CENTER OF PLANNING AND ECONOMIC RESEARCH

LECTURE SERIES

30

PROJECT LINK

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LAWRENCE R. KLEIN

ATHENS 1977

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Opinions or value judgements in this book are those of the author and do not necessarily represent those of the Center of Planning and Economic Research.

CENTER OF PLANNING AND ECONOMIC RESEARCH

The Center of Planning and Economic Research (KEPE) was founded in 1961 as an autonomous public organisation, under the title "Center of Economic Research", its basic objective being research into the problems of the operation, structure and development of the Greek economy. Another of its objectives was the training of young Greek economists in modern methods of economic analysis and research. For the establishment and operation of the Center considerable financial aid was provided by foreign foundations.

During 1964, the Center of Economic Research was reorganised into its present form, as the Center of Planning and Economic Research. In addition to its function as a Research and Training Institute, the Center, in its new form, was assigned the following tasks by the State: (1) The preparation of economic development plans at a national and regional level, (2) the evaluation of public investment programmes, and (3) the study of short-term developments in the Greek economy and advising on current problems of economic policy.

For the realisation of these aims, the KEPE, during its first years of operation (1961-1966) collaborated with foreign scientists and foundations. The latter helped in *the selection of foreign economists who joined the Center to carry out scientific research into the problems of the Greek economy and in the organisation of an exchange programme, including the post-graduate training of young Greek economists at universities abroad.*

The Center has also developed a broad programme of scholarships for post-graduate studies in economics. Thus, in collaboration with foreign universities and international organisations, a number of young economists from Greece are sent abroad each year, to specialise in the various fields of economics. In addition, the KEPE organises a series of training seminars and lectures, frequently given by distinguished foreign scholars invited for that purpose to Greece.

In addition to the above, the KEPE maintains contact with similar institutions abroad, and exchanges publications and information concerning developments in methods of economic research, thus contributing to the promotion of the science of economics in the country.

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The subject matter of this publication is based on a lecture delivered at the Center of Planning and Economic Research in June 1976.

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PROJECT LINK

The central research strategy of the project on the international linkage of national economic models (LINK) is to tie together, in a consistent way, the ongoing major macro-econometric models being used in each of the main countries or regions of the world, on the assumption that each model builder knows his own country (area) best. An alternative approach would be to construct a standardized (perhaps simplified) model for each country or region centralized in one research institute, and link them together by a given mechanism.

An American model for the US, a Canadian model for Canada, a Japanese model for Japan, etc., have formed the constitutent parts of LINK. The approach is so general that we have allowed some models to be annual and some quarterly; some to have large monetary sectors and some mainly real; some are demand oriented and some are supply oriented. The key to linkage was that in 1968, when the cooperative international study group was first formed, the trade accounts for each model would be designed along particular lines. Freedom in model structure ceases at this point.

Most national or regional models of this type that make up LINK treat imports and export prices as endogenous. Imports are demanded or required along the same lines that corresponding domestic goods/services are demanded or required. Export prices, for the most part, follow domestic costs as do other prices. The exceptions, for export prices, are world commodity prices, for which many individual countries are price takers or attempts by countries to remain competitive in pricing manufactures. Special treatment of the commodity price case will be taken up later.

In contrast to the endogenous treatment of imports and export prices, most national macroeconometric models treat exports and import prices as exogenous. Some models explain exports and import prices as functions of both endogenous and exogenous variables, but the latter are the more significant. The purpose of the LINK system is, in a sense, to endogenize exports and import prices. On a world scale both exports and imports (export prices and import prices) are endogenous. At a restricted country or regional level, a full endogenous explanation is not generally possible.

Let us assume that if exports and import prices are given for each country or region, the individual models can be solved. How does the world

(LINK) model determine exports and import prices? To answer this question, it is convenient to introduce the concept of a world trade matrix. A square array showing exports from country i (row) to country j (column) will be denoted

$$X = (x_{ij})$$

This can be converted into a trade shares matrix by dividing the entries by the j-th country's imports.

$$A = (a_{ij}) = (x_{ij} / x_{.j})$$

$$X \cdot j = \sum_{i=1}^{n} X_{ij}$$

Let E be a column vector of exports and M a column vector of imports. Corresponding prices are PE and PM.

By definition, we shall be able to show the relation between exports and imports as

$$\text{(1)} \qquad E = AM$$

If the column sums of A are each unity, by construction, we find that the generation of E from equation (1) guarantees that the world identity

$$(2) \qquad \sum_{i=1}^{n} E_i = \sum_{i=1}^{n} M_i$$

holds. This says that world exports equal world imports. This is a "law of conservation" or an accounting identity that takes account of the fact that somebody's imports are someone else's exports. This relation holds for subgroups of commodities as well as for total trade. Of course, all E_i and M_i have to be measured in common units — let us say, in constant US dollars. Valuations must also be identical, say, FOB. There may be some delays and discrepancies in valuation among countries; therefore (2) may not hold precisely, but with world totals in the neighborhood of $1,000 billion, the identity ought to hold within an error of about $1.0 billion.

A companion identity is given by

$$(3) \qquad (PE)' E = (PM)' M$$

This states that the nominal (dollar) value of world exports equals the nominal (dollar) value of world imports.

If we substitute from (1) into (3), we obtain

$$(PE)' AM = (PM)' M$$

This is an identity in M; hence term-by-term we have

$$(4) \qquad \sum_{i}(PE)_i A_{ij} = (PM)_j \qquad j = 1,2,\ldots,n$$

The two fundamental relations for endogenizing exports and import prices in the world economy are thus (1) and (4). We may call (1) the row problem or transformation, by which rows of A are used as weights to combine imports (endogenously generated in national models) and transform them into exports.

$$(5) \qquad E_i = \sum_{j=1}^{n} a_{ij} M_j \qquad i = 1,2,\ldots,n.$$

In (5), we use the i-th row of A to convert the vector M into the i-th element of E. Correspondingly, we call (4) the column problem or transformation, by which columns of A are used as weights to combine export prices (endogenously generated in national models) and transform them into import prices.

