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ON THE UTILITY OF INTERINDUSTRY PROJECTION MODELS

by

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D. C. Cole
First Draft
July 10, 1967

ON THE UTILITY OF INTERINDUSTRY PROJECTION MODELS

There is probably a natural tendency for economists interested in economic planning to push on fairly quickly from linear projection models to optimizing models of the linear and non-linear variety. Most of the theoretical and expository literature on planning presents models in this sort of logical sequence moving from the simple to the more complex. Also the basic data requirements are much the same for these several types of models. Admittedly the computational problems are somewhat more complicated for optimizing models and it may take considerable experimentation to devise a well behaved system, but these are the kinds of things we like to play with anyway.[1] But perhaps the most important factor is the point, stressed by Chenery and Clark, that optimizing or programming models are designed to make choices. "They take account of the fact that there are many different ways of producing goods and satisfying wants and that choices in one part of the economy may be dpendent on choices in other parts." /Chenery and Clark, p. 81/. Such choices are the heart of economics and inevitably economists have been eager to apply the new techniques which helped in the making of these choices.

I do not intend to criticize the use of optimizing models, especially since I am just beginning to learn something about them and can already see many ways in which they can be extremely helpful. On the other hand, I do want to suggest that we may have overlooked some of the potentialities of the interindustry projection model, not necessarily as a substitute for, but as a complement to optimizing models. It is for this reason that I have con-

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[1] Bergsman and Manne recently were criticized by Lefeber for using a projection rather than an optimizing model simply because of its computational advantage. (See Adelman and Thorbecke, p. 258.)

tinued to work with the Korean projection model to test its properties, refine its structure, generalize and improve the computer program, and finally see how the projection model can be used in conjunction with Westphal's recently constructed optimizing model for Korea.

Potential Advantages of Projection Models.

The main advantage of an interindustry projection model over an optimizing model would appear to be its simplicity of structure which permits not only easier and cheaper solution, but also much greater disaggregation in terms of both industrial sectors and time periods. As a simple illustration on this score we can compare three recent solutions of the Korean projection and programming models. The projection model encompasses more than double the number of sectors and time periods of the programming model, and the relative time required for single solutions is nearly double. When multiple solutions of the projection model are run concurrently, the time per solution drops appreciably, e.g. from 5.8 minutes for a single solution to an average of 3.9 minutes for one of three solutions. Such computer time differences are not very significant, but the ability to disaggregate may well be.

Clark has made the point [in Adelman and Thorbecke pp. 236] that interindustry models can play an important role "in integrating the sectoral analyses of...various specialists....To perform this integrating function effectively, a projection technique must be sufficiently disaggregated to provide each sector specialist with links between his analysis and the general projection." These comments imply that sector specialists are expected to participate in the structuring and revision of the model to help make some of the choices that are handled as part of the formal solution by a programming model. Thus one possible criterion for the appropriate degree of dis-

Table I

Comparison of Dimensions and Computer Time

of Projection and Programming Model Solutions

	Projection Model		
	Single Solution	Three Simultaneous Solutions	Programming Model
Number of Sectors	43	43	18
Number of Time Periods	7	7	3
Computer Time Per Solution (min)	5.8	3.9	3

aggregation for a projection model of a particular country may be the point at which specialists can be found who have a usable knowledge of their special industry.[2] Experience with efforts to project structural change in the Korean input-output tables would suggest that the existing 109 sector disaggregation was more serviceable for the industry specialists than the 43 sector level. An 18 sector table undoubtedly would have been even more difficult.

Although all solutions of the Korean sectoral model have been made at the 43 sector level, there is no reason why the 109 sector breakdown could not be used. There is also a 270 sector input-output table, but this raises some inversion problems (perhaps not serious) and the matrix probably is quite thin in many parts, so that it does not add much to the solution.

/ I have not yet explored the practical limits of disaggregation for a programming model, but will add a discussion of the subject when I have done so. /

Deriving from the practical degrees of disaggregation of the two types of models is the proposition that programming models are better suited for looking at fairly major or basic alternatives of structure or timing in a development program. There are apparently still some questions about how good such models are in answering these questions of basic structure, but this is clearly the area in which they are likely to be most effective, if at all.

