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SEMINAR ON THE DEVELOPMENT OF THE CHEMICAL INDUSTRIES IN LATIN AMERICA*

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PLANNING OF THE CHEMICAL INDUSTRIES AT THE NATIONAL LEVEL

presented by

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Introduction

The chemical industries constitute one of the dynamic sectors of a modern economy. These industries, together with other manufacturing activities, expand substantially faster than the economy as a whole: the growth rate for the chemical industry is, roughly speaking, some two-thirds higher than the growth rate of the economy.[1/] [2/] The chemical industry also expands faster than manufacturing itself, since food and textiles, which form a large part of manufacturing output, depress the overall growth of the manufacturing sector. Apart from the latter industries, however, most of the other manufacturing industries show growth rates that are comparable to that of chemicals, or higher. These

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1/ The best information that is available refers not directly to growth rates but to the related concept of growth elasticities derived from cross-section studies covering countries with different per capita income levels. The growth elasticity of the chemical industry is 1.66, as determined by Chenery (Patterns of Industrial Growth, 1960). The numerical data presented in the text have either been taken from this source, or have been calculated from the correlations to be found there. See also: UN-Stat. Off. (1963:PIG), UN-Stat. Off. (1963:GWI), UN-Centre for Industrial Development (1963:SIG).

2/ References to the bibliography at the end of this paper are usually given by the author and year of publication. If a possibility of confusing several items should exist, the first three significant initials of the title are added.

/industries include

industries include clothing, wood, paper, leather, rubber, petroleum, non-metallic minerals, metals, machinery and transport equipment.[3/]

The dynamic nature of the chemical industry is manifest not only in its rate of growth but also in the rapid pace of technological change which is one of the outstanding characteristics of this industry. Both the nature of its processes and of its products is in rapid and continuous transition, and the expenditures on research and development,[4/] as well as the role which these activities play in management decisions pertaining to the industry, places it among the most "research-minded" of the industrial sectors.[5/]

Table A indicates the orders of magnitude of the participation of the chemical industry in gross national product, the manufacturing sector, and imports, at three different country sizes and income levels. In part one of the table, the absolute values of per capita production and per capita imports are given for the chemical industries.[6/] As can be seen, both production and imports increase sharply with income level. Production also increases with country size, but imports diminish for larger countries, indicating a substantial influence of country size on the possibilities of replacing imports by national production.

3/ The growth elasticity of manufacturing is 1.44, thus this sector grows substantially faster than the economy as a whole. Food and textiles have growth elasticities of 1.13 and 1.44, respectively; rubber, metals, machinery and transport equipment have growth elasticities of 2 or over.

4/ Indices concerning the rate of change of the product assortment of an industry and data on research and development expenditures will be found in Sec. II-E.

5/ See McLaurin (1954).

6/ Chenery's figures are based on the definition of the chemical industry as industry No. 31 of the United Nations International Standard Industrial Classification UN-Stat. Office (1958:ISI). See also following section on "Coverage".

/TABLE A

TABLE A

Chemicals

PART ONE

Production: value added, US$ per capita

Imports: US$ per capita

Population (10^6)		INCOME: US$/CAP		
		100	300	600
1	Production	.28	1.75	5.50
	Imports	2.08	5.93	11.21
10	Production	.51	3.16	9.95
	Imports	1.18	3.37	6.37
100	Production	.93	5.72	18.01
	Imports	.67	1.91	3.62

PART TWO

% of GNP

Population (10^6)		INCOME: US$/CAP		
		100	300	600
1	Production	.28	.58	.92
	Imports	2.08	1.98	1.87
10	Production	.51	1.05	1.66
	Imports	1.18	1.12	1.06
100	Production	.93	1.91	3.00
	Imports	.67	.64	6.03

(Table A (cont'd)

Table A (Cont'd)

PART THREE All Manufacturing

Value Added per capita

Population (10^6)	INCOME: US$/CAP		
	100	300	600
1	7.54	36.70	99.56
10	11.92	57.99	157.40
100	18.85	91.68	248.85

PART FOUR % of GNP

Population (10^6)	INCOME: US$/CAP		
	100	300	600
1	7.54	12.23	16.59
10	11.92	19.33	26.23
100	18.85	30.56	41.48

PART FIVE Chemical production as % of all manufacturing

Population (10^6)	INCOME: US$/CAP		
	100	300	600
1	3.71	4.77	5.52
10	4.28	5.45	6.32
100	4.93	6.24	7.24

(Table A (cont'd)

Table A (Cont'd)

All Imports

PART SIX US$ per capita

Population (10^6)	INCOME: US$/CAP		
	100	300	600
1	38.96	115.33	229.10
10	20.40	60.38	119.95
100	10.68	31.61	62.80

PART SEVEN All imports as % of GNP

Population (10^6)	INCOME: US$/CAP		
	100	300	600
1	38.96	38.44	38.18
10	20.40	20.13	19.99
100	10.68	10.54	10.47

PART EIGHT Chemical imports as % of all imports

Population (10^6)	INCOME: US$/CAP		
	100	300	600
1	5.34	5.14	4.89
10	5.78	5.58	5.31
100	6.27	6.04	5.76

/In the second

In the second part of the table, chemical production and imports are expressed as percentages of gross national product. Production varies from 0.28 per cent at an income level of 100 US$/capita and a country size of 1 million inhabitants, to 3 per cent for a country with an income level of 600 and a population of 100 million. (The 600 dollar income level represents a convenient upper limit to the range of incomes that are of direct interest to the less developed countries. The correlations, however, extend also to higher incomes).

