

STRUCTURE OF THE WORLD ECONOMY

Outline of a Simple Input-Output Formulation*

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by

WASSILY LEONTIEF

Harvard University, Cambridge, Massachusetts, USA.

I

The world economy, like the economy of a single country, can be visualized as a system of interdependent processes. Each process, be it the manufacture of steel, the education of youth or the running of a family household, generates certain outputs and absorbs a specific combination of inputs. Direct interdependence between two processes arises whenever the output of one becomes an input of the other: coal, the output of the coal mining industry, is an input of the electric power generating sector. The chemical industry uses coal not only directly as a raw material but also indirectly in the form of electrical power. A network of such links constitutes a system of elements which depend upon each other directly, indirectly or both.

The state of a particular economic system can be conveniently described in the form of a two-way input-output table showing the flows of goods and services among its different sectors, and to and from processes or entities ("value added" and "final demand") viewed as falling outside the conventional borders of an input-output system. As the scope of the inquiry expands, new rows and columns are added to the table and some of the external inflows and outflows become internalized. Increasing the number of rows and columns that describe an economic system also permits a more detailed description of economic activities commonly described in highly aggregative terms.

Major efforts are presently underway to construct a data base for a systematic input-output study not of a single national economy but of the world economy viewed as a system composed of many interrelated parts. This global study, as described in the official document, is aimed at

"helping Member States of the United Nations make their 1975 review of world progress in accelerating development and attacking mass poverty and unemployment. First, by studying the results that prospective environmental issues and policies would probably have for world development in the absence of changes in national and international development policies, and

* The author is indebted to Peter Petri for setting up and performing all the computations, the results of which are presented in this lecture, and to D. Terry Jenkins for preparing the graphs and editorial assistance.

secondly, by studying the effects of possible alternative policies to promote development while at the same time preserving and improving the environment. By thus indicating alternative future paths which the world economy might follow, the study would help the world community to make decisions regarding future development and environmental policies in as rational a manner as possible.¹

Preliminary plans provide for a description of the world economy in terms of 28 groups of countries, with about 45 productive sectors for each group. Environmental conditions will be described in terms of thirty principal pollutants; the use of non-agricultural natural resources in terms of some 40 different minerals and fuels.

II

The subject of this lecture is the elucidation of a particular input-output view of the world economy. This formulation should provide a framework for assembling and organizing the mass of factual data needed to describe the world economy. Such a system is essential for a concrete understanding of the structure of the world economy as well as for a systematic mapping of the alternative paths along which it could move in the future.

Let us consider a world economy consisting of (1) a Developed and (2) a Less Developed region. Let us further divide the economy of each region into three productive sectors: an Extraction Industry producing raw materials; All Other Production, supplying conventional goods and services; and a Pollution Abatement Industry. In addition to these three sectors, there is also a consumption sector specified for each region. The function of the Abatement Industry is to eliminate pollutants generated by the productive sectors, consumers, and the Abatement Industry itself.

The two input-output tables displayed as Figure 1 describe the inter-sectoral flows of goods and services within the Developed and the Less Developed economies. The flow of natural resources from the Less Developed to the Developed Countries, as well as the opposite flow of Other Goods from the Developed to the Less Developed Countries are entered in both tables: positively for the exporting region, and negatively for the importing region.

In each of the two tables the right-most entries in the first and second row represent the total domestic outputs of the Extraction Industry and of Other Production, respectively.

Each positive number along the third (Pollution) row shows the physical amount of pollutant generated by the activity named at the head of the column in which that number appears. The negative quantity shown at the intersection of the third column and the third row represents the amount of

¹Quoted from: "Brief Outline of the United Nations Study on the Impact of Prospective Environmental Issues and Policies on the International Development Strategy." April 1973.

Fig. 1.

