The Inforum-IIASA International System of Input-Output Models

Almon, C.

IIASA Working Paper

WP-79-022

March 1979

Almon, C. (1979) The Inforum-IIASA International System of Input-Output Models. IIASA Working Paper. WP-79-022

THE INFORUM-IIASA INTERNATIONAL SYSTEM OF INPUT-OUTPUT MODELS

Clopper Almon

March 1979
WP-79-22

Prepared for the Seventh
International Conference
on Input-Output Techniques
Innsbruck Austria, 9-13 April 1979

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

THE INFORUM-IIASA INTERNATIONAL SYSTEM OF INPUT-OUTPUT MODELS

ABSTRACT

Today's economies depend heavily on one another through international trade. To model them properly, the models need to depend on one another. For the models to work together, they must observe similar conventions for input and output of data, and ways of specifying alternative futures must be similar. At the same time, economies are very different and the models describing them must have much freedom for diversity in internal structure.

These simple ideas are the foundation of a gradually evolving consortium of input-output models and their builders. By working together, much time can be saved by avoiding repetitious programming and very little freedom lost in model specification. What could never be done by one group may perhaps be accomplished together.

Models are presently available for Japan, the United States, Canada, Belgium, France, the Federal Republic of Germany, and Britain. Models of Hungary and the Netherlands are under construction. Groups in Austria, South Korea, Sweden, Finland, and the German Democratic Republic expect to begin work on members of the family in the near future.

This paper describes the steps in the construction of a national model in this family; it explains how scenarios may be specified and shows typical structures of the real and the price sides of these models. The plan for the international linking system is explained and progress towards its realization described.

THE INFORUM-IIASA INTERNATIONAL SYSTEM OF INPUT-OUTPUT MODELS

An input-output model of one country, no matter how perfect, is always incomplete, for exports and imports depend on developments in other countries. Just as the economies of nations depend on one another through international trade, so models of those countries need to be connected by a trade model. But for national models to be connected to one another, there must be similarities in the output of the models, and the input conventions must be sufficiently alike for one person to be able to run them all. On the other hand, economies differ in what they produce, how they function, and -- perhaps most of all -- in the statistical system used to describe them; the models must be flexible enough to accommodate these differences.

These three points,

* connection through international trade
* similarity in input and output conventions
* freedom for diversity in internal structure

form the foundation for a gradually evolving consortium of input-output models and their builders. The Inforum model of the United States is the eldest and at present most complete member of the group. Models, varying in size from the 190 sector U.S. model to the 50-sector Belgian model, are presently available for Japan, the United States, Canada, Belgium, France, Federal Republic of Germany, and Britain. Models of Hungary and the Netherlands are under construction, and groups in Austria, South Korea, Sweden, Finland, and the German Democratic Republic expect to begin work on members of the family in the near future. I expect to work personally on a simple Italian model in the next few months. For most of countries, we are working with groups in the country involved. Their participation ranges, in principle, from oraganization of data and guidance in its use to full determination of the model's equations.

The programming for reading in data and equations, for imposing scenarios in convenient ways, for performing standard input-output calculations, and for making nice output displays is the same in all the models. This programming is extensive, tedious, and almost devoid of economic content, except for the input-output accounting scheme which it embodies. There is no need for it to be different for different countries. Indeed, it is precisely its uniformity from country to country that makes it possible of the basic operating manual of all of the models to be similar enough for one person to run scenarios on all of the models.

On the other hand, each national model works within the statistical system of its own country. Consequently, it can use the most up-to-date information and the most detailed input-output tables available. The results are in the statistical system familiar to economists and business planners within the country. The international trade model, however, works in a standard, 119-commodity classification based on the Standard International Trade Classification (SITC). How we bridge between the country models in their diverse classifications and the SITC-based trade model is explained below where the trade model is described.

I. CONSTRUCTUION OF A NATIONAL MODEL

The construction of a country model of this family begins, of course, with the collection and organization of data. An appendix to this paper lists the kinds of data needed. With as little as a single input-output table, however, one can produce a functioning model using the basic program. The forecast this model first makes are extraordinarily uninteresting: all final demands grow at five percent per year, all input-output coefficients are constant, so outputs also grow at five percent per year. But without any further programing, one can easily specify the time path of any cell or group of cells in the final demand matrix, or the path of any input-output coefficient, or of labor productivity or of any component of value added in any industry. Nice tabular displays, clearly labled in any language, can be easily made. The program which does this is known as Slimforp -- forp for forecasting program, Slim because the program will fatten slightly (probably not more than five or ten percent) as the model is developed.