These are consistent transformations that preserve the world trade accounting identities in both current and constant prices.

The trade matrix A is assumed to be a set of technical parameters. If countries are involved, the diagonal elements are zero — a country does not trade with itself internationally. If regions are involved, intercountry trade, within the region, is entered on the diagonal. This approach is quite elegant and useful, but the problem is that A is not a constant matrix. It varies through time, and much of LINK research is devoted to attempting to project the elements of A directly or indirectly for their dynamic movement. There are great similarities between A and the matrices used in input-output analysis. The problem of allowing for changing trade shares is quite the same as the problem of allowing for changing technology in input-output analysis.

The LINK Matrix

The rows and columns of the LINK matrix stand for the individual countries and regional groupings. At this time, they are:

Australia (Reserve Bank of Australia Model)
Austria (Institute for Advanced Studies Model)
Belgium (Free University of Brussels Model)
Canada (Trace Model, University of Toronto)
Finland (Bank of Finland Model)
France (POM POM Model, Free University of Brussels)

Germany (Bonner Model, Bonn University)
Italy (Bologna Model, Istituto di Scienze Economiche)
Japan (Kyoto Institute of Economic Research Model)
Netherlands (Central Planning Bureau Model)
Sweden (National Institute of Economic Research Model)
U.K. (London Business School Model)
U.S. (Wharton Model)
Developing countries (UNCTAD Models)
Socialist countries (SOVMOD of Wharton EFA and Stanford Research Institute, CMEA Models of UNCTAD)
Rest of World (residual calculation)

This is an evolving system. Models are regularly being replaced or added. A new Swedish Model built at the Stockholm School of Economics is to be used soon in place of the present Swedish model. New models for the six CMEA countries outside USSR (Czechoslovakia, Bulgaria, East Germany, Hungary, Poland, Rumania) are being built by UNCDPPP. The USSR is separately represented in SOVMOD of WEFA/SRI. The developing world is modeled in four regions — Africa, Middle East, Latin America, and South/East Asia. OPEC and non-OPEC nations are treated separately in trade equations. Individual small models have been built for each of the

ROW countries, but these have not been fully introduced into the LINK solution yet. For trade purposes, China, Vietnam and North Korea are included in the socialist row and column of the trade matrix.

The regional models for developing countries are solved separately. Their exports and imports are added together (all in US dollar units) to obtain single area totals for the trade matrix calculations. Total exports are determined from the developing world component in (1), but the distribution among regions in the developing world is determined by the area models solved in satellite mode. The same procedure is used for the socialist countries and could be used for the ROW countries when centrally built models are introduced for them.

The matrix, therefore, consists of 16 rows and columns. It could be expanded into a larger matrix with separate representation for each of 12 ROW countries, but it will be difficult to make further disaggregation of the matrix for individual developing and socialist countries. It would be possible, but would require a great deal of work.

The latest period for which a matrix is fully available is 1971. In Table 1, the matrix is presented in current dollars (US). The data are made available in 10 SITC groupings at the

TABLE 1

TRADE MATRIX (b. $US)

YEAR 1971

SITC TOTAL

	AUSL	AUST	BELG	CANA	FINL	FRAN	GERM	ITAL	JAPA	NETH	SWED	U.K.	U.S.	DEVE	CMEA	ROW
AUSL	0.0	0.001	0.45	0.131	0.007	0.122	0.150	0.083	1.423	0.046	0.013	0.506	0.590	1.165	0.145	0.450
AUST	0.014	0.0	0.030	0.040	0.039	0.070	0.685	0.272	0.014	0.088	0.112	0.215	0.122	0.214	0.374	0.689
BELG	0.029	0.076	0.00	0.055	0.044	2.580	3.197	0.556	0.077	2.420	0.218	0.463	0.863	0.993	0.198	0.924
CANA	0.179	0.009	0.175	0.0	0.011	0.122	0.310	0.202	0.761	0.227	0.044	1.322	11.846	1.226	0.362	0.489
FINL	0.018	0.021	0.045	0.017	0.0	0.087	0.234	0.048	0.004	0.097	0.368	0.437	0.112	0.153	0.336	0.330
FRAN	0.063	0.146	2.169	0.209	0.075	0.0	4.132	2.123	0.147	1.095	0.240	0.868	1.040	3.731	0.806	2.404
GERM	0.272	1.718	3.115	0.392	0.409	4.561	0.0	3.090	0.488	3.915	1.246	1.467	3.526	4.352	1.569	6.383
ITAL	0.084	0.267	0.547	0.156	0.052	1.952	3.278	0.0	0.111	0.663	0.173	0.559	1.415	2.063	0.772	2.164
JAPA	0.736	0.040	0.221	0.848	0.049	0.185	0.636	0.189	0.0	0.352	0.128	0.554	7.371	9.359	1.113	1.489
NETH	0.058	0.116	1.881	0.082	0.087	1.373	4.471	0.695	0.072	0.0	0.281	0.965	0.535	1.175	0.259	1.044
SWED	0.081	0.128	0.215	0.105	0.440	0.354	0.781	0.203	0.069	0.307	0.0	0.945	0.462	0.604	0.321	1.978
U.K.	0.843	0.244	0.778	0.799	0.326	0.901	1.222	0.570	0.358	0.937	0.876	0.0	2.501	5.032	0.646	4.908
U.S.	0.974	0.096	1.020	9.826	0.083	1.310	2.708	1.259	3.837	1.701	0.452	2.235	0.0	12.877	0.366	3.345
DEVE	0.534	0.193	1.322	1.213	0.097	3.519	4.581	3.109	6.239	2.164	0.495	4.868	11.567	11.835	3.304	3.292
CMEA	0.099	0.364	0.220	0.103	0.507	0.610	1.360	0.890	0.826	0.282	0.335	0.924	0.240	4.424	21.249	1.797
ROW	0.251	0.478	0.505	0.300	0.249	1.320	2.750	1.316	0.657	0.660	1.293	3.996	2.254	3.321	1.469	2.294

one-digit level. They are regrouped for LINK calculations into the following categories :

SITC	0,1	food, beverages, tobacco
	2,4	basic materials
	3	fuels
	5-9	manufactures and other.