WORLD ECONOMY IN 1970 (Billions of 1970 dollars)

DEVELOPED COUNTRIES

| | Extraction Industry | Other Production | Abatement Industry | FINAL DEMAND | | Total output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 76 | 0 | 2 | -15 | 63 |
| Other Production | 21 | 1809 | 21 | 2414 | 19 | 4284 |
| Pollution | 5 | 62 | -63 | 60 | 0 | 64 |
| Employment | 18 | 1372 | 20 | 287 | 0 | |
| Other Value Added | 21 | 996 | 22 | 0 | 0 | |

LESS DEVELOPED COUNTRIES

| | Extraction Industry | Other Production | Abatement Industry | FINAL DEMAND | | Total Output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 8 | 0 | 2 | 15 | 25 |
| Other Production | 7 | 197 | 0 | 388 | -19 | 573 |
| Pollution | 2 | 8 | 0 | 11 | 0 | 21 |
| Employment | 9 | 149 | 0 | 99 | 0 | |
| Other Value Added | 8 | 220 | 0 | 0 | 0 | |

pollutant eliminated by Abatement activities.²Inputs such as power, chemicals, etc. purchased by the Abatement Industry from other sectors, and value added paid out by that industry are entered as positive amounts in the same third column. The difference between the total amount of pollution generated in all sectors and the amount eliminated by the Abatement sector is represented by the net emission figure, the right-most entry in the third row. Finally, labor inputs used in each sector and payments made to other income-receiving agents are shown in the bottom two rows.

²All quantities are measured in billions of dollars "in current prices"; pollutants are "priced" in terms of average "per unit" abatement costs.

The numbers in these two tables are strictly speaking, fictitious. But their general order of magnitude reflects crude, preliminary estimates of intersectoral flows within and between the Developed and Less Developed regions during the past decade.

For analytical purposes, the outputs and inputs of the Extraction Industry and Other Production, as well as the amounts of pollutants generated and abated, can be interpreted as quantities measured in the appropriate physical units (pounds, yards, kilowatts, etc.). The same is true of the services of some of the so-called primary factors: labor inputs, for example, are entered in the second to last row of each table. A similar physical measurement of the other components of value added, even if it were possible in principle, is impossible given the present state of knowledge. In pure, or should I say speculative economic theory, we can overcome this kind of difficulty by introducing some convenient albeit unrealistic assumptions. But a theoretical formulation designed to permit empirical analysis has to account for the fact that at least some components of value added cannot be interpreted as payments for measurable physical inputs, but must be treated as purely monetary magnitudes.

III

The flows described in the two input-output tables are interdependent. They have to satisfy three distinct sets of constraints. First, within each production or consumption process there exists a technological relationship between the level of output and the required quantities of various inputs. For example, if we divide each figure in the first column of the first table of Figure 1 (the inputs of the Extraction Industry) by the total output of that sector (the last figure in the first row), we find that to produce one unit of its output this sector absorbed .3372 units of the output of Other Production, used .2867 units of Labor Services and spent .3332 dollars for other value added. Moreover, for each unit of useful output the Extraction Industries generated .0859 units of pollution. Other sets of input-output coefficients describe the technical structure of every sector of production and consumption in both groups of countries.

While statistical input-output tables continue to serve as the principal source of information on the input requirements or "cooking recipes" of various industries, increasingly we find economists using engineering data as a supplemental source. Complete structural matrices of the two groups of countries used in our example are shown in Figure 2.

The second set of constraints that has to be satisfied by every viable system requires that the total (physical) amounts of outputs and inputs of each type of good must be in balance, i.e., total supply must equal total demand. In the case of a pollutant, net emission must equal the total amount generated by all sectors less the amount eliminated by the abatement process.

For example, the balance between the total output and the combined inputs of extracted raw materials can be described by the following equation:

$$(1) \quad \frac{(1-a_{11})x_1 - a_{12}x_2 - a_{13}x_3 - c_1y - T_1}{\text{net output of Extraction Industry} \quad \text{amount delivered to Other Production} \quad \text{amount delivered to the Abatement Industry} \quad \text{amount delivered to Final Users} \quad \text{amount exported}} = 0$$

The equation describing the balance between generation, abatement and net emission of pollution reads as follows:

$$(2) \quad \frac{-a_{31}x_1 - a_{32}x_2 + (1-a_{33})x_3 - c_3y + E}{\text{gross amount of pollution generated by sectors 1 and 2} \quad \text{amount abated by abatement activities} \quad \text{gross amount generated by consumers and government} \quad \text{net amount emitted into the environment}} = 0$$

Fig. 2.

