STRUCTURE OF THE WORLD ECONOMY

Outline of a Simple Input-Output Formulation*

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by

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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

[1] Quoted 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 Domestic	FINAL DEMAND Trade	Total output
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 Domestic	FINAL DEMAND Trade	Total Output
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 activites.[2] Inputs 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.

[2] All 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) $(1-a_{11})x_1 \; - \; a_{12}x_2 \; - \; a_{13}x_3 \; - \; c_1y \; - \; T_1 \; = 0$

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

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

(2) $-a_{31}x_1 - a_{32}x_2 + (1-a_{33})x_3 \; - \; c_3y \; + \; E \; = 0$

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

Fig. 2.

TECHNICAL AND CONSUMPTION COEFFICIENTS*

Developed Countries

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

$$\iota_1 = [\,.2867 \quad .3203 \quad .3161\,] \qquad \iota_1^c = [\,.1050\,]$$

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

Less Developed Countries

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

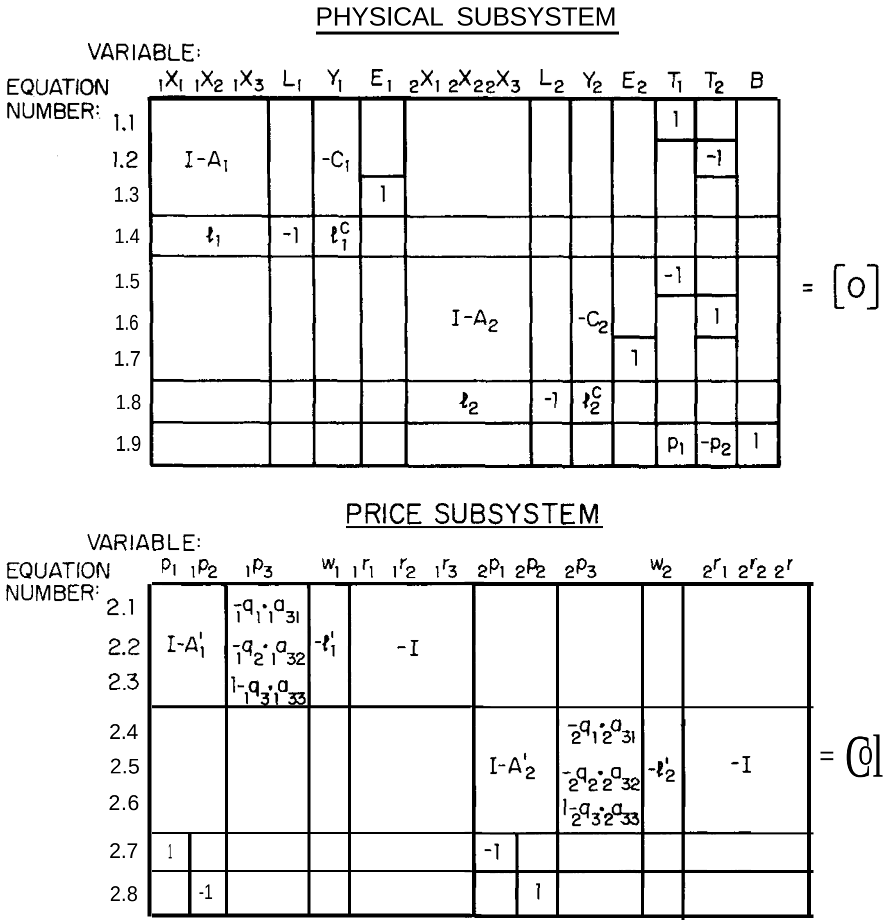
$$\iota_2 = [\,.3729 \quad .2597 \quad .3161\,] \qquad \iota_2^c = [\,.2020\,]$$

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

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.

Fig. 3.



unit of its output; c_j is a "consumption coefficient" describing the number of units of the output of sector j consumed (or generated in the case of pollution) per unit of total value added, i.e., per unit of Gross National Income.

Figure 3 displays the complete set of linear equations describing the physical balances between outputs and inputs of all sectors in both countries in terms of compact matrix notation. The last of these equations - written below in its explicit form - describes the flows of exports and imports that link the Developed and Less Developed areas into a single world economy.

$$B = T_2p_2 - T_1p_1 \tag{3}$$

The balance of trade B, i.e., the difference between the monetary value of the two opposite trade flows, depends not only on the quantities T_1 and T_2 of traded goods but also on their prices, p_1 and p_2. The higher the price a country receives for its exports, or the lower the price it pays for imports, the better are its "terms of trade".