In the third and fourth parts of Table A, the typical position of the manufacturing sector as a whole is indicated; in the fifth part, chemical production is related to the manufacturing sector. It can be seen that the chemical industries typically represent from about four up to seven percent of total manufacturing.

In parts six and seven, the typical role of imports is presented; part eight indicates the significance of chemical imports within total imports. It may be seen that the fraction of chemical imports within total imports is remarkably constant both with income level and with country size: it is between 5 and 6 per cent.

On any one of the above criteria, the chemical industries form a significant part of the industrial structure in developing countries. In view of the importance and the dynamic nature of these industries, it is not surprising that developing countries pay increasing attention to the possibilities of expanding them. Since chemicals are largely imported in the early stages of development, the existence of a domestic market is often self-evident; in addition, many countries have raw materials which can be turned to economic use in chemical processes. It is also envisaged that the new chemical industries will give employment to a significant number of workers and will be instrumental in training them to higher levels of specialized skills.

It is the objective of the present report to investigate carefully the

/extent to

extent to which the expectations in regard to the potential of the chemical industries can be realized in developing countries. In particular, the problems of planning the development of these industries will be taken up in detail. Since no sector of an economy can be planned in isolation, the first part of this paper will focus on the relationship between the planning of the chemical sector as a whole and overall industrial and national economic planning. In the second part, the principal features of the chemical industry and their relation to planning within this sector will be taken up: the problems of economies of scale and markets, raw materials, labour, equipment needs, and research and development.

Coverage

The field of the chemical industry can be defined to comprise, besides the production of chemicals proper, a number of other related industrial branches. On the one hand, the production of certain raw materials which the chemical industry uses may be treated as part of the chemical industry for some purposes. Such processes include, e.g., the production of salt from sea water or brines, the separation of certain constituents of natural gas or petroleum refinery gases, etc. On the other hand, many so-called "end-chemical products" can be logically thought of as belonging to the chemical industry, such as plastic materials, rubber, fertilizers, insecticides, pharmaceuticals. In addition to these, there are a number of important industries and industrial branches in which chemical-type processes predominate and which are closely related to the chemical industry. These industries are often referred to as chemical process industries: for example, chemical metallurgy, pulp and paper, petroleum refining, cement.

The principal raw materials of the chemical industry are listed in Table B; end-chemical products are listed in Table C. Chemical process industries are listed in Table D.

/Table B

Table B

Principal raw materials of the chemical industries

Hydrocarbons:	petroleum, natural gas, liquefied petroleum gases, fuel oil
Carbon:	coal, lignite, graphite, coke, petroleum coke
Other minerals:	sulphur, salt, limestone, phosphate rock, potassium salts, fluorspar, sand, pigment minerals
Raw materials of organic origin:	cellulose, fats and oils, waxes, naval stores, bones and hides, molasses, agricultural wastes
Other:	metals

Table C

Principal end-chemical products

Inorganic:	fertilizers, copper sulphate, pigments
Organic:	solvents, dyes, pharmaceuticals, insecticides, pesticides, herbicides, detergents, essential oils, cosmetics, perfumes, explosives, tetraethyl lead
Organic polymers:	plastics and resins, synthetic fibres, rubber, adhesives, glue and gelatine, gums
Compounded and miscellaneous products:	paint and varnish; oils, fats and waxes; photosensitive surfaces (film etc.)

/Table D

Table D

Chemical Process Industries

Chemicals

End-chemical products

Thermoelectric power generation
Water purification and waste water treatment
The coking of coal

Petroleum refining, including topping, cracking, visbreaking, coking, polymerization, alkylation, reforming, hydrogen treating, desulphurizing, etc.

Cement, lime, gypsum and magnesium products

Ceramics and glass
Chemical metallurgy of ferrous and non-ferrous metals

Electrothermal products; abrasives

Leather tanning

Textile dyeing and finishing

Pulp and paper

In the standard industrial classification (ISIC) of the United Nations,7/ the chemical industry appears as class 31 and comprises the following subclasses:

- 311: Basic industrial chemicals including fertilizers; organics, dyes, explosives, synthetic fibres, resins, plastics, rubber, nuclear materials
- 312: Vegetable and animal oils and fats
- 313: Paints, varnishes and lacquers
- 319: Miscellaneous: pharmaceuticals, cosmetics, soaps, polishes, inks, matches, candles, insecticides.

The focus of attention for the present paper has been on the production of homogeneous basic chemicals. Other branches of the chemical industry, widely defined as above, have been of interest primarily insofar as they represent input requirements for the basic chemicals.

/PART I

7/ UN-Stat. Office (1958:ISI)

PART I

RELATIONSHIP BETWEEN THE PLANNING OF THE CHEMICAL SECTOR AND OVERALL INDUSTRIAL AND NATIONAL ECONOMIC PLANNING

A. The objectives of industrial development

While it can be taken as a starting point that the objective of economic development is the growth and diversification of an economy, it is significant to ask what the specific role of industry should be within this wider objective, and how the development of the chemical industries in particular is related to the role of industry as a whole.