Valuations of exports and imports are both FOB.

Goods (merchandise) alone are included in the trade matrices, but total trade must be made consistent with the same concept that is used in the national income accounts because the macro models in LINK are all built around the NIA concepts, and that means exports/imports of goods and services. Service imports and exports must be added to the FOB goods totals, but there are no controlling accounting statements to show the bilateral flows of services. They must be determined separately from total relations of service flows for each country/region. There is no automatic procedure for equating world exports of services with world imports of services.

The goods groupings by SITC classes appear to bring a fair amount of detail into the analysis of trade; but in some economies, these groupings are too crude, especially in the broad grouping SITC 5-9. Trading relations for some countries are so specialized that equations for finer subgroups must be used in order to give economic meaning for analysis of the country's economy. To fit into the LINK system, however, it is only necessary to add together results from the more detailed equations to get estimates for the standard groupings used.

The LINK Algorithm

A standard procedure is used to solve the LINK system so that the world restrictions on equality between exports and imports are preserved. If each country specialist is left to his own information for making economic projections from solutions of his particular model, there is no mechanism for insuring that the total of exports will equal the total of imports. In fact, the usual situation is that countries/regions, as a whole, will expect to export more goods in the world economy than the same countries/regions will expect to import. It is not necessarily the case that exports so determined will exceed imports, but it usually works out that way.

To start a solution (projection or simulation) of the LINK model for the world economy, each individual model is solved by itself in pre-LINK mode; i.e., for given assumptions about the country's or region's exports and import prices. In a symbolic sense, we can express any endogenous variable of a model as a function; in reduced form, of exogenous inputs including exports and import prices.

$$M_i = f_i(E_i, PM_i, \ldots) \tag{6}$$

$$PE_i = g_i(E_i, PM_i, \ldots) \tag{7}$$

The pre-LINK solution of the model for country i will be determined on the basis of assumptions about exports and import prices, together with assumptions about other input values associated with domestic policies and other exogenous variables. These import values and export prices so determined from f_i and g_i for each country/region are then substituted into equations (1) and (4). The pre-LINK values are in own-currency units and must be converted at exchange rates into $US for use in (1) and (4). After values for E and PM are computed from these trade matrix equations, they are converted into own-currency units before being put back into individual models. It is generally the case that the values of E_i and PM_i will be different from those used in the original pre-LINK solutions.

This set of calculations will be iterated until the values of E_i and PM_i do not change from iteration to iteration. Actually, the convergence criterion is implemented on iterated values of $\sum_{i=1}^{n} E_i$ (total world trade). The equality between world imports and world exports is guaranteed by the structure of equations (1) and (4). This is a statement of the algorithm. It is portrayed graphically in Figure 1.

There is one major complication in the LINK methodology. It is implicitly assumed that the trade matrix A is constant. Over historical periods with some time delay, there is an annual observation of A_t, and we could use a different A_t for each year's solution, but in forecasting, it is not possible to know A_t in advance. Equation (1) is an identity if written as

$$E_t = A_t M_t$$

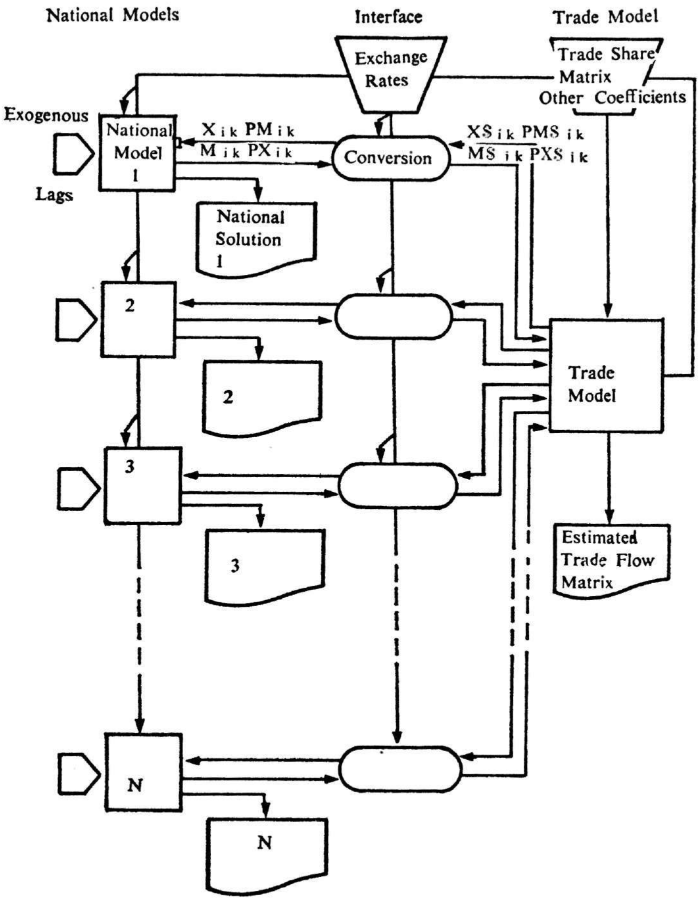
On the other hand, if a base period value A_0 is used, the equation must be

$$E_t = A_0 M_t + R_t$$

where R_t is a "residual" vector. There are two options for research: 1. Model the elements of A_t in order to project the whole trade matrix through time or 2. Model R_t to project the movements of total country exports through time. Both methods

FIGURE 1

SCHEMATIC DIAGRAM OF LINK SYSTEM



are being investigated within the LINK project.