TECHNICAL AND CONSUMPTION COEFFICIENTS*

Developed Countries

$$A_1 = \begin{bmatrix} .0 & .0178 & .0 \\ .3372 & .4223 & .3298 \\ .0859 & .0144 & .0118 \end{bmatrix} \quad C^1 = \begin{bmatrix} .0007 \\ .8834 \\ .0218 \end{bmatrix}$$

$$t_1 = [.2867 \quad .3203 \quad .3161] \quad t_1^c = [.1050]$$

$$r_1 = [.3332 \quad .2324 \quad .3482] \quad r_1 = [.0 \quad]$$

Less Developed Countries

$$A_2 = \begin{bmatrix} .0 & .0141 & .0 \\ .2934 & .3437 & .3298 \\ .0859 & .0144 & .0118 \end{bmatrix} \quad C_2 = \begin{bmatrix} .0037 \\ .7943 \\ .0218 \end{bmatrix}$$

$$t_2 = [.3729 \quad .2597 \quad .3161] \quad t_2^c = [.2020]$$

$$r_2 = [.3337 \quad .3825 \quad .3541] \quad r_2^c = [.0 \quad]$$

x_1 and x_2 represent the total outputs of the Extraction Industry and of Other Production respectively; x_3 , the level of activity of the Abatement sector; y , the sum total of values added, i.e., Gross National Income. The "technical coefficient" a_{ij} represents the number of units of the product of sector i absorbed (or generated in the case of pollution) by sector j in producing one

* The coefficients in these tables do not sum to unity because the pollution generated by industry and by final demand is only partially abated in the developed countries and not abated at all in the less developed countries.

Figure 4

PHYSICAL SYSTEM ASSUMPTIONS

| Variables | Developed countries | | | Less developed countries | | |
|-------------------------------|--|--|----------|--|---------|---|
| | Case I | Case II | Case III | Case I | Case II | Case III |
| Extraction output | Capacity limited to 150 % of 1970 levels | | | Endogenous | | |
| Other production | Endogenous | | | Capacity grows 6.4 % per annum between 1970 and 2000 | | |
| Abatement output | Endogenous | | | 0 | | |
| Employment | Increase proportional to population increase | | | Endogenous | | |
| Final Demand | Y | | | Endogenous | | |
| Net pollution emission | E | | | Endogenous | | |
| Net trade in Extractive goods | T ₁ | | | Endogenous | | |
| Net trade in Other goods | T ₂ | | | Endogenous | | |
| Trade balance | B | | | A deficit for Less Developed Countries amounting to 1 % of Developed Countries' income, reflecting capital flows and aid | | |
| Technical Coefficients | A | Unchanged from 1970 | | Twice 1970 levels for Extraction Industry | | Unchanged from 1970 |
| Labor Coefficients | ι | 1/3 1970 levels, due to increased productivity | | 2/3 1970 levels for Extraction Industry | | 1/3 1970 levels due to increased productivity |
| Consumption coefficients | C | Unchanged from 1970 | | | | |
| Extraction goods price | P ₁ | Obtained from solution of price system | | | | |
| Other goods price | P ₂ | Obtained from solution of price system | | | | |

Figure 5
PRICE SYSTEM ASSUMPTIONS

| Variable | Developed countries | | Less developed countries | |
|--|---------------------|---|---|--|
| | Case I | Case II | Case I | Case II |
| Extraction goods price | P_1 | Case III | Case I | Case III |
| Other goods price | P_2 | | | |
| Abatement Price | P_3 | | | |
| Wage rate | w | | | |
| Other value added in Extraction per unit of output | r_1 | Kept at 1970 level (index = 1.0) | Endogenous | |
| Other value added in Other Production | r_2 | | Endogenous | |
| Other value added in Abatement | r_3 | | Kept at 1970 level (index = 1.0) | |
| Technical coefficients | A | Unchanged from 1970 | Twice 1970 levels for Extraction Industry | Unchanged from 1970 |
| Labor coefficients | ι | 1/3 1970 levels, due to increased productivity | 2/3 1970 levels for Extraction Industry | 1/3 1970 levels, due to increased productivity |
| Abatement coefficients | q | $q_1 = q_2 = q_3 = x_3 / (x_3 + E)$, that is, all Abatement coefficients of a given country are set to a value that reduces net pollution to the exogenously specified level E | | |

tion of the Less Developed Countries can be expected to be higher than in Developed Countries. Because of this, the value added earned per unit of output in that sector tends to be relatively low.