The more disaggregated projection models can be most useful in spelling

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[2] This is in addition to, not in lieu of the normal criteria for aggregation discussed in Chenery and Clark, and the references there cited.

out in greater detail the pattern of movement over time. Once the basic choices have been made, then it is important to work out the scheduling to assure overall consistency and that bottlenecks of one sort or another will not occur. The more disaggregated solution of a projection model is also more susceptible to a kind of detailed feasability check by the technical and sectoral specialist which simply would not be possible with a more aggregated system.

Other Uses of Projection Models.

If necessary, a projection model can be used to help analyse many of the basic choices which planners are interested in. By making multiple solutions, one can indicate the gains and costs of discrete alternatives, but,as is well known, there is no assurance of reaching an optimum.

The Korean projection model has been used in this way, partly because no optimizing model was available. At the time of formulating the second five year plan (Spring, 1966), one of the basic investment choices was between a petrochemical complex and an integrated steel mill. In an effort to test the consequences of carrying out none, one or the other, or both of these large investment complexes, four different solutions of the model were made. The choices were introduced into the model by varying the patterns of imports over time in a manner consistent with the imports that would result from the projects. Comparisons of the overall capital output ratios and employment effects of the several solutions did not indicate significant differences among them. Thus the main question which was tested with the model was one of feasibility, i.e. whether domestic demand for the output of these sectors was likely to grow sufficiently during the plan period to absorb production from plants of minimum efficient size.

Recently we have explored the relative effects on the endogenous variables (investment, imports, total final demand and total output) of

changes in the level of the main exogenous variables (private consumption, exports, infrastructure investment and competitive imports). The results are shown in table 2 .[3] The incremental domestic investment coefficient is highest for an increase in exports (.586), somewhat lower for infrastructure investment and private consumption. The investment saving from increased competitive imports is relatively modest (.286). The second column of the table shows the derived demand for imports, which is high (.41) for infrastructure investment and moderate (.14 to .19) for the other exogenous changes.

These coefficients can be used to estimate the overall effects of changes of varying magnitudes in the main exogenous variables of the model, which are equivalent to alternative development strategies. Also if a given solution of the model turns out to be infeasible, these coefficients can be used to estimate the required changes in one or several of the exogenous variables to arrive at a feasible or acceptable solution.

Another role for the projection model is in connection with plan implementation. It provides a useful framework for organizing information about available capacity, output, imports, investment and exports, for seeing how the plan is progressing, where changes in demand or supply may require adjustment of the investment program or import policies, and for testing the impact of possible revisions in plan targets or strategy.

The Korean model is being used in this manner. It is expected that each year, in connection with the formulation of an overall resources budget, new solutions of the model will contribute to an analysis of the adjustments

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[3] The patterns of change of the exogenous variables, i.e. the distribution by sector of the demands for additional exports or investment, or the supply of additional competitive imports, were worked out by specialists rather than being increased proportionately. Private consumption increases, on the other hand, are derived from expenditure elasticities.

Table 2

Comparison of Effects of Unit

Changes in Various Components of

Final Demand

Exogenous Variable	Relative Change in:[a] Gross Endogenous Investment	Total Annual Imports	Final Demand	Total Output
Private Consumption	.417	.167	1.08	1.92
Exports	.586	.192	1.0	2.0
Competitive Imports	-.286	-.143	-1.0	-2.0
Infrastructure Investment	.525	.41	.88	1.86

[a] The change in gross endogenous investment relative to the change in private consumption is defined as:

$$\frac{\sum_{1}^{5} (Kn + S)^* - \sum_{1}^{5} (Kn + S)}{C^*_{p5} - C_{p5}}$$

Where Kn = gross investment in mining and manufacturing.
S = gross change in stocks in all sectors
C_p = private consumption

The other relations are of the following form: $\frac{M^*_5 - M_5}{C^*_{p5} - C_{p5}}$

where M = total imports.

The unstarred variables are from the base solution.

required in the plan because of recent developments, new information or revised assumptions. One critical area of analysis for which the current version of the model is particularly suited is the substitution between imports and creation of domestic capacity. This is especially relevant in sectors where large and lumpy capacity expansion is scheduled to occur. Often these are the intermediate goods sectors which depend for their markets on the previous growth of final processing industries. Thus it is desireable to schedule sufficient growth in the capacity of the processing industries, adequate imports of intermediate goods to support their production until such time as the demand for the intermediate good is sufficient to justify domestic production and that production is actually available. By combining information on existing capacity, annual capacity expansion and utilization rates of available capacity, it is possible to adjust import coefficients and derive the appropriate import patterns.