It is easier, in a sense, to model R_t because there are fewer elements in R_t than in A_t. An obvious specification is to use principles of the linear expenditure system (LES). It has the property of preserving budget restrictions in consumer theory, and these can be immediately adapted to the preservation of the accounting identity between aggregate imports and aggregate exports. The LES also has the property of taking account, in a simplified way, of relative price effects on demand. In the present case, the analogous idea is to take account of relative changes in international prices to explain changes in trade. In particular, the changes that are associated with exchange revaluations, energy prices, food prices, and other raw material prices are important in the context of international trade analysis of the recent and present period.

Country i's exports can be computed from

$$(8) \qquad (PE)_{it}\, E_{it} = \alpha_i\, (PE)_{it} + \beta_i\, [A_{0i}\, (M\$)_t] - \gamma_i \sum_j \alpha_j\, (PE)_{jt}$$

In this equation, A_{0i} is the i-th row of the base period (0) trade shares matrix A_0, where A_0 is understood to be evaluated from current-priced trade flows. $(M\,\$)_t$ is a column vector of imports, evaluated in current US$. If $\beta_i = 1$ and $\sum_i \gamma_i = 1$, we have the full restrictions of the LES and the adding-up property holds

$$\sum_i (PE)_{it} E_{it} = \sum_i A_{0i} (M\$)_t$$

or

$$\sum_i (E\$)_{it} = \sum_i (M\$)_{it}.$$

The export equations are written in static form, but time trends for taste or technical changes and lags may be introduced in order to make the export side dynamic. In practice, we have usually estimated β_i by regression methods (slightly above or below unity) and γ_i (also by regression) by assuming an *a priori* weighting scheme for $\sum_i \alpha_j (PE)_{jt}$. The results show, empirically that the world identity holds within $1-2 billion in a total of $800-1,000 billion. In some special calculations, however, we have also estimated the LES system under full constraint. These constrained equations are presently being tested in the LINK system.

The Hickman-Lau method based on Armington's Constant-elasticity-of-substitution (CES) trade world comes to practically the same aggregate export equation, but estimates elasticity of substitution parameters from the moving time series sample of trade matrices. It uses some more bilateral trade information in its estimates before making a linear approximation and aggregation to a final export equation.

Hickman and Lau[1] index the quantity of imports for country j as

$$(9) \qquad X \cdot j = [\sum_{i=1}^{n} b_{ij} X_{ij}^{-\rho_j}]^{-1/\rho_j}$$

This is the CES formula. Cost minimizing quantities of bilateral import flows for given X.j are:

$$(10) \qquad \frac{X_{ij}}{X \cdot j} = b_{ij}^{\sigma_j} \left(\frac{P_i}{p_j m}\right)^{-\sigma_j}$$

where the import price index is

$$(11) \qquad P_j^m = [\sum_{i=1}^{n} b_{ij}{}^{\sigma_j} P_i{}^{(1-\sigma_j)}]^{1/(1-\sigma_j)}$$

$$\sigma_j = \frac{1}{1+\rho_j}$$

1. B.G. Hickman and L. Lau, "Elasticities of Substitution and Export Demands in a World Trade Model", *European Economic Review*, 4 (1973), 347-380.

The cost minimizing equations are estimated from pooled cross-section, time series samples to get estimates of σ_j for each country. Dummy variables for country designations are used to estimate different constant terms for each exporting country in the j-th market.

Their linear approximation to the export equation for the i-th country is:

$$(12) \qquad E_i = \sum_{j=1}^{n} a_{ij}^0 X \cdot j - (\bar{\sigma}_i E_i^0)(P_i - P_i^c)$$

a_{ij}^0 = base period trade share coefficient.

$$\bar{\sigma}_i = \sum_{i=1}^{n} \frac{X_{ij}^0}{E_i^0} \sigma_j$$

$$P_i^c = \sum_{i=1}^{n} \frac{\sigma_j}{\bar{\sigma}_i} \frac{X_{ij}^0}{E_i^0} p_j^m$$

In this form, the export equation is very close to the LES type. The first term on the right hand side is the base period weighted sum of partner country imports, with weights given by the i-th row of A_0. The next term shows the partial variation in exports as a function of the spread between export prices of country i and an average of other countries' prices. In the LES case, a price ratio would be used in place of a price difference.

Finally, direct modelling of the trade share coefficients has been proposed by Moriguchi.[1] His equations are

$$(13)\quad \ln a_{ijt} = \beta_i \ln \frac{(PE)_{it}}{(PCE)_{it}} + \gamma_i \ln \frac{(EC)_{it}}{M_{jt}} + \sum_{k \neq i} (\alpha_{ik} + \delta_{ik} Q_t) Q_{kt}$$

a_{ijt} are real trade share coefficients.

$$(PCE)_{it} = \sum_{k \neq i} w_{kj} (PE)_{kt}$$

$$w_{kj} = \frac{a_{kj0}}{\sum_{k \neq i,j} a_{kj0}}$$

EC = export supply capacity (fitted trend)

$Q_t = 1$ after 1965; otherwise zero

$Q_{kt} = 1 \qquad k = j$

$\quad\; = 0 \qquad$ otherwise.