Industrialization is the leading edge of economic development: it is the carrier of modern technology, of new ways of organization, and of the entire social transformation which is implied by the concept of development.[8/] It is, therefore, natural that the industrial sector will have to carry a significant share of the burdens and problems raised by the process of development. From the point of view of the planner, there are three areas in particular which require constant attention: (1) foreign-exchange balance, (2) employment, and (3) structural vulnerability versus flexibility.

1. Foreign trade problems

Economic growth almost universally places a heavy strain on the balance of payments. Import requirements engendered by investment needs,

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8/ On the role of industrialization in economic development see for example, Chenery (1955:RID; 1960:PIG) UN-ECAFE (1960:PTE; 1961:FID), UN-Stat. Office (1963:PIG), Bryce (1960), Baran (1957), Hirschman (1958).

For comprehensive bibliographies of economic and industrial development see UN-HQ Library (1962), US-ICA (1960:IED), Hazelwood (1959). On the planning of industrial development see UN-ECLA: The Industrial Development of Peru (1959), Arnold, Borchert and Schmidt (1957), Academy of Sciences, USSR (1956), Lesz (1952), Tinbergen (1952-1956), US-ICA (1958), UN-ECAFE (1961), Lubimzev (1963), and the materials of the United Nations Seminar on Industrial Development Programming held in Sao Paulo, 4-15 March 1963. On the use of mathematical models in planning, see UN-Div. Ind. Dev. (1961:UMP). For a preliminary bibliography on industrial development programming in general, see Vietorisz (1962:PBI) and on the programming of the chemical industries, UN-Bull. Ind. Prod. (1963:PBI).

/intermediate-product

intermediate-product and consumption goods demand increases outstrip the increase in traditional exports,[9] and a structural change in the direction of import substitution and the generation of new lines of export is called for. Industry is the sector from which a contribution to the solution of this problem is primarily expected. Even the contributions that can and must be made by agriculture to the closing of the foreign-exchange gap depend heavily on a structural transformation of agriculture -its modernization and technification (use of fertilizers, agricultural machinery) - which has to lean largely on an industrial base to have the best chance of success.

The expansion of the chemical industry has to be viewed against this background. On the one hand, its development can replace substantial amounts of existing imports and even more significantly, potential imports that would be generated by the process of development itself; on the other hand, the chemical industry can constitute a large drain on foreign-exchange resources through its needs for capital investment, for maintenance and replacement, as well as for current inputs of foreign raw materials and intermediate goods. Royalties, profit remissions and amortizations due to foreign-licensed or foreign-owned processes constitute a further foreign-exchange drain. These foreign-exchange needs depend crucially on whether, simultaneously with the development of the chemical industry, other industries and the extractive industries, are also developed or not; they also depend heavily on considerations involving economies of scale and the domestic growth of research and development activities, as will be shown below.

2. Employment

In regard to employment, economic development generally means the displacement of working population from rural areas to the cities as

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9/ See, for example, UN-ECLA (1951:TDD): Economic Survey of Latin America, 1949, Part I; UN-ECLA, The Industrial Development of Peru (1959), Summary.

/agricultural productivity

agricultural productivity rises, and its absorption by industry, for whose expansion it constitutes the indispensable manpower base. Unfortunately, the smooth functioning of this structural transformation presupposes at least two conditions which are rarely met.

(a) Considerably higher rates of growth than have been realized in most of the developing areas. Under conditions of insufficient overall growth coupled with a largely autonomous urban-rural migration (which is nevertheless insufficient to cope with rural underemployment) there is a general oversupply of untrained labour.

(b) Much larger investments in education and training than have been allocated to this purpose in most developing areas. Consequently, the employment problem presents itself in the guise of an oversupply of untrained labour together with a shortage of critical skills and a low general productivity. In this situation, industry is charged with the task of helping to alleviate the unemployment problem by creating additional jobs with the right distribution of skills.

This problem, as posed, is capable only of palliative solutions; in the short run, nevertheless, such palliatives can assume considerable urgency. Unfortunately, the structure of new consumer demand at the per-capita income levels of the developing countries is heavily weighted towards additional goods as against additional services;[10/] simultaneously, the investments which are needed to keep the growth process going also translate themselves into a demand for the kinds of goods whose production is intensive in capital and skilled labour and slack in regard to unskilled labour.

Among all industries, the chemical-process sector in particular constitutes a typical and often an extreme case of this pattern. Huge chemical plants or petroleum refineries can be satisfactorily run by a

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10/ For data and methods on consumer expenditures at different income levels, see Houthakker (1957, 1960, 1961), UN-Centre Ind. Dev. (1963:MAP).

/handful of

handful of operators, and very little opportunity exists for replacing equipment or skill requirements by untrained labour.[11] For example, it is impossible to compress synthesis gas to hundreds of atmospheres in order to make ammonia, no matter how many common labourers are set to the task with their bare hands. Thus, very little is to be expected of the chemical industries in attempting to mitigate the unemployment problem. Conversely, at high rates of growth when manpower shortages become binding on the potential of development, the chemical industries become especially attractive due to their high labour productivities.