Another use of the projection model is to provide information for the optimizing model. So far it has been used in an operational sense only to project the terminal conditions to be satisfied by the latter model. But its more important role may be as a sort of bench mark for the optimizing model. The projection model spells out a relatively smooth growth path for all variables in the system, whereas the linear programming model tends to bounce along from one constraint to another. Thus the projection model can be used as a guide to what is reasonable, or at least a smooth progression, and this information should prove helpful in setting constraints on the more fractious system.

A second type of benchmark is to compare the relative efficiency of an optimizing solution over a straight projection. How much is gained in maximizing the objective function by achieving an optimal solution rather

than simply the best estimate of a feasible solution? This is likely to vary depending upon the specific formulations of the two models, and such matters as the time horizon, but it will begin to provide an empirical test of the utility of programming models. It may also shed some light on how to construct better projection models.

Generalizing the Computer Program

On the assumptions that interindustry projection models are useful and that more use might be made of them if a good serviceable computer program was readily available, we are endeavoring to devise a fairly general program for the model. Obviously this will incorporate what has been learned from the practical applications on Korea. We would like to test the generality and transferability of the model and program by trying it out on another country for which the data is readily available. A listing of the data requirements and a description of the program are contained in the attached annex.

Data requirements for Korean sectoral projection model.

1. Initial sectoral capacity estimates

2. Sectoral depreciation rates and gestation periods

3. Projections of final demand by sector and year for

   a. Private consumption
   b. Government consumption
   c. Exports
   d. Investment in sectors for which capital coefficients are not available

4. Stock change coefficients (a vector)

5. Competitive import coefficients (a separate vector for each year)

6. Non-competitive import coefficients (a separate vector for each year)

7. Capital coefficients (a single matrix (a x b) where a is the number of sectors supplying capital goods--including imports, and b is the number of using sectors, i.e. where investment is endogenous)

8. Employment coefficients (a vector)

9. Interindustry matrices, $(I-A)^{-1}$ (a separate matrix for each year to incorporate structural change).

Results Produced by the Projection Model

For all sectors

1. Annual output levels
2. Annual growth rates of total output
3. Annual competitive imports

For mining and manufacturing sectors (i.e. sectors for which investment is determined endogenously

1. Planned annual capacity levels
2. Annual gross and net capacity increments
3. Annual gross investment by using sector
4. Annual rates of capacity expansion
5. Annual rates of capacity utilization
6. Annual increments of employment

Overall

1. Total final demand, including the derived demand for
    a. Investment in mining and manufacturing
    b. Competitive and noncompetitive imports
    c. Inventory investment
2. Total imports of current and capital goods
3. Total investment

Alan Samansky
First Draft
July 10, 1967

ANNEX I

DESCRIPTION OF COMPUTER PROGRAM FOR THE KOREAN PROJECTION MODEL

Introduction

The program outlined below represents an input-output model of a national economy. It consists of a main program and one subroutine. The main program computes the output from each sector necessary to meet the specified final demand; the subroutine determines the necessary annual additions to capacity in selected sectors. The investment that is needed to effect these additions to capacity is called endogenous investment.

Final demand for each sector and for each year within the range of the model must be specified in advance. The first time through the main program, output from each sector necessary to meet final demand is computed under the assumption that endogenous investment is zero. The subroutine then determines the additions to capacity that would be sonsistent with this output. Back in the main program the corresponding amount of endogenous investment is computed and added to final demand and to output. This completes one iteration. If additional iterations are requested, the new value of output is used to determine the necessary endogenous investment. This will continue for as many iterations as desired.