Still, at this point, the model has only the input-output table as economic content. So one then goes to work to estimate various sets of behavioral equations and to introduce them set-by-set. For example, one may estimate any sort of consumer demand functions one wishes, write the parameters in a standard format expected by the program, and add to the Slimforp program, at a clearly indicated spot, the fortran necessary to interpret those parameters properly. The same is true for investment, import, export, input-output coefficient change, inventory change, labor productivity, wage and profit equations. As each group of equations is added, the model can be run to check the programming and the parameters for that particular addition. One is not required to make all of the equations for say, labor productivity have the same functional form, for one of the parameters can be used to indicate which of several forms a particular equation uses.

All of the programming for modifying or overriding the results of the equations remains in place and ready to use after the "fattening" of the program. If, for example, one wants to multiply the 1980 exports of input-output sector 3 by 1.01, the 1985 forecast of this item by 1.15; the 1990 forecast, by 1.18; and the intervening years, by multipliers obtained from these by linear interpolation, then one needs only the following card:

```
 EXP,M 3, 80,1.01, 85,1.15, 90,1.18,
```

and the program does the rest.

Instead of multiplying the equation's result by a specified function of time, we could add the function to it or replace it by the function by changing the M in the example to the appropriate letter. Fixes of this sort may also be applied to groups of cells; we could, for example, control the total consumer expenditure on durables to some prespecified value. This feature has proven especially valuable when using the models to spell out the consequences for idustries of macro-economic forecasts made by more aggregate models.

Changes in input-output coefficients are equally easily specified. For example, if the base year of the model is 1975 and we want the A-matrix coefficient for sales from insustry 17 to industry 25 to drop to 80 percent of it 1975 value by 1979, to 60 percent by 1984, and to only 55 percent by 1990, we need only the card

```
 AM,I 17,25, 75,1.0, 79,.80, 84,.60, 80,.55.    .
```

The AM stands for A-matrix, and the I indicates that the coefficient is being specified as an index.

Each national model has, when finished, two parts, or "sides" -- the real side and the price-wage-income side, called, for short, the price side. The real side determines consumption expenditure, exports, imports, industry outputs, and investment -- all in constant prices -- and employment. The price side determines, for various industries, the wage rate and the capital income per unit of output. It allows one to specify the effect on prices of changes in social security taxes, excise taxes or subsidies. The effect of the prices of foreign goods on the prices of domestic products which use them is also built in. The results of the price side influence the real side through the role of relative prices in the personal consumption functions and the input-output coefficient change functions. Likewise, the export and import functions take account of domestic prices relative to prices in other countries. The price side receives influences from the real side primarily through the action of unemployment on wage rates and capital utilization on profit rates.

It would be natural to iterate back and forth between the real side and the price side during each year of the forecast. In fact, because the real side is usually fairly well-developed before the price side is started, the two models are separate, and each side is, at present, run separately over the entire forecast period, first the real side, then the price side, then the real side again. This procedure does not correspond to the way the economy works but rather to the evolutionary history of the models. However, on the basis of experience with the U.S. and Japanese models, the only ones with well-developed price sides at present, it seems to work reasonably well.

Structure of the Real Side

The basic logic of the real side model begins from a target level of employment for future years. A trial projection of disposable income is made, personal consumption expenditures calculated, exogenous government expenditures added in, exports based on foreign demands and domestic-to-foreign price ratios also added, along with investment, based, in each year, on replacement requirements and growth in output in that year and previous years. The sum of these components gives final demands except for inventory change and without offsetting imports. Imports and inventory change are then calculated sector-by-sector along with outputs in a Seidel iterative process. Imports generally depend upon domestic use of the product and inventory change depends on changes in this use since the previous year. From outputs, employment is calculated and compared with the target employment. If it is below the target, the disposable income projection is revised upward and the calculation repeated to achieve the specified level of employment. This logic leaves unanswered the question of whether the income generated by this level of employment and output would give the disposable income which was assumed. The full answer to that question is one of the tasks of the price model, to which we shall come in a few pages. For the moment, however, it is enough to realize that by properly adjusting the tax rates this level of disposable income can certainly be obtained from the before-tax income generated by the forecast.