3. Structure

The issue of structural vulnerability versus flexibility is a third area in need of critical attention in development planning. Underdevelopment is not only a matter of a low level of per capita income: it also has a structural dimension, typically represented by a poor integration between diverse activities, and consisting, in the extreme, in a precarious reliance on one or a few crops or one or two dominant extractive industries. In such situations, trade on the world market is the principal means of meeting many fundamental economic needs, and crop failures or adverse price movements in key markets can have catastrophic consequences for the economy as a whole. The most elementary prudence suggests that economic development should be guided with an eye to cushioning such shocks, even if this means some sacrifice - in the nature of an insurance premium - in terms of maximum growth under fortuitously optimal outside conditions.

The problem has two aspects:

(a) The supply of the critical resource (or resources) has to be diversified and its overall demand, if possible, reduced. This means in practice primarily the diversification of exports and a general tendency toward import substitution, since foreign exchange is generally the most vulnerable scarce resource. In addition to foreign exchange, basic food

11/ See Section II-D.

/crops may

crops may also come under this heading, with a strong indication for diversification and partial substitution by other food staples.

The potential contribution of the chemical industries to import substitution has already been touched upon earlier, and will be taken up in detail in Part II below. The opening up of new lines of chemical exports offers generally poor promise unless it results from solid joint-planning arrangements between countries within a common market. As far as crop diversification is concerned, chemical fertilizer industries may make a substantial contribution in this field.

(b) The demand for the critical resource has to be made elastic with regard to price so that a sudden increase in its cost may be cushioned by a substantial fall in demand. For example, a prudent raw-materials policy for a country in this situation is the maintenance, if possible, of standby lower-grade domestic resources in readiness for exploitation as a second line of defence if the supply of the customarily utilized higher-grade imports is shut off due to a general foreign-exchange squeeze. The possibilities of raw-material, fuel and other input substitution in the chemical industries are excellent in the long run but poor in the short run unless special provision is made for them ahead of time. Without such a provision, many chemical processes are totally dependent on inputs of highly specific kinds, and the time lag required for effecting a change may be as long as the lifetime of the equipment used. In addition, taking best advantage of the possibilities for flexibility offered by local conditions presupposes a substantial local ability in the field of research and development.

Another example of great importance relates to the establishment of the final stages of chemical manufacturing without a supporting domestic heavy-chemical base. Such a course has certain advantages from the point of view of economies of scale and import substitution, but it also entails considerable risks due to the resulting inflexibility of foreign-exchange demand for intermediate chemical commodities. This point will be taken up later in more detail.

/After this

After this brief survey of the objectives of industrial development from the point of view of the chemical industries, we now turn to the basic problems faced by all planning efforts, and to the tools available for tackling them.

B. Basic problems and planning tools

All economic plans have to satisfy criteria related to consistency, efficiency and feasibility; in addition, plans have to allow for several levels of decentralization in their conception, elaboration and execution.[12/] The present section is dedicated to these problems.

1. Trend projections and consistency problems

Consistency in regard to a plan means that resource supplies will be balanced with their demands: in other words, the plan will not attempt to allocate between alternative uses of a larger quantity of any scarce resource than the amount that is planned to be available.

In relation to the chemical sector, consistency implies:

(a) The sources (production, imports), of any chemical product are equilibrated with the uses (inputs to other industries, final demand) of the same product;

(b) The requirements of basic factors (labour, capital, foreign exchange) and of intermediate products arising in the chemical industry are consistent with requirements and available supplies in the economy as a whole.

Consistency problems arise chiefly in connexion with the simplest and most widely utilized methods of plan preparation, namely trend projections and priority schemes. (In the more sophisticated planning methods, e.g., the efficiency models to be discussed below, consistency is

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12/ See for example, Chenery (1958:DPP), UN-ECAFE (1961:FID), Vietorisz (1963:SSE).

/achieved as

achieved as a part of the operation of the model, provided of course that a credible model can be formulated at all). If the historical trends of individual industries are projected forward independently from each other, for example, it is typical to obtain a large foreign exchange deficit, and several intermediate products are also likely to be out of balance. A similar situation arises when priority schemes are applied independently to a large set of projects. The adjustments to eliminate these inconsistencies can be made by revising the historical proportions between domestic production and imports or between individual productive branches, either by means of trial and error in an iterative procedure, or by means of a simultaneous solution of a system of equations using an input-output model.[13/] In either case, it is necessary to have knowledge of the technological structure of production; i.e., of the links between various industries consisting in the use of the output of one industry as an input by another.

As an illustration of the principal linkages between the chemical industry and the rest of the economy, Table I-B-1 shows input coefficients (what the chemical industry uses) and output coefficients (where the chemical industry sells) in a standardized form for several countries. The table shows that the chemical industry is both its own principal supplier and principal customer. Among the inputs, the dominant ones represent raw materials, transport, energy, and various services. The principal markets of the chemical industry are agriculture and the textile, food, rubber and paper industries.

The table also indicates considerable variation in the coefficients between countries, in part due to differences in the definitions of industries and differences in the price structures of the individual countries.