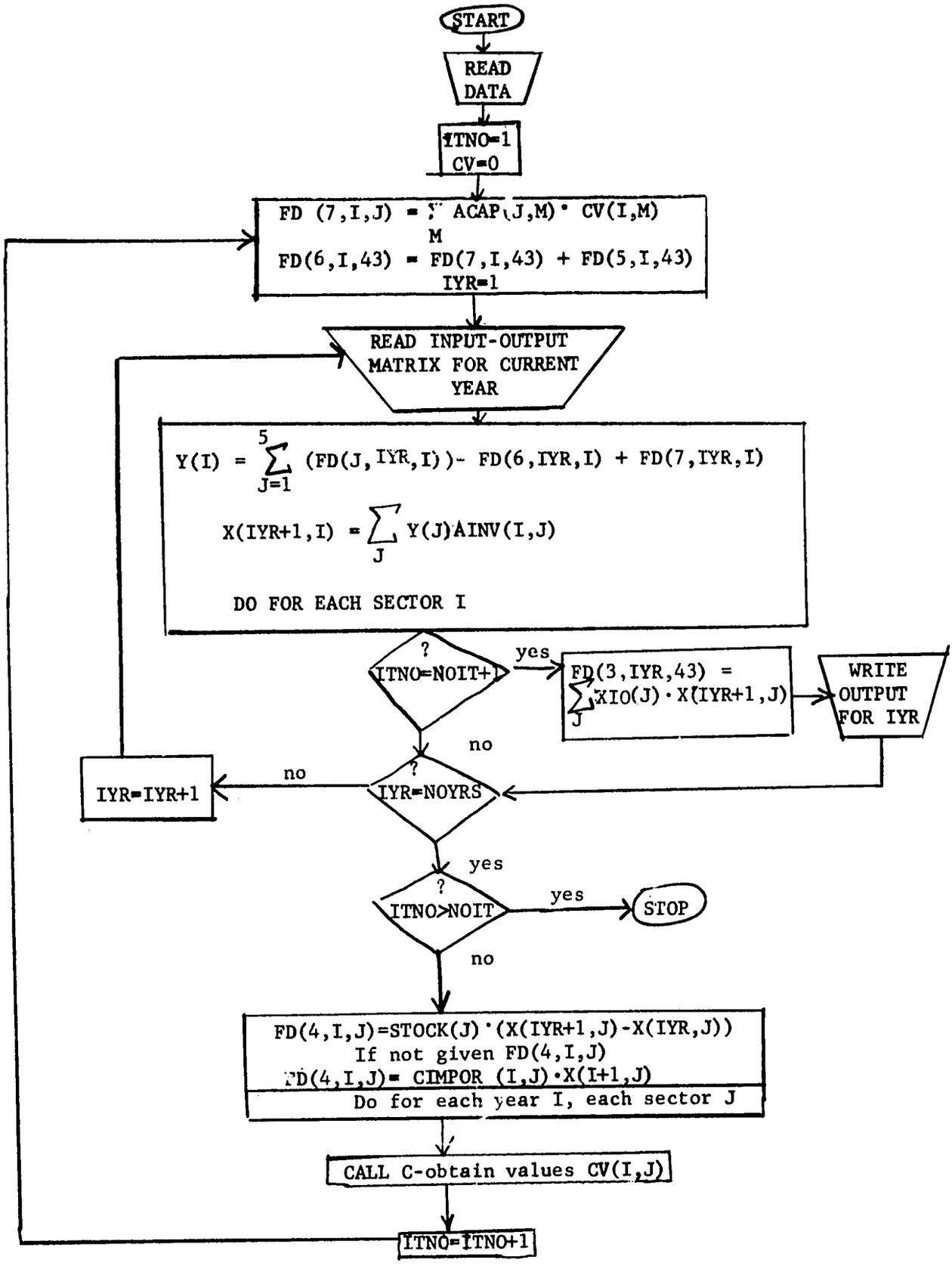
The competitive import and stock change (inventory) components of final demand are also functions of total output which are built up through the iterative process.

The Main Program

A more detailed explanation of the operation of the main program can be gained from the flowchart. If certain conventions are kept in mind, one who is unfamiliar with this device or with Fortran programming can make use of the flowchart. The most important convention is that an equals sign ("=") means replace. Thus ITNO = ITNO+1 means take whatever value the variable ITNO has, add one to it, and assign to ITNO this new value. In the flowchart itself, the directions followed by the program are shown by the arrows. A rectangle indicates that computations are taking place; a trapezoid, that data is being inputted or outputted; a diamond that a comparison is taking place between two variables. The arrows show how the next step depends on this comparison.

As the flowchart shows, the data is first inputted, then the iteration number (ITNO) and investment (CV) are set respectively to one and zero. By adding (and subtracting) the given different components of final demand for each sector, final demand for each sector is obtained.