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1. Chikashi Moriguchi, "Forecasting and Simulation Analysis of the World Economy", *American Economic Review, Papers and Proceedings*, LXIII, (May, 1973), 402-409. The Moriguchi model presented here is an updated version.

The period-to-period variation of a_{ij} thus depends on relative sizes of E and M and on relative prices, PE compared with PCE. The dummy shift variables denote country of destination. A pooled cross-section, time-series sample as in the case of Hickman and Lau is used for estimation. They can also be dynamized by the introduction of trends and lags. These are the three main linkage mechanisms being used or investigated in the LINK system:

LES
Hickman-Lau
Moriguchi.

Other approaches have also been suggested.[1] They all have similar objectives, but use more or less of the trade matrix data available.

Some LINK Applications

The most straightforward case of LINK system application is simulation of the model—either over an historical period or into the future in genuine forecast applications. Both applications have been made extensively but it may be more interest-

1. Kanta Marwah, "A World Model of International Trade, Forecasting Market Shares and Trade Flows", *Empirical Economics*, 1 (1, 1976), 1-39.

ing to explain the procedure of forecast simulation into the unknown future. Customarily, the model has been projected three years into the future, but the system simulation from which the calculations have been made has been either four or five years in duration. There is no reason to stop at the three year forecast horizon, other than the amount of work to be done in assembling input values, accordingly, a "stretched" simulation for another 3-8 years is described in a subsequent section.

Towards the end of a calendar year, all LINK model proprietors are requested to send new input values for the year just completed (not fully known in economic reporting detail at the time) and for three future years. The inputs consist of initial conditions (lagged values of variables), future values of exogenous variables, and any equation changes since the last LINK solution. They are sent by card deck, tape, or telex listing of input changes. Every separate model is solved in pre-LINK mode at LINK Central (Philadelphia) to see if the model proprietor's solution can be duplicated. A complete listing of pre-LINK solutions is presented to all participants, at an international meeting in March. There may also be a first attempt at full post-LINK simulations. The main point is that all model proprietors see the whole range of country/area results all at once. After the March meeting, the post-LINK simulations are revised with reconsidered input values and adjustment to new readings on the economy. Another round of forecast critique occurs at the end-of-summer meeting (August-September) and a final post-LINK simulation is issued during the closing months of the year. At that time, a new three-year forecast cycle begins.

International trade data are reported with considerable time delay; therefore, at the time the first calculations are being made in a forecast round for years t, $t+1$, $t+2$, only scattered information is available for $t-1$. The first step in a LINK forecast simulation is to solve the system for year $t-1$; i.e., a 1975 solution in early spring 1976. Broad features for the economy of $t-1$ are known. The largest countries have up-to-date reporting systems. Each separate model is adjusted, with add factors in some leading individual equations, to come as close as possible to correct or plausible values for $t-1$ (occasionally for $t-2$ as well). Unless there is firm evidence of a very temporary disturbance, the add factors are left at values set in $t-1$ and kept as "exogenous" input for t, $t+1$, $t+2$. Once a solution for $t-1$ is obtained, the dynamic sequence of solutions for the future years follows fairly quickly. At the time the forecast is first made for year t, some months of the year may have already elapsed, but very little is known on a quantitative level for the whole world economy at that time. As the year progresses and the solution continues to be refined, some preliminary indications of the year's outcome are accumulated, but they are not fully known until $t+1$.

The LINK system consists of some 5,000 equations, and it is hard to summarize it in just a few variables. Records of LINK performance have been made for the past six years in terms of main world, country, or region magnitudes. These consist of world trade, world GDP growth, world inflation, and the same variables for individual countries or regions.[1] To summarize the main results of these retrospective error analyses, let me say

The system has been perceptive in picking out the main movements in total world trade.

Forecasts of volume have been better than forecasts of price movements.

World and country GDP movements have been reasonably well forecast, especially some of the recession-recovery effects of 1974-1975.

Individual trade flows have been estimated with

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1. L. R. Klein, "Five-year Experience of Linking National Econometric Models and of Forecasting International Trade", *Quantitative Studies of International Economic Relations*, ed. H. Glejser (Amsterdam: North-Holland, 1976); Keith Johnson and L.R. Klein, "Error Analysis of the LINK Model (3rd World Congress of the Econometric Society, Toronto, Canada, August, 1975, LINK Working Paper ≠7 (LINK Central: Economic Research Unit, University of Pennsylvania, Phila, Pa., 19174).

fair accuracy, but estimates for some large regional groupings have been poor.

The main imbalances, especially some that are persistent, have been indicated in advance.

Following a LINK forecast meeting during March, 1976, the central secretariat distributed in July 1976, some post-LINK projections for 1974-1978. The historical years 1974-1975 were used for lining up LINK system relationships so as to reproduce, approximately, the main economic magnitudes. The system, so tuned, was then extrapolated to 1976-1978. It may be useful to summarize here the main results of the forecasting exercise, although the projection will be revised for the September, 1976, meetings of LINK.[1]

There is a very definite story to this forecast.

(i) World inflation is projected to decline gradually. This holds both for world export prices and world GNP (GDP) deflators. The former is a dollar denominated index and the latter in own-currency units. This has been a familiar LINK forecast position since 1974 and is basically working out in that way.

(ii) World trade, after falling in real terms

1. The division of the change in world trade at current prices into a volume component and price component was changed so that volume was projected to grow relatively more strongly in 1976. Also, the strong rate of growth for 1978 in world trade was scaled down slightly, while 1976 and 1977 were raised.