The last of the three sets of relationships describes the interdependence of the prices of all goods and services and the values added paid out, per unit of output, by each industry. For example, a typical equation in this set states that the price at which the Extraction sector sells one unit of its output equals the average outlay incurred in producing it. This includes the costs (i.e., quantities X prices) of inputs purchased from other sectors, wages paid and all other value added:

$$(4) \qquad \underbrace{p_1}_{\text{price of output}} - \underbrace{a_{11}p_1 - a_{21}p_2}_{\text{cost of material inputs}} - \underbrace{q_1 a_{31} p_3}_{\text{cost of pollution abatement}} - \underbrace{\iota_1 w}_{\text{cost of labor inputs}} - \underbrace{r_1}_{\text{other value added}} = 0$$

The technical coefficients (a_{ij} and ι_i's) appearing in this equation are the same as those appearing in the structural matrices of Figure 2. The abatement ratios q_i represent the fraction of the gross pollution emission of industry i that is eliminated (at that industry's expense)* by the Abatement Industry.

In this example, the system of physical balances contains 9 equations with 15 variables, while the price-values-added system has 8 equations with 14 variables. But these 14 variables are reduced to 12 and the number of equations to 6 if one assumes from the outset that the internationally traded products of the Extraction Industry and Other Production have the same price in the Developed and the Less Developed Countries. Equations 2.7 and 2.8 worked out explicitly read:

$$(5) \qquad {}_1p_1 = {}_2p_1 \; (\equiv p_1) \text{ and } {}_1p_2 = {}_2p_2 \; (\equiv p_2)$$

The combination of both systems viewed as a whole contains 29 unknowns but only 17 equations. Thus, to arrive at a unique solution, we have to fix the values of 12 variables on the basis of some outside information, i.e., their values have to be determined exogenously.

Two types of quantitative information are required for the solution of this system. First, some data are used in the form of appropriate structural coefficients. Other kinds of factual information are introduced by assigning specific numerical values to appropriate "exogenous" variables.

In view of the uneven quality of data that will constitute the empirical basis of the present inquiry, it would be a tactical mistake to pour all the factual information we possess into the rigid mold of a single, all-embracing, inflexible

* This formulation is based on the assumption that the pollution generated by a particular sector is being eliminated at its own expense. In case the abatement cost is being paid out by the government out of its tax revenues, the price equations have to be modified accordingly. See W. Leontief, "Environmental Repercussions and the Economic Structure," *Review of Economics and Statistics*, August 1970 and *The Measurement of Economic and Social Performance*, edited by Milton Moss, Studies in Income and Wealth Series, No. 38 (New York: Columbia University Press, 1973, pp. 565-576.

explanatory scheme. The decision of which variables should be treated as dependent and which should be fixed exogenously is essentially a tactical one. The theoretical formulation is a weapon; in deciding how to use it we must take into account the nature of the particular empirical terrain.

To assess the influence of factors considered external to our theoretical description of the world economy, we earmark six physical and five value added variables as "exogenous". Figures 4 and 5 show which variables are endogenous and assign values to all exogenous variables. These assumptions permit us to project changes in our simple world economy from a state representative of the present ("1970") to three alternative hypothetical states about thirty years hence ("2000 (I)", "2000 (II)" and "2000 (III)").

Total labor input in Developed Countries, L_1, is exogenous: under full or nearly full employment, its magnitude depends on demographic and cultural factors not accounted for within our formal theoretical system. Substantial endemic unemployment in the Less Developed Countries makes it advisable to consider the level of total employment as depending on the level of output - that is to treat L_2 as endogenous.

The output of the Extraction Industry in the Developed Countries is restricted by the limited availability of natural resources. We account for this limitation by making ${}_1x_1$ exogenous. In the Less Developed Countries, where natural resources are still plentiful, the output of the Extraction Industry, ${}_2x_1$, depends partly on a small domestic market but primarily on the import requirements of Developed Countries. Thus, ${}_2x_1$ can be treated as a dependent variable.