I have stressed the flexibility of these models to accommodate various types of equations. Nonetheless, it is undeniable that if the specification of the equations is left to me and my close associates at Inforum and IIASA, we will use equations with which we have had good experiences and avoid some otherwise popular types that have given us trouble. For personal consumption expenditure, we are prone to use a system of consumption functions which accommodates both complimentarity and substitutability among products, allows strong interdependence among closely related products and weak interdepence among others, yet avoids certain peculiar properties of the other systems known to me. This system is described in [1]. Import functions are apt to take the form

(1) $y_{it} = (a_i + b_i u_{it})(pf_{it}/pd_{it})^{n_i}$

where

y_{it} = imports of good i in year t

u_{it} = domestic use of good i in year t

pf_{it} = foreign prices for i, averaged over several years prior to t and averaged over countries with weights proportional to our country's imports from them.

pd_{it} = domestic prices averaged over several years, ending in t.

Note that although this function has a constant price elasticity, it is a linear function of total use. The parameter b_i gives the assymptotic share of imports in total use as use grows without change in the ratio of foreign and domestic prices.

Labor productivity, if no one has a better idea, is apt to follow a simple exponential trend, because we have had many problems with more ambitious forms. Investment usually depends on lagged first differences of output, with some provision for replacement investment. Results of the estimation of the behavioral equations are available in Inforum research reports on the various models.

In the American model, we are experimenting with the Diewert or "square-root" production function for input-output coefficient change, as described in the contribution of Peter Taylor to this congress.

Structure of the Price Side

The price side of the model is based on the equation

$$p = pD + fM + v \qquad (2)$$

where

p is the row vector of domestic prices
f is the row vector of foriegn prices
v is the row vector of value added
D is the i-o matrix of domestically produced inputs
M is the i-o matrix of imported inputs.

On the real side, we needed only the total input-output matrix, $A = D + M$; we did not attempt to use the import matrix, M, to calculate imports by product, because (1) its use would nearly double the core storage requirements of the program at precisely the point -- the input-output computations -- where they already limit the size of the model, and (2) the presence of total use, rather than import-weighted use, makes it easy to keep imports in a reasonable relation to total use.

But on the price side of the model, the logic of the equations requires the separation of the D and M matrices. For the U.S. model, where there is no M matrix available, we simply assumed that each row of M was proportional to the corresponding row of A, that is, that for any given product, imports were the same share of each flow in the row. But for most of the European models, the statisticians have prevented us from making this convenient assumption by providing both D and M matrices. We feel duty-bound to use them.

But how do we forecast D and M separately? It is only the total matrix, A, which has technological meaning and can be forecast from technological or production-function considerations. If we have from the real side model a forecast of total imports of product i for year t, y_{it}, a forecast of the total input-output flows in each cell in row i in year t, x_{ijt} , and the base year import shares in each of these cells, m_{ijo}, how should we revise the import shares to be consistent with the total imports? Scaling them all up by the same percentage may drive some of them above 1.0. A rule was needed which would put the highest percentage increases in cells which initially had low import penetration, yet recognize that zero initial penetration probably meant that imports were not feasible for that cell. Such a rule is given by the formula

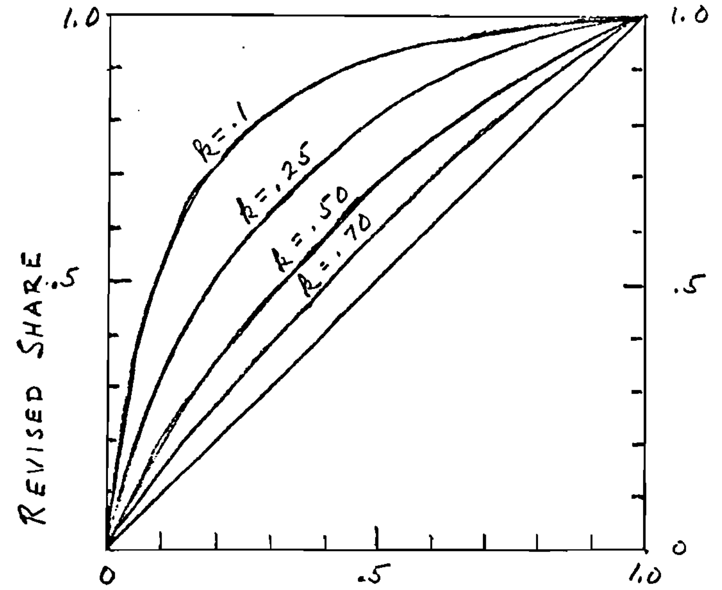
$$m_{ijt} = m_{ijo} / (m_{ijo} + k_i (1 - m_{ijo}))$$