TABLE 2

MAIN WORLD AGGREGATES

	1975	1976	1977	1978
World trade (bil. curr. $)	858.3	951.3	1075.5	1237.8
World export price (1970 : 100)	2.144	2.282	2.416	2.504
(% Change)	(6.1)	(6.4)	(5.9)	(3.6)
World trade (bil. 1970 $)	400.3	416.9	445.2	494.3
(% Change)	(–5.0)	(4.1)	(6.8)	(11.0)
GNP(GDP) (% Change)	–0.22	5.51	5.52	5.17
Deflator GNP* (GDP) (%Change)	10.5	8.1	7.2	5.9

* Main OECD (LINK) Countries only.

1974-1975 (a most unusual event) is expected to recover significantly and improve year-by-year over the forecast horizon. By 1978, world trade is projected to return to the vigorous growth path that it had enjoyed before 1973. This is a hopeful sign for the world economy.

(iii) World production paused in 1975, with practically no change. There was a serious recession throughout the industrial (OECD) world. Its effect was felt in the developing world, and the Soviet grain failure contributed much to a poor showing in the Socialist world. The poor Soviet performance was factored into LINK forecasts during summer 1975, partly as a result of discussion at the annual LINK meeting. The world recovery in production is strong but shows a tendency to slow a bit by 1978, subject, of course, to a generous allowance for forecast error.

This world summary, useful and indicative as it is, covers up a great deal of variability among countries or regional areas. Some output, inflation, and trade projections are given for individual models in Table 3. Trade deficits for Italy and US persist in spite of currency devaluations. Also, France shows a tendency to develop a trade deficit. The German and Japanese surpluses are noteworthy, as is the tendency of the US balance to move towards surplus after experiencing a deficit in 1976.

TABLE 3

LINK PROJECTIONS 1975-1978

	1975	1976	1977	1978
Australia				
Exports (FOB goods, b$)	11.7	11.3	13.0	15.2
Imports (FOB goods, b$)	9.0	10.9	12.2	14.3
GDP (b 1966-67 A$)	32.0	33.5	35.9	37.7
Deflator GPD (1966-67 : 1.0)	1.943	2.215	2.501	2.851
Austria				
Exports (FOB goods, b$)	7.2	8.5	9.2	10.8
Imports (FOB goods, b$)	8.7	10.2	9.9	11.6
GNP (b 1964 AS)	358.3	373.7	386.8	410.2
Deflator GNP (1964 : 1.0)	1.803	1.939	2.094	2.243

TABLE 3 (cont'd)

Belgium				
Exports (FOB goods, b$)	27.9	32.3	35.1	40.6
Imports (FOB goods, b$)	29.5	33.7	35.4	38.2
GNP (b 1961 BF)	1131.6	1153.0	1200.1	1255.5
Deflator GNP (1961 : 1.0)	8.232	9.184	9.902	10.608
Canada				
Exports (FOB goods, b$)	33.3	36.6	42.7	49.9
Imports (FOB goods, b$)	34.8	36.5	42.3	49.3
GNP (b 1961 C$)	78.4	80.8	85.9	91.9
Deflator GNP (1961 : 1.0)	1.932	2.108	2.206	2.284
Finland				
Exports (FOB goods, b$)	5.1	6.0	6.6	7.8
Imports (FOB goods, b$)	6.7	7.0	7.1	7.6
GNP (b 1959 FM)	32.7	33.0	34.0	34.9
Deflator GNP (1959 : 1.0)	3.029	3.339	3.610	4.116

France				
Exports (FOB goods, b$)	50.5	53.6	57.3	66.7
Imports (FOB goods, b$)	47.4	54.5	64.7	75.6
GDP (b 1963 F)	659.2	691.2	741.3	789.4
Deflator GDP (1961 : 1.0)	1.850	2.037	2.209	2.337
Germany				
Exports (FOB goods, b$)	89.4	99.1	108.9	123.8
Imports (FOB goods, b$)	70.9	75.3	83.1	99.6
GDP (b 1962 DM)	565.4	600.6	630.1	671.8
Deflator GDP (1962 : 1.0)	1.704	1.805	1.887	1.995
Italy				
Exports (FOB goods, b$)	34.3	40.9	43.5	48.9
Imports (FOB goods, b$)	40.6	43.8	47.5	51.2
GNP (tr 1965 L)	49.9	51.2	52.7	55.3
Deflator GNP (1963 : 1.0)	2.419	2.773	3.092	3.280

TABLE 3 (cont'd)

Japan				
Exports (FOB goods, b$)	55.3	61.9	75.2	89.4
Imports (FOB goods, b$)	49.0	50.8	65.3	76.9
GNP (tr 1965 yen)	91.0	98.6	105.9	112.7
Deflator GNP (1965 : 1.0)	1.578	1.735	1.905	2.066
Netherlands				
Exports (FOB goods, b$)	35.7	38.0	40.5	46.0
Imports (FOB goods, b$)	33.8	39.4	41.8	45.1
GNP (b 1963 fl)	97.4	101.5	105.9	113.0
Deflator GNP (1963 : 1.0)	2.169	2.272	2.406	2.524
Sweden				
Exports (FOB goods, b$)	16.5	18.9	20.6	24.3
Imports (FOB goods, b$)	15.8	18.6	20.7	22.6
GDP (b 1968 SK)	172.9	175.9	178.6	185.7
Deflator GDP (1968 : 1.0)	1.594	1.730	1.893	1.969