13/ On the problem of consistency in the plan preparation by projection, see UN-ECLA (1955:ITP).

On input-output methods, see for example, Leontief (1951, 1953), Chenery and Clark (1959); Conference on Research in Income and Wealth (1955).

/TABLE I-B-1

TABLE I-B-1

INPUT AND OUTPUT COEFFICIENTS FOR

THE CHEMICAL INDUSTRY

	Input Coefficients[a/] $a_{ij} = \frac{X_{ij}}{X_j} * 10^4$					Output Coefficients[b/] $\alpha_{ij} = \frac{X_{ij}}{X_i} * 10^4$				
	Japan	Italy	Norway	USA	India	Japan	Italy	Norway	USA	India
1. Apparel	1	0	0	0		27	97	4	98	
2. Shipbuilding	0	0	0	0		23	5	28	5	
3. Leather & Pr	1	0	3	3		2	127	95	91	
4. Proc'd food	167	289	81	486	448	301	224	1144	777	116
5. Fishing	226	0	2102	12		4	0	53	0	
6. Grain Milling	21	2	0	28		0	0	0	311	
7. Transport	172	112	56	279		46	1	72	43	
8. Ind. N.E.C.	0	58	0	39		149	184	38	156	
9. Transp. Eq.	0	0	0	1		12	100	20	107	
10. Rubber Prod.	45	1	0	13		216	244	37	444	102
11. Textiles	40	49	12	64		1676	1206	116	600	776
12. Machinery	5	0	0	7		65	69	33	334	131
13. Iron & Steel	63	6	199	118		15	122	50	124	36
14. Nonmet. M. Pr.	73	52	20	74		94	104	35	75	71
15. Lumber & Wood	19	8	21	36		39	40	73	53	21
16. Chemicals	2361	3534	1972	2090	1887	2361	3534	1972	2090	1887
17. Print & Publ.	18	0	1	12		53	68	26	71	
18. Agr. & Forst.	581	235	830	901	237	1440	967	1094	622	633
19. Nonmet. Min.	53	182	125	144	279	5	19	14	15	
20. Pet. Prod.	14	135	177	157		21	50	1	126	
21. Nonfer. Prod.	199	152	35	128		33	67	89	53	
22. Met. Mining	106	106	9	40	*	19	34	13	15	
23. Coal Prod.	234	128	27	86		16	7	0	10	
24. Trade	268	216	296	225		0	40	1	92	
25. PAP & Prod.	452	62	423	260	50	105	293	190	145	163
26. El. Power	198	401	158	66	59	12	0	0	2	
27. Coal Mining	293	85	49	58	135	53	7	4	38	54
28. Services	311	373	84	417	181	502	162	349	312	
29. Pet. & Nat. G.	0	10	0	19		0	0	0	15	
Interindustry Total (U_j/X_j)	6123	6193	6682	5737		(U_i/X_i) 7306	7781	5565	6839	
Total Prod. (X_j)	5853	6678	1299	1356		(X_i/X_i) 10000	10000	10000	10000	
Imports (M_i)	254	630	258	66		(M_i/X_i) 434	943	1986	487	
Total Supply (Z_i)	6107	7308	1557	1422		(Z_i/X_i) 10434	10943	11986	10487	
Final Demand						(Y_i/X_i) 3128	3163	6420	3648	
Unit for Value	10^8 yen	10^8 lire	10^6 kron	10^7 $	10^7 rup					

/Notes to Table

NOTES TO TABLE I-B-1

a/ Input coefficients are defined as

$$a_{ij} = (X_{ij}/X_j) * 10^4$$

where X_{ij} are the corresponding interindustry flows and X_j are the production levels of the consuming industries, both measured in value terms. Output coefficients are defined as

$$\alpha_{ij} = (X_{ij}/X_i) * 10^4$$

where X_i are the production levels of the selling industries.

b/ In the table, input coefficients a_{ij} are given for j: the chemical industry, and output coefficients α_{ij} are given for i: the chemical industry.

Sources: Japan, Italy, Norway, USA: Chenery and Watanabe (1958). In this source, input-output tables for the above four countries are presented on a conceptually comparable basis. India: UN-ECAFE (1961). The Indian data have not been made consistent with the data of the first issue.

/Generally, the

Generally, the preparation of a satisfactory plan requires knowledge of the principal linkages for the country under study, which may pose a difficult statistical problem. If adequate statistics are not available, the linkages may be estimated from data referring to other countries.[14/] In addition, if large changes of the structure of the industry are contemplated in the plan, allowance should be made for the effect of future projects on the historical coefficients. These effects can be estimated on the basis of technical-economic data referring to these projects. The transfer of input-output coefficients from one country to another is far from satisfactory: when it is unavoidable, special care is required to compensate for differences in the definition of industries and in the price structures.[15/]

The material-balance coefficients used for planning in countries with centrally planned economies[16/] are conceptually very closely related to the input-output coefficients mentioned above. In practice, however, three differences arise in their application to developing countries:

(a) These coefficients are expressed largely in physical rather than value units. This is often an advantage, because it eliminates the problem of compensation for price-structure variations.