The situation is reversed in the case of Other Production. In Developed Countries the output of manufactured goods normally adjusts to the level of final demand, making ${}_1x_2$ a dependent variable. Yet in the Less Developed Countries the output of Other Production, ${}_1x_2$, is restricted by external factors such as weak infrastructure and limited capital. In this case rising domestic inputs usually stimulate a growing demand for imports. Hence, ${}_2x_2$ is treated as independent and T_1 and T_2 as dependent variables.

In the price-value added system of equations, all money wages and other value-added payments in the Developed Countries (w, r_1, r_2 and r_3) are exogenously determined. This means that the prices of all three products can be derived endogenously. In Less Developed Countries the situation seems to be different: since the prices of commodities produced by Extraction and Other Production are determined by the cost of their production (including the exogenous value added) in the Developed Countries, the value added that can be paid out by the two sectors producing these goods in the Less Developed Countries, ${}_2r_1$ and ${}_2r_2$, simply reflect the difference between a given price and the production costs.

Raw materials are, as a rule, relatively more abundant and more cheaply extracted in Less Developed Countries, thus the value added earned by Extraction Industries in Less Developed Countries can be expected to be relatively high. Ricardo speaks in this connection of "mining rents". On the other hand, technical input coefficients or, more properly, costs in Other Produc-

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	X_1	Capacity limited to 150 % of 1970 levels			Endogenous		
Other production	X_2	Endogenous			Capacity grows 6.4 % per annum between 1970 and 2000		
Abatement output	X_3	Endogenous			0	Endogenous	
Employment	L	Increase proportional to population increase			Endogenous		
Final Demand	Y	Endogenous					
Net pollution emission	E	Limited to current levels assuming 1970 standards			Endogenous	Limited to twice 1970 levels	
Net trade in Extractive goods	T_1	Endogenous					
Net trade in Other goods	T_2						
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						

Figure 5

PRICE SYSTEM ASSUMPTIONS

Variable		Developed countries			Less developed countries		
		Case I	Case II	Case III	Case I	Case II	Case III
Extraction goods price	P_1	Endogenous					
Other goods price	P_2						
Abatement Price	P_3						
Wage rate	w	Kept at 1970 level (index = 1.0)					
Other value added in Extraction per unit of output	r_1	Kept at 1970 levels (index = 1.0)			Endogenous		
Other value added in Other Production	r_2						
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.

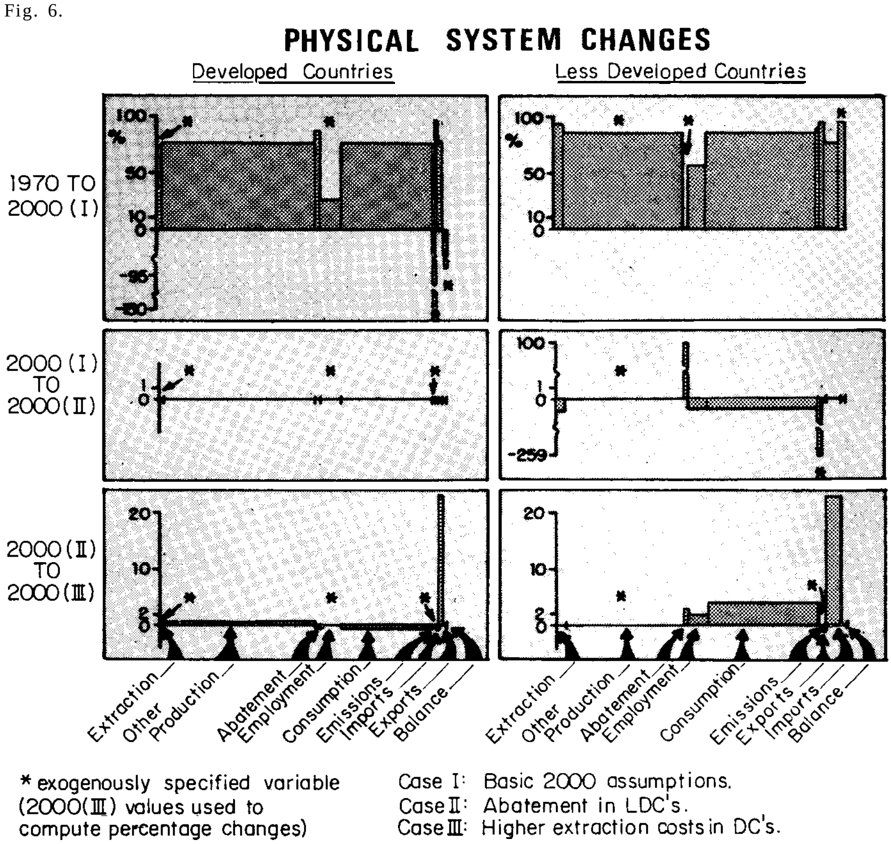
IV

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.