Since a principal purpose of the aforementioned United Nations project is a "realistic evaluation of the effects of alternative types of environmental policies on the economic prospects of Less Developed Countries", net pollution emissions E_1 and E_2 are treated as exogenously determined in two of our projections.

Assigning specific numerical magnitudes to all exogenously determined variables permits effective use of a variety of external data in arriving at a unique numerical solution of the formal input-output system. As the empirical inquiry advances, exogenous variables can be internalized through introduction of additional equations.

The most important but also the most demanding step in implementing an empirical input-output system is the determination of values of hundreds or even thousands of structural coefficients. The relevant methodologies are so varied and specialized that I abstain from discussing them in this general context.

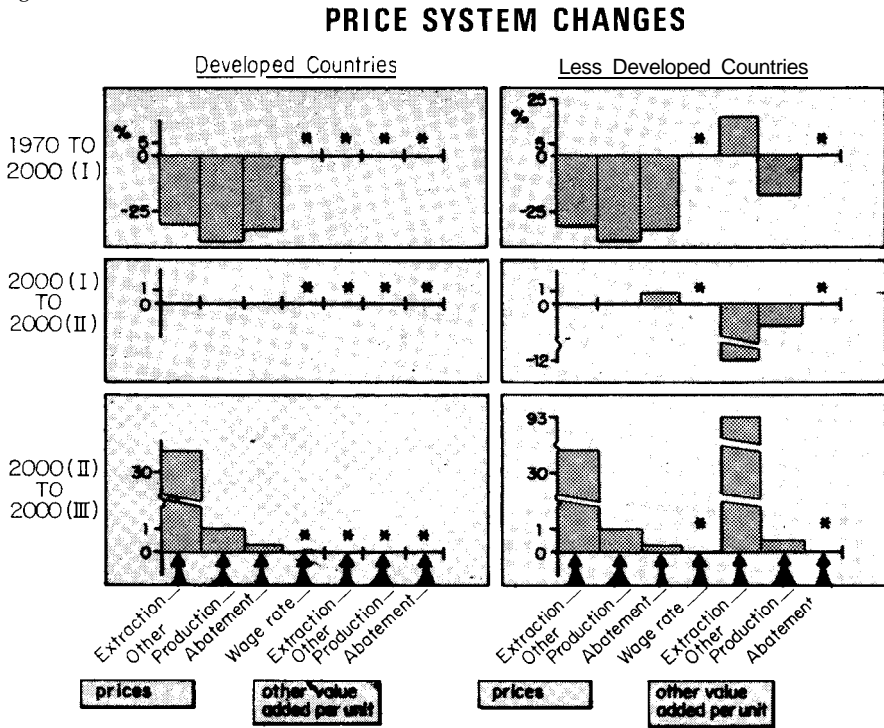
IV

As has been explained above, three different sets of factual assumptions provided the basis for the three alternative projections of the state of one simple world economy for the year "1970" to the year "2000." Figures 4 and 5 contain their full specification, while the results of the computations are summarized in three pairs of input-output tables presented in the Appendix.

The bar charts displayed in Figure 6 and 7 facilitate a systematic examination of these findings. The width of each bar represents the relative size of the corresponding economic activity measured in base-year dollars. The length of each bar indicates the percentage increase or decrease in the level of each activity as the world economy passes from one state to another. Exogenous variables are identified by asterisks.

The long bars in the uppermost rows of these economic profiles indicate an upsurge in output and total consumption and a downward movement of prices: a "great leap forward" from 1970 to 2000. Case I is a projection that critically depends on two assumptions. First, the employed labor force in Developed Countries will increase with population growth. Second, labor productivity in both regions (the reciprocal of the labor coefficient) will be three times as high in 2000 as in 1970, with all other input coefficients remaining the same. Strict enforcement of standards contained in the United States Clean Air Act of 1967 (as amended in 1970) will bring about a sharp drop in unabated emissions in the Developed areas, while in Less Developed Countries the absence of any abatement activity will force the pollution level up. International trade will expand faster than domestic economic activities. Prices (measured in wage units) will decline, while the value added in Less Developed Countries will rise in the Extraction Industry but fall in Other Production.

Fig. 7.