14/ A bibliography of input-output tables is given in Chenery and Clark (1959). The coefficients of the US input-output tables (450 x 450, 200 x 200, 50 x 50) are available in various degrees of detail. The Japanese and Latin American material is closer to the kind of structure more typical of developing countries. Recent tables are also available for India, Yugoslavia, etc. Coefficients may also be taken from economy-wide linear programming models. At a level of aggregation embodying considerably more detail, the material-balance coefficients used in the planning process of countries with centrally planned economies are also highly useful.

15/ The methodological problems of these compensations are discussed in Chenery and Watanabe (1959).

16/ See references on centrally planned economies listed in first footnote to Sec. I-A; also Marczewski (1956), Montias (1959, 1962).

/(b) Their level

(b) Their level of aggregation is far lower than that customary for economy-wide input-output models. This need not be a disadvantage, provided that there is information available from local sources on the proper weights to be attached to each item.

(c) The coverage of the coefficient is not complete: in other words, only the principal categories in each resource class will be covered, and if they are to be applied to the estimation of input-output relations, the corresponding residuals need to be estimated.

What will consistency-oriented methods achieve in the planning of the chemical industry? Generally, they will eliminate gross errors in the plan if models are used which focus on the national economy as a whole; they will not, however, guarantee the absence of inconsistencies in regard to fine detail, unless balances are drawn up at the corresponding level of detail. Thus, the question of whether these methods lead to plans with a sufficient degree of consistency in their execution hinges on the complementary planning work undertaken at a level of detail considerably greater than that considered in the overall plan. In a mixed economy, this level of detail can at times be left to private enterprise; if there is a failure at this level, however, or if a greater degree of control over the functioning of the economy is desired, detailed material balances or other consistency checks drawn up within the sectors are indispensable. In any event, this level of detail requires explicit attention to problems of decentralization, to be taken up below.[17/]

Examples of consistency-oriented planning of the chemical sector for three countries (China: Taiwan, India, Japan) are available in a survey by the United Nations Economic Commission for Asia and the Far East.[18/] In each of these cases, balances of a few basic chemical commodities are drawn up and projected to a future target date. Further examples

17/ See section I-B-3

18/ UN-ECAFE (1963:IPE).

/of approaches

of approaches to planning and general studies of the chemical industries in a variety of countries will be found in a recent bibliography.[19]

An outstanding example of the utilization of planning methods aimed at consistency is the industrial development study of Peru prepared by the United Nations Economic Commission for Latin America.[20] While not a plan, this published study has pioneered the use of methods which have later been applied to the preparation of national industrial development plans for Chile, Colombia, Bolivia, and other countries. It embodies an interindustry projection for the economy as a whole based on a 20 x 20 input-output table, with historical coefficients which have been modified after allowing for import substitution. The analysis of import substitution possibilities has been undertaken sector by sector in side studies. Among these, the study of the chemical industry has been conducted at a level of detail comprising some thirty branches or individual products, for each of which total demand, national production, and imports have been projected. In these projections, the level of activity in each of the other industries with which significant linkages occur has been considered in detail. The degree of import substitution has been estimated on the basis of existing projects, priority criteria and other available empirical information, without a formal analysis of comparative costs. This study can be regarded as a model of the application of relatively simple formal techniques to the preparation of consistent plans at several levels of detail, with sufficient flexibility in the method to allow incorporation of efficiency criteria, i.e., in regard to import substitution, on an informal, empirical basis.

2. Efficiency problems

The notion of efficiency in economic planning arises in connexion with the choice between alternative courses of action. These alternative courses can be compared in the light of their contribution to socially

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19/ UN-Bull. Ind. Prod. (1963:PBI)

20/ UN-ECLA (1959:IDP)

/desirable objectives,

desirable objectives, primarily economic growth, often made more specific by reference to an increase of national income, consumption or employment, or a decrease in the requirements of some scarce resource, such as capital or certain skills.

Efficiency problems arise in planning due to the linkages in the economic system which induce complex sequences of changes propagating throughout the economy, in response to a simple change applied to almost any of its constituent parts. The formal consideration of the initial and induced changes and the comparison of alternatives, can accordingly become quite complex and has only recently become accessible to precise quantitative study. Nevertheless, the striving towards efficiency in the formulation of development plans is ever-present, no matter if formal methods of analysis are utilized or not. Pricing and priority schemes attempt to furnish criteria for the comparison of alternative courses of action and such schemes can be adopted by reference to an existing market or on the basis of simple empirical considerations (e.g., capital intensity). It is the aim of this section to indicate the more recent methods which have been applied to improving such empirical pricing and priority schemes, and to discuss the possibilities of their utilization in connexion with chemical-industry planning.

Linear programming (with nonlinear extensions)[21/] is the tool which has recently made possible a formal quantitative attack on efficiency problems in planning. While still largely experimental in the latter application, this method has advanced sufficiently far to merit detailed consideration.

21/ Some basic texts on mathematical programming are: Koopmans (1951), Dantzig (1963), Simonnard (1962), Hadley (1961), Gass (1958), Graves and Wolfe (1963). For applications to economic and planning problems, see also Dorfman, Samuelson and Solow (1958), Chenery and Clark (1959), Manne and Markowitz (1963).