U.K.				
Exports (FOB goods, b$)	43.8	51.5	60.7	71.3
Imports (FOB goods, b$)	49.4	59.5	62.0	76.2
GDP (b 1970 £)	46.7	48.4	50.0	51.5
Deflator GDP (1970 : 1.0)	1.998	2.289	2.546	2.659
U.S.				
Exports (FOB goods, b$)	106.1	108.1	133.3	155.1
Imports (FOB goods, b$)	96.1	110.7	127.0	144.7
GNP (b 1958 $)	797.3	844.8	891.0	928.6
Deflator GNP (1958 : 1.0)	1.854	1.970	2.093	2.205
LDC				
Exports (FOB goods, b$)	201.3	216.6	242.7	273.4
Imports (FOB goods, b$)	179.2	193.5	227.3	261.7
GNP (b 1960 $)	360.6	376.0	396.7	418.3
CMEA				
Exports (FOB goods, b$)	77.6	96.7	108.3	126.1
Imports (FOB goods, b$)	82.9	99.0	112.4	129.8
Net Material Product USSR (b 1963 $)	223.1	235.1	246.9	259.2
Net Material Product other CMEA (b 1963 $)	220.6	236.9	253.4	271.1

A pattern of early strong growth in US, Japan, Germany for 1976 is supplemented by later strong performance in Canada, France, Italy, Netherlands. The UK remains on a moderate growth path for the duration of this simulation. The developing countries gradually pick up towards their established growth targets after the slow down in 1975-1976. The Soviet Union is also expected to perform closer to growth potential after the set back from the poor harvest of 1975.

The tendency towards improvement on the inflation front is seen to be pervasive across countries.

This example is a straightforward case of pure forecasting. A greater application potential is in the area of alternative simulations. Over the past several years, the LINK system has been used to study:

exchange rate alternatives
synchronized business cycle movements
different (lower—towards 1973 values) oil prices
alternative fiscal policies in the U.S.
transfers to developing countries

Some of these have been reported in the second LINK volume.[1]

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1. *The Models of LINK*, ed. by J. Waelbroeck, (Amsterdam: North-Holland, 1976). See also, K. Johnson and L.R. Klein, "LINK Model Simulations of International Trade: An Evaluation of the Effects of Currency Realignment", *Journal of Finance*, XXIX (May, 1974), 617-30, and *Economic Report of the President*, (Washington, USGPO, 1976) p. 1935.

New LINK Horizons

Over the years of Project LINK development since 1968, deficiencies in the system have been pointed out, only to spur research proposals for remedying the situation. Year by year, research along the lines of improving the system are brought to fruition. The areas of investigation are:

1. Introduction of more models, especially for ROW countries and Socialist countries.
2. Integration of commodity models in the LINK system.
3. Addition of capital flows to the present analysis of trade flows.
4. Stretching the time horizon of extrapolation simulations.

In the early years, new models were added to the LINK system, particularly for France and Italy, where there were no ongoing econometric model projects that would have provided suitable participants. Substantial French and Italian models are now in LINK, although it is hoped that a French domiciled model will eventually become available. Models for Austria, Australia, and Finland were gradually added in the formative years. In the future, more countries now classified in the ROW group will eventually appear with explicit models. In fact, a moderate sized model of each

ROW country is now available, and these will be entered in due course, but some larger models from specific ROW countries will be included, too. The same is true of LDC countries, that are now covered up in regional model groupings.

A major step has just been taken with regard to the modelling of socialist countries. The large scale model of the Soviet Economy (SOVMOD II) that has been built by Wharton EFA, Inc. and Stanford Research Institute has been fully linked to the system. Pre-LINK solutions of SOVMOD II have been consulted for some time in judging socialist area results, but it is only in recent months that SOVMOD II has been made part of the system. Work is under way to build in separate models for the other socialist countries in a similar way. Models are available from the UN for East Germany, Poland, Czechoslovakia, and Hungary. Soon, we expect to have models for Bulgaria and Rumania, as well.

We have the capability of working with a larger trade matrix to devote separate rows and columns to each ROW country, but the socialist and developing countries are represented by two row-column pairs, and it is unlikely that individual rows and columns can be prepared in the near future for the separate socialist and developing countries.

Commodity models are important in the context of LINK for determining prices of basic materials that are widely traded on world markets. In the endogenous explanation of export price in separate LINK models, it is only partly true that internal or domestic costs and capacity pressures determine export prices. In many cases, countries act as price takers on world markets for the major grains, tropical foods, fibers, metals, and other industrial materials. These prices, together with world demand factors, determine export earnings. It has proved easy enough to use LINK output to determine world demand and use that as input in world commodity models, but the feedback from the balance of supply-demand conditions to the functioning of country models is just being developed and programmed into the LINK system. There will have to be some iterations, back and forth, between the commodity and country models of LINK. It is entirely possible that first results in a feedback mode will become available in 1976.

The balance of payments statement contains the balance of trade as a subgrouping. In a world of floating rates it is more urgent than ever to extend quantitative international economic analysis from trade to payments.

For an individual economy, a basic identity is

$$(PE)E - (PM)M - TR + NSK + NLK = \Delta R$$

$(PE)E$ = current value of exports

$(PM)M$ = current value of imports

TR = remittances and transfers
NSK = net short term capital inflows
NLK = net long term capital inflows
R = reserves

The trade balance (goods and services) is given by the first two terms. If remittances and transfers are subtracted (-TR) from the trade balance, we obtain the balance on current account. To this, we add *net* capital inflows on both short (NSK) and long (NLK) term to complete the payments balance. The payments balance will cause reserves to rise, if positive, or fall, if negative. Errors and omissions will naturally throw off this identity, but we are assuming full and accurate measurement.

Equations must be developed for TR, NSK and NLK. The change in reserves will be determined by the identity. TR will depend on incomes earned domestically and needs in the countries of destination. Such equations will not be easy to construct. As for the grants part of TR, they should probably be treated as exogenous.

Capital flows, short or long, will depend on interest rates at home and abroad, the latter being represented in many cases by the Euro-dollar rate. These flows will also depend on the current account balance, relative growth rates, relative inflation rates, and exchange rates among other possible variables. The main point for model design is that the explanatory variables for capital flow equations should be variables that are generated elsewhere in the LINK system. This property will necessitate a financial module in the separate LINK models. At the present time, only about one-half the models have financial sectors.