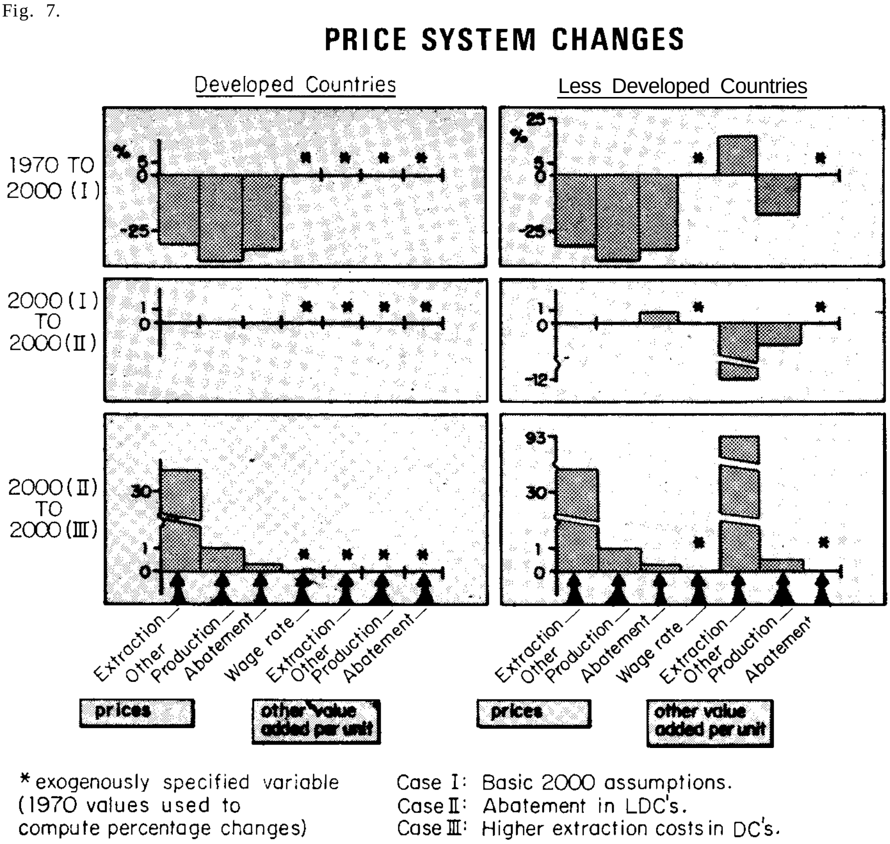
Fig. 6.



How would the future economic picture change if strict anti-pollution standards were also observed in Less Developed Countries? The answer is presented in the second row of bar graphs on Figures 6 and 7. In the Developed Countries there will be practically no change. In Less Developed Countries the inauguration of abatement activities aimed at limiting pollution to twice its 1970 level would bring about expanded employment while requiring some sacrifices in consumption. Value added would fall sharply in the Extraction Industry and somewhat less in Other Production.

How would the situation thus attained be affected by a significant increase in the operating costs of the Extraction Industry in the Developed Countries? The bottom row of profiles in Figures 6 and 7 shows how the conditions in both regions of the world economy would be affected if the productivity of labor in the Extraction Industry of Developed Countries rose only 1 1/2 rather than 3 times between 1970 and 2000 while the amounts of other Extraction inputs doubled per unit of output. The output of Other Production in the Developed Countries would register a slight increase and the level of consumption a slight decrease. Consumption in the Less Developed Countries would experience a substantial increase. The mechanism responsible for such a redistribution of income between the Developed and Less Developed Coun-

Fig. 7.



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 trace."

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

LESS DEVELOPED COUNTRIES

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