* exogenously specified variable
(1970 values used to compute percentage changes)

Case I: Basic 2000 assumptions.
Case II: Abatement in LDC's.
Case III: Higher extraction costs in DC's.

tries involves a steep increase in the price of Extraction goods compared to other prices, a corresponding rise in value added (rents yielded by the Extraction Industry of the Less Developed Countries) and finally, a substantial increase in imports accompanied by slight reduction of exports from these countries, both reflecting a marked improvement in their "terms of trade."

I refrain from drawing any factual conclusion from the economic projections presented above. The computer received fictitious inputs and necessarily issued fictitious outputs. All theories tend to shape the facts they try to explain; any theory may thus turn into a procrustean bed. Our proposed theoretical formulation is designed to protect the investigator from this danger: it does not permit him to draw any special or general conclusions before he or someone else completes the always difficult and seldom glamorous task of ascertaining the necessary facts.

PROJECTED WORLD ECONOMY IN 2000 (CASE I)
(Billions of 1970 dollars)

DEVELOPED COUNTRIES

| | Extraction Industry | Other Production | Abatement Industry | FINAL DEMAND | | Total Output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 316 | 0 | 8 | -226 | 98 |
| Other Production | 33 | 7502 | 160 | 9713 | 357 | 17765 |
| Pollution | 8 | 256 | -479 | 240 | 0 | 25 |
| Employment | 9 | 1897 | 51 | 379 | 0 | |
| Other Value Added | 33 | 4129 | 169 | 0 | 0 | |

LESS DEVELOPED COUNTRIES

| | Extraction industry | Other Production | Abatement Industry | FINAL DEMAND | | Total Output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 52 | 0 | 12 | 226 | 290 |
| Other Production | 85 | 1255 | 0 | 2668 | -357 | 3650 |
| Pollution | 25 | 53 | 0 | 73 | 0 | 151 |
| Employment | 36 | 316 | 0 | 226 | 0 | |
| Other Value Added | 112 | 1143 | 0 | 0 | 0 | |

PROJECTED WORLD ECONOMY IN 2000 (CASE II)
(Billions of 1970 dollars)

DEVELOPED COUNTRIES

| | Extraction Industry | Other Production | Abatement Industry | FINAL DEMAND | | Total Output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 316 | 0 | 8 | -226 | 98 |
| Other Production | 33 | 7502 | 160 | 9713 | 357 | 17765 |
| Pollution | 8 | 256 | -479 | 240 | 0 | 25 |
| Employment | 9 | 1897 | 51 | 379 | 0 | |
| Other Value Added | 33 | 4129 | 169 | 0 | 0 | |

LESS DEVELOPED COUNTRIES

| | Extraction Industry | Other Production | Abatement Industry | FINAL DEMAND | | Total Output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 52 | 0 | 12 | 226 | 290 |
| Other Production | 85 | 1254 | 36 | 2632 | -357 | 3650 |
| Pollution | 25 | 53 | -108 | 72 | 0 | 42 |
| Employment | 36 | 316 | 12 | 223 | 0 | |
| Other Value Added | 100 | 1118 | 39 | 0 | 0 | |

PROJECTED WORLD ECONOMY IN 2000 (CASE III)
(Billions of 1970 dollars)

DEVELOPED COUNTRIES

| | Extraction Industry | Other Production | Abatement Industry | FINAL DEMAND | | Total Output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 315 | 0 | 8 | -225 | 98 |
| Other Production | 66 | 7472 | 159 | 9678 | 461 | 17836 |
| Pollution | 8 | 255 | -477 | 239 | 0 | 25 |
| Employment | 19 | 1890 | 51 | 378 | 0 | |
| Other Value Added | 33 | 4112 | 168 | 0 | 0 | |

LESS DEVELOPED COUNTRIES

| | Extraction Industry | Other Production | Abatement Industry | FINAL DEMAND | | Total Output |
|---------------------|---------------------|------------------|--------------------|--------------|-------|--------------|
| | | | | Domestic | Trade | |
| Extraction Industry | 0 | 51 | 0 | 13 | 225 | 289 |
| Other Production | 85 | 1254 | 37 | 2735 | -461 | 3650 |
| Pollution | 25 | 53 | -111 | 75 | 0 | 42 |
| Employment | 36 | 316 | 12 | 232 | 0 | |
| Other Value Added | 189 | 1125 | 40 | 0 | 0 | |