Assuming that reasonable equations for TR, NSK, and NLK can be developed, what can be done with them? The determination of ΔR from the identity provides us with an important determinant of money supply. In many countries, but not all, money supply will depend on the net foreign balance and the net domestic balance. Internal surpluses or deficits are generated in the typical model. If the external surplus or deficit can also be generated, we then can relate money supply to these two bases. In a country like the United States, monetary authorities can affect money supply independently of ΔR, but this is not possible in countries with limited markets for public securities. But if money supply is to be determined on a comprehensive basis throughout the world, it will be necessary to know ΔR, country by country.

Finally, the balance between demand and supply of a nation's currency will determine movements in the exchange rate; so the end of the process should be an attempt to endogenize the exchange rates within the world LINK system. This is the potential pay-off in this long line of research that lies ahead in augmenting the trade flows of LINK by adding capital flows to the system.

The fourth area of LINK system enhancement is the time horizon for simulation, particularly extrapolation simulation into the future. At an early stage of LINK research there were programming difficulties in constructing multiperiod simulations. These were purely technical matters of storage facilities and programming effort. At the present time, there is no effective limit on the number of time periods in the span of a simulation. The only limitation is in the set-up and filling in of exogenous inputs over the span of the simulation. This is no problem when simulating historically over the sample period, because each model's data file is on a disc file and can be accessed automatically for purposes of withdrawing exogenous inputs over several years.[1]

There is a big difference between simulating history and projecting possible future scenarios. In the latter case, it is necessary to prepare extensive lists of exogenous inputs for each of several models. It is a major task to do this for the typical 3-year horizon of LINK and has not been undertaken on a system-wide basis to 1980 or 1985.

1. See K. Johnson and L.R. Klein, "Error Analysis of the LINK System", *op. cit.*

In the formative stages of the LINK project, there were urgent pleas from some quarters, especially developing and socialist countries, to try to simulate for longer run periods, say to 1980 or 1985. With the advent of major disturbances — Smithsonian agreement, harvest failures, oil embargo, world recession cum inflation — interest focussed keenly on the short run. The three-year horizon still retains its attraction, but as world economic events have calmed a bit, attention has shifted again towards somewhat longer run simulation calculations.

In order to save computer costs and to get round the chores of making up long series of exogenous inputs, we have developed a shortcut approach to stretching the LINK time horizon. The method works through a reduced-form trend approach. It is assumed that, notionally speaking, there exists for each model a set of reduced-form equations.[1]

$$
\begin{aligned}
&(14) \qquad M &= f_M\,(E, PM, t)\\
&(15) \qquad PE &= f_E\,(E, PM, t)\\
&(16) \qquad GNP &= f_G\,(E, PM, t)\\
&(17) \qquad P &= f_P\,(E, PM, t)
\end{aligned}
$$

These equations imply that if total exports, aggregate import price, and time trends (surrogate for

1. See equations (6) and (7) above.

smooth development of other exogenous variables), are given, we can find a solution for the unlinked version of each model by itself. We then proceed to try to estimate these equations f_M, f_E, f_G, f_P by using system properties. We systematically shock a model in pre-LINK mode by changing E or PM and compute the corresponding values for the left hand side variables. This is a typical *multiplier* calculation, and we compute multipliers as

$$\frac{\Delta M}{\Delta E}, \frac{\Delta M}{\Delta PM}, \frac{\Delta PE}{\Delta E}, \frac{\Delta PE}{\Delta PM}, \frac{\Delta GNP}{\Delta E},$$

$$\frac{\Delta GNP}{\Delta PM}, \frac{\Delta P}{\Delta E}, \frac{\Delta P}{\Delta PM}.$$

We form the linear approximations

$$M = \left(\frac{\Delta M}{\Delta E}\right) E + \left(\frac{\Delta M}{\Delta PM}\right) (PM) + \alpha_0 + \alpha_1 t$$

$$PE = \left(\frac{\Delta PE}{\Delta E}\right) E + \left(\frac{\Delta PE}{\Delta PM}\right) (PM) + \beta_0 + \beta_1 t$$

$$GNP = \left(\frac{\Delta GNP}{\Delta E}\right) E + \left(\frac{\Delta GNP}{\Delta PM}\right) (PM) + \gamma_0 + \gamma_1 t$$

$$P = \left(\frac{\Delta P}{\Delta E}\right) E + \left(\frac{\Delta P}{\Delta PM}\right) (PM) + \delta_0 + \delta_1 t$$

We fix the first two coefficients on the right hand side of each approximation from the multiplier results and estimate the next two from a trend regression. In place of using the whole country model with exogenous input values in the usual post LINK solution, we use the above reduced-form approximations. The only input needed is t. After M and PE are generated from initial assumptions about E and PM, we pass the results through the usual LINK algorithm and iterate until world trade value converges. After a convergent solution is found for trade values and prices, we compute GNP and P from the corresponding reduced form approximations. Extensions to other model variables besides GNP and P can easily be made. The calculations are made, naturally, by separate SITC groups for all the trade values and prices.

In some cases, good multiplier estimates have not been obtainable. We have then estimated the approximate reduced-form equations by straightforward applications of regression methods.

No attempt is made in this short cut procedure to capture short-run business-cycle movements. The aim is only to extrapolate the main trend component of the simulation. The reduced-form equations are introduced at the end (last period) of a regular full LINK solution. The equations are adjusted so that they reproduce the same results across countries or regions for the trade, GNP, and price variables. The adjusted system for reduced form is then extrapolated further into the future with the objective of capturing trend results in world trade.

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