/The mathematics

The mathematics of linear programming and some of its nonlinear extensions is well established. The method in general lends itself to solving optimum problems constrained by simultaneous linear inequalities (or generalizations of these) and finds applications in many technical fields including operations research. The difficulty of its application to planning is not a mathematical one, but resides in problems of statistics and other data sources, aggregation problems, the interpretation of results, and other matters of concern to economists. It is fair to say that almost any planning problem that can be sensibly formulated in linear programming terms can also be solved within the bounds of existing knowledge.

A linear programming model of an economy as a whole can best be viewed as an extension of an input-output model. Whereas an input-output model furnishes a single set of balances for all resources of the economy (a single "plan"), linear programming works with a chain of such plans or "programmes", each obtained by modifying a previous one. In order to give the input-output system the necessary flexibility for yielding alternate programmes, it is necessary to provide alternative ways of producing output in at least some of the industries. These alternatives may represent different technologies (e.g. different degrees of mechanization), different locational patterns (e.g., concentrated production versus regional dispersion of facilities) or different trading possibilities (domestic production versus indirect production by means of imports).

Since linear programming works with alternative programmes, it is possible to evaluate each trial programme under some common social objective, and to obtain the next programme in such a way that there is an improvement under the stated objective. The process of adjustments stops when no

/further improvement

further improvement is possible. Each programme in the chain, including the final "optimal" one, is characterized by two sets of quantities: first, the scales at which each of the alternative processes in the various industries are to be operated; and second, the prices at which the scarce resources are to be valued in the programme.[22/] In the optimal programme the production scales are such that all resources are in balance: there are no overdrawn resources, although there may be some free goods which are left partly unutilized. At the same time, the prices are such that all processes simulate perfect competition: there are no profitable processes, only those which break even and/or those which suffer losses. The losing processes are never to be operated at positive scales.

Programmes which are not optimal may show profits on some of the processes: this is an indication that the scales of these processes are being set too low; or else, they may show bottlenecks in regard to some resources: This is an indication that the shadow prices of these resources are too low. Adjustments are carried out accordingly, and thus a next trial programme is obtained.[23/] All of these steps can be carried out by a predetermined mathematical procedure, and optimal solutions for very large problems - involving several thousand resources and activities - may be obtained by the use of electronic computing equipment.[24/]

22/ These prices are called "shadow-prices", in order to distinguish them from prices actually prevailing in the market or in a planned economy. They furnish guidelines for price and wage planning, but they cannot be accepted for planning purposes without important modifications especially in regard to their effects on income distribution.

23/ For correspondence between the mathematical techniques of solving linear programming problems and iterative adjustments that can be undertaken in actual planning practice, see Chenery (1958:DPP), Chenery and Clark (1949), Chap. 4, 11.

24/ Computer programme libraries are being maintained by computer manufacturers. An example of a large linear programming computer code is the LP-90 system widely available in the United States, which can handle problems with over a thousand inequalities. By the employment of decomposition methods, much larger systems whose special structure can be mathematically exploited are amenable to solution by computer. (See Gomory, 1963).

/So far,

So far, only a few linear programming models referring to entire economies have been published: for Southern Italy, Norway, India and Mexico.[25/] The latter has approximately a hundred resources. In addition, a number of models are under preparation, including (to the knowledge of the present author) models for France and Greece, as well as improved models for India and Mexico. What can be learned from these models, and, in particular, in what respect are they useful for chemical-industry planning?

(a) All of these models, whether they incorporate significant detail in regard to the chemical industries or not, are useful as sources of greatly improved pricing and priority criteria for the evaluation of investment projects[26/] in the chemical as well as in other industries. Whereas in the absence of these models, such criteria have to be derived in an approximate fashion, based on single resources (e.g., capital intensity, foreign-exchange use) or combinations of these, at best calculated from considerations of marginal investment, import-substitution, or marginal export activities, with few corrections for the propagating effects of factor use within the interindustry system, the prices derived from linear programming models have the virtue of a consistent view of interindustry relations as a whole. These prices can be applied to the evaluation of detailed projects which do not form part of the model itself.

25/ Chenery (1955:RID), Chenery and Kretschmer (1956), Frisch (1956), Sandee (1960), Manne (1963:KSM).

26/ On investment criteria in economic planning, see Chenery (1953:AIC), Bohr (1954), Galenson and Leibenstein (1955), Eckstein (1957), Novozilov (1956), Massé (1959), UN: Manual on Economic Development Projects (1958), UN-Comm. Ind. Dev. (1963:EPP).

/(b) A model

(b) A model which is sufficiently detailed to include at least one aggregate production process representing the chemical industry, with import and export possibilities also considered, can make an explicit choice between these alternatives, of course at a level of aggregation corresponding to the industry as a whole. In other words, the relative priority of import substitution and possibly of new exports can be evaluated in the chemical industry as against other industries.

(c) If there exists even more detail, representing individual branches of the chemical industries, the corresponding indications with regard to domestic expansion versus imports become more concrete, and the model may even exercise some choice between competing technical processes.