with k_i determined by

$$\sum_j m_{ijt} * x_{ijt} = y_{it} .$$

This non-linear function of k is easily solved by a Newton iteration. The relation between the base year and the revised value of m_{ij} is shown in figure 1 for several values of k.

FIG 1. SHARE REVISION FUNCTIONS



By careful programming, it is possible to bring into core the A matrix, convert it row-by-row to the D matrix by the above formula, and at the same time to create the fM vector, so that it is never necessary to have both the D and M matrices in core. Consequently, core requirements are kept to the size of the A matrix plus a few vectors.

The calculation just described is part of the standard slimforp for the price side. The economic substance of the price side is contained in the equations explaining the vector of value added, v. Actually, the model works with a V matrix in which typical rows are:

Wages and salaries of employees
Wage supplements
Proprietors' income
Indirect taxes
Depreciation
Property income (before tax profits and interest).

Each of the may be further subdivided. The slimforp model provides for a number of equations to be calculated and then, guided by an indexing matrix, moves forward each element of the base-year V matrix by the percent indicated by the appropriate equation. The labor income rows are automatically adjusted for labor productivity. The rows of V are then added together to get the v vector that goes into equation (2).

This standard slimforp for the price side is brand new and is now being tested on the Dutch model. As with the slimforp for the real side, it provides easily used, flexible ways to specify scenarios. The other European models do not yet have price sides, and these must be constructed before the price-dependent part of the international linking mechanism can be used.

The computing power required by these models is modest. National models of up to 100 sectors can be run on a PDP 10/75, a large "mini" selling for about $250,000 complete. We have made every effort to keep the fortran simple and easy to read. We believe that it can be run with minor change on nearly any system. Massive data input and output is handled by a special subroutine which makes use of special, system dependent, high-speed data input-output routines. This subroutine would need to be re-written for a different system; however, a slow-working fortran version of the subroutine is available.

II. THE INTERNATIONAL LINKING MECHANISM

Because the national models are not yet all operating, the linking mechanism has not yet been put to work. The necessary data, however, have been gathered; and many of the equations, estimated.

The trade model, which links the national models, works with 119 commodity groups, defined in SITC terms, and carefully selected to complement the sectoring plans of the most detailed national models. Time series back to 1962 on bilateral trade flow in these categories has been organized from OECD tapes kindly made available to us through the World Bank. Because of the immense amount of work involved in assembling these time series, and the small extra cost of carrying more product detail, the 119 sectors were designed to give the national models "room to grow."

Each national model generates imports in its own classification. These will then be put into dollars and used as independent variables in regression equations having the country's imports in the 119 sectors as the dependent variables. Clearly, imports of some national sectors may be used as explanitory variables for more than one of the 119 sectors. Less frequently, where one of the 119 overlaps several national sectors, the imports of all of these may be used to explain the imports in the one international sector. Note that we have no intention of undertaking a detailed matching of national and SITC classifications; we will go by general names and the results of the regressions.

With a country's imports thus converted into the 119 SITC-based categories, we set about deviding the imports of each category among the source countries. Equations for this purpose have been estimated and described by Douglas Nyhus [2]. They use, as variables to explain changes from the base year shares, principally relative prices and time trends. Export-push factors, such as investment in the exporting country, have not been considered for lack of data at the time of the estimation. We now have more investment data and could -- and probably should -- try to include such effects. The form of the equation, in so far as prices are concerned, is the following

$$s_{ijt} = s_{ijo} * (EP_{it}/WP_{jt})^{b_{ij}}$$

where

s_{ijt} = share of country i in imports of country j in year t

EP_{it} = the "effective" price of this product in country i in year t, that is, it is a weighted average of previous years' prices. No exact matching of the SITC product is attempted. The most appropriate price available from the country model is used.

