Index and Employment Level	1950-54	Yearbook of Labor Statistics	International Labor Office	1957
	1955-59	YLS	ILO	1965
	1960-65	YLS	ILO	1970
	1966-75	YLS	ILO	1976
Capital/Output (Average ICOR)	(1968-73)	World Tables 1976	The World Bank	1976

(cont.)

* The regional figures are from UN's "Yearbook of International Trade Statistics, 1965 & 1975."

Table 3. REFERENCES FOR DATA (cont.)

Variable	Observation Period	Title of Publication	Publisher	Reference Issue
For CPE only *				
1. China GDP, Private Consumption, Government Consumption, Gross Investment, Population, Labor Force & Capital/Output	1950-74 (capital output ratio is for 1970)	"An Econometric Model of China"	L.I. Lau, W.W.F. Choa, W. L. Lin, & J.D. Shea	Jan. 1978
Imports & Exports	1950-74	"China: Economic Indicators"	CIA, USA	Oct. 1977
2. Cuba Index of Real GNP Population and Civilian Employment	1957-74 1955-74	"The Cuban Economy, A Statistical Review, 1968-76"	CIA, USA	
Net Material Product	1962-64	Yearbook of National Accounts Statistics	UN	"1965-66"
	1965-74	YNAS	UN	1975
S/NMP, I/NMP	1962-74	YNAS	UN	1975
3. Eastern Europe Real GNP Indices	1955-64	"Economic Structure and Growth in Eastern Europe"	T.P. Alton	
	1965-74	"Comparative Structure and Growth of Economic Activity in Eastern Europe"	T.P. Alton	
S/NMP, I/NMP	1962-74	Yearbook of National Account Statistics	UN	1975

(cont.)

* NMP deflator, wage rate, population except for China & Cuba, employment index and employment level from the same detailed source as for market economies.

Table 3. REFERENCES FOR DATA (cont.)

Variable	Observation Period	Title of Publication	Publisher	Reference Issue
4. USSR				
Real GNP, Private Consumption, Government Consumption, Gross Investment,	1955-74	SOVMOD III	Wharton Econometric Forecasting Associates	
GNP Deflator and Capital Output Ratio for 1970	1958-74			