Stock changes and (if not given directly) competitive imports are originally set to zero and will be computed later. Output for each sector is determined by multiplying final demand by the inverse of the input-output matriz. This is done for each year. Next stock changes, a function of the change of total output, and competitive imports, a function of total output are computed and then the subroutine is used to determine the capacity expansion necessary to meet this demand. The amount of investment necessary for this capacity expansion is computed in the main program and then new final demand totals taking account of the newly calculated endogenous investment, stock changes, and competitive imports are determined. In the last iteration, non-competitive imports, a function of the output in each sector, (represented by FD(3, IYR, 43) in the flowchart) are determined.


START
READ DATA
ITNO=1
CV=0
FD (7,I,J) = Σ ACAP(J,M) · CV(I,M)
M
FD(6,I,43) = FD(7,I,43) + FD(5,I,43)
IYR=1
READ INPUT-OUTPUT MATRIX FOR CURRENT YEAR
Y(I) = Σ (FD(J,IYR,I)) - FD(6,IYR,I) + FD(7,IYR,I)
J=1
X(IYR+1,I) = Σ Y(J) AINV(I,J)
J
DO FOR EACH SECTOR I
ITNO=NOIT+1 ?
yes
FD(3,IYR,43) = Σ XIO(J) · X(IYR+1,J)
J
WRITE OUTPUT FOR IYR
no
IYR=NOYRS ?
no
IYR=IYR+1
yes
ITNO>NOIT ?
yes
STOP
no
FD(4,I,J)=STOCK(J) · (X(IYR+1,J)-X(IYR,J))
If not given FD(4,I,J)
FD(4,I,J)= CIMPOR (I,J) · X(I+1,J)
Do for each year I, each sector J
CALL C-obtain values CV(I,J)
ITNO=ITNO+1

Key:

NOYRS = number of years to be calculated

IYR = current year

ITNO = current iteration number

NOIT = number of iterations desired

FO (K, I, J) = final demand

K = type of data

I = 1 denotes personal consumption

I = 2 denotes government consumption

I = 3 denotes exports

I = 4 denotes stock accumulation

I = 5 denotes exogenous capital investment

I = 6 denotes imports

I = 7 denotes endogenous capital investment

I = year

J = sector

Y (J) = final demand in J^{th} sector

X(I,J) = output of sector J in year I.
note: X(I+1, J) corresponds to FO(K,I,J) in time

CV(I,J) = Investment in I^{th} year from J^{th} sector

ACAP(I,J) = capital input matrix

AINV(I,J) = I-A inverse matrix for current year

XIO(I,J) = non-competitive import coefficients

Capacity Expansion Subroutine

The purpose of this subroutine is to determine for each year and for each sector the desired increase in capacity. Use is made of the following variables, the values of which are transferred from the main program. All of these can assume different values for different sectors: (1) a depreciation rate; (2) original capacity; (3) output for each year; (4) horizon period, number of years in future the output of which is taken into account in planning investment for the current year; (5) gestation period, number of years necessary to investment to become operative.

For each sector the average annual growth rate of output is computed. The assumption is made that output will increase by this amount for one year after the last year for which final demand was specified. This assumption is made so that such things as required capacity growth can be determined for the last year within the model.

The following computations are done in order for sectors #5 through #32 inclusive, for each year. The current depreciation rate is calculated to be the given depreciation rate times the ration of original capacity to present capacity, (i.e. only original capacity is depreciated.)* Original capacity stays constant throughout time unless in some year net investment is negative (i.e. new investment does not fully offset depreciation).

The utilization rate is computed, and it is compared with the optimum utilization rate. If the actual is greater than the desired rate, the

* The first year's capacity for each sector is read into the program; capacity for the year directly after whichever year is then the current year is calculated later in the subroutine. Thus, here present capacity is known even though no calculations of capacity have yet been shown.

annual decrease in utilization necessary to reach the optimum in the final year is determined.

Now for each year in the interval between (t gestation period) and (t horizon period) where t is the current year, the utilization rate consistent with the pattern outlined just above for reaching the optimum capacity is determined. Since the output for each year in this interval has been calculated in the main program, the desired capacity for the year of interest and then average annual growth in capacity from year t to reach the desired capacity are easily found. For each year t, within the model, a number of such growth rates of capacity are determined (equal to the number of years between t gestation period and t horizon period). The maximum of these and of the depreciation rate is taken as the growth of capacity in year t. If the growth of capacity for the last year is less than the average growth of output, the latter is taken to be the growth of capacity for the last year. Capacity in year t 1 then equals previous capacity plus the increase. Additions to capacity are the increases in capacity plus the corrected depreciation rate times the current capacity.