WP_{jt} = the "world" price of this product as seen from from country j.

This last, the world price as seen from country j, is not calculated by any simple averaging process, but is defined implicitly from the requirement that the sum of the shares add up to 1.0:

$$\sum_{i} s_{ijt} = {}_{i}\, s_{ijo} \left(EP_{it}/WP_{jt}\right)^{b_{ij}} = 1.$$

In previous work known to us, the b_{ij} have been the same for all i; the above formulation with the calculation of the world price form its implicit definition add greatly to the flexibility of the equation, and makes it possible to find quite substantial price effects on trading patterns.

Once the imports of every modelled country have been thus broken down by country of origin, they can be summed over importing countries to give the "exports" of the origin countries. Of course, these "exports" are not precisely exports as reported by the origin countries, partly for the usual reasons that make X's exports to Y different from Y's imports from X, and partly because not all countries are included in the system. Nonetheless, when aggregated to match as nearly as possible a national model's classification, they should prove very good explanatory variables in regression equations for exports in the national models.

As with the iteration between the real side and the price side of the national models, the natural order of iteration of the international system would be to go around all countries each year until equilibrium is reached. But because the national model is the computing unit, that procedure would waste much computer time in shifting from one model to the next. We plan, therefore, to make a ten-year forecast with each national model and then seek the international equilibrium over all ten years at the same time. We hope to have the first version this trade linking mechanism working before the end of this year. It will be largely the creation of

Douglas Nyhus.

* * *

The International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, where Nyhus and I have been for the past nine months, intends to continue this work. It is our hope that, through this work, IIASA may become a center for international cooperation in long-term economic forecasting for business planning and government policy making.

REFERENCES

1. C. Almon, "A System of Consumption Functions and its Estimation for Belgium," *Southern Economic Journal*, forthcoming.

2. D.E. Nyhus, *The Trade Model of a Dynamic World Input-Output System*, Inforum Research Report No. 14, July, 1975

APPENDIX

DATA REQUIREMENTS FOR AN INPUT-OUTPUT MODEL IN THE INFORUM-IIASA FAMILY

Indispensable

An input-output table for one year. It should distinguish, within the final demands, at least private consumption, government demands, exports, imports, capital investment, and inventory change.

For Real-Side Model

For the estimation of behavioral equations, historical time series are necessary. Probably the most important equations for determining the future growth of the economy are the labor productivity equations. They require, at a minimum, historical series for

Industry output in constant prices for I-O sectors
Employment by I-O sectors or aggregates thereof

If historical series cannot be established for the outputs of all the sectors in the published input-output tables, perhaps some of the sectors can be aggregated to form a sector for which outputs are available; or, if aggregation would combine a nice, clean sector like "railroads" with a mess like "travel agents, freight forwarders, and miscellaneous transportation services," then it may be better to make up some very weak series for the mess sector. Dummy sectors that have no employment, investment, or import need no output series.

The biggest final demand component is always personal consumption. To develop equations for it, one needs at least

either

Personal Consumption by Input-Output sector in current and constant prices

or

Personal Consumption Expenditure by categories found in the national accounts <u>and</u> a bridge matrix showing the composition of each of these categories in terms of the I-O sectors for the base year of the table.

To complete a standard real side, one needs

- Imports, by I-O sector in constant prices
- Exports, by I-O sector in constant prices
- Domestic price indexes by I-O sector, at least for goods
- Investment, by purchaser, in I-O sectors, or aggregates thereof, and
- An investment flow matrix showing how the purchases of each investing industry were divided among products of the various I-O industries
- Inventory change (= stock building) by I-O sector

It is nice to have also, for coefficient change studies,

- Time series on individual flows in the I-O table

For the Wage-Price-Income Side

For this side of the model, it is necessary to have

- The value-added rows of the base year table
  - They should include at least a devision among labor income, capital income, and taxes.
- Wage rates, unemployment rates, and any other variables to be used in the wage rate equations, profitability equations, or relative wage equations.

It is nice to have,

- A time-series of the value added rows, perhaps at a more aggregate level available from the national accounts.

It is not, of course, necessary to have all of these data at the outset. The data bank can grow as the model is built.

%