An example of the first kind of model is an illustrative import substitution model based on data from Southern Italy.[27/] This model (see Table I-B-2) has only four sectors (agriculture, basic industries, finished goods, and services), and thus it cannot give direct indications with regard to the role of the chemical industry in relation to other industries. It is suggestive, but not necessarily conclusive, that in the optimal programme derived by the use of this model, the production of basic commodities is set to zero, and their demand is met entirely from imports; the latter are financed by exports of finished goods. The optimal solution also gives a set of shadow prices for the resources that occur in the model, namely the products of each of the four sectors, and the productive factors capital and foreign exchange.

This small model was not intended for planning purposes; it is a reduced illustrative version of a larger model for Southern Italy which has considerably more claim to a realistic representation of the economic

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27/ The coefficients of this model, taken from a model by Chenery (Development Policies and Programs, 1958) have been modified by Manne so as to make investment endogenous (1962:PDP).

/TABLE I-B-2

Table I-B2

ILLUSTRATIVE ECONOMY-WIDE LINEAR PROGRAMMING MODEL

		Finished goods			Agriculture			Basic Ind.			Services	Final demand		
		Prod.	Imp.	Exp.	Prod.	Imp.	Exp.	Prod.	Imp.	Exp.				
	Activity Levels:	780	0	160	380	0	0	0	160	0	280	1.0	Shadow prices of resources	Recalculated shadow price
	Resource surpluses													
Finished goods	0	.73	1.0	-1.0	-.2			-1.8			-.055	-320.	2.90	(1.0)
Agriculture	0	-.3			.9	1.0	-1.0					-105.	3.27	(1.13)
Basic Ind.	0	-.1			-.1			.7	1.0	-1.0		-40.	2.90	(1.0)
Services	0	-.2			-.1			-.1			.9	-60.	.79	(.27)
Foreign Exch.	0		-1.0	.9		-1.1	1.0		-.9	.8			3.22	(1.11)
Capital	-1 460.	-.7			-2.0			-1.8			-.55		1.0	(.35)
Shadow profits on activities:		0.	-.32	0.	0.	-.27	-.05	-.37	0.	-.32	.0	0.	-1 460.	

/Notes to Table I-B-2

NOTES TO TABLE I-B-2

(1) The model is presented in Tucker's condensed format (Tucker in Graves and Wolfe, 1963). The numerical parameters constituting the model appear in the interior of the tableau; the solution values of variables appear in the four margins. These variables are: the activity levels (top) and resource surpluses (left) which constitute one side of the problem; and the shadow prices of resources (right) and shadow profits on activities (bottom) which constitute the other side. In the solution to the model, the surplus of capital is at a maximum (i.e., the required capital is at a minimum) while no other resources are allowed to have negative surpluses (no bottleneck resources); at the same time, the shadow profit on the final demand activity is at a minimum (this is equivalent to giving the highest possible valuation to the commodities in the model) while no other activity shows positive profits (this is an analogue to perfect competition).

(2) Note that input coefficients are negative, output coefficients are positive. When a row of coefficients is multiplied by the activity levels and the products are summed, the total always equals the number in the left margin. Likewise, when a column of coefficients is multiplied by the shadow prices and the products are summed, the total always equals the number in the bottom margin. The row equalities represent balances of input and output quantities for a resource; the column equalities represent balances of input values (costs) and output values (revenues) for an activity.

(3) Note that activities with losses have activity levels of zero, except for the activity whose profit was being minimized, and whose level is unity. In fact, this level had been pre-set when formulating the problem, in order to create a reference scale for the other activities. In the present problem there are no redundant resources (no positive resource surpluses), but if there were any, their shadow prices would be zero, except for the resource whose surplus was being maximized, and whose

/shadow price

(Notes to Table I-B-2, cont'd).

shadow price is unity. This shadow price had been pre-set when formulating the problem, in order to create a reference scale for prices in the model; i.e., this is the "numeraire" resource familiar from economic theory. The solution can of course be recalculated using another resource as numeraire: this has been done in the present case to obtain commodity prices closer to unity (shown in parenthesis at right).

(4) Note that the maximal capital surplus coincides with the minimal profit on the final-demand activity. This equality of the optima of the two sides of the problem is a general property of linear programming problems. Another general property is the one already mentioned in (3) above involving losing activities and redundant resources: this is referred to as the property of "complementary slacks".

/choices confronting

choices confronting the region.[28] It will be useful to consider, however, how a model of even such a high level of abstraction and condensation can provide some background for planning decisions. Given a concrete investment project, the shadow prices derived by the model can be used as indices for adjusting the market prices of the inputs and outputs of an investment project, and thus the evaluation of the project can take into account the effect of an improved allocation of resources as contrasted with the prices observed in a highly imperfect market.[29]

It is of course true that a model with just four sectors is much too crude for planning purposes: the errors due to the aggregation of diverse productive processes and different resources can easily outweigh the advantages of a more rational representation of economic interrelations. Larger models can overcome this objection to a considerable extent, but the problem of aggregated representation of economic reality is never entirely absent from planning models.

In Sandee's model of the Indian economy,[30] for example, chemicals do not occur as a separate industry, but fertilizer is treated as an industry apart. The model makes an explicit choice concerning fertilizer production, imports and exports; to the extent that fertilizer can be regarded as representative of other chemical production processes, this choice can be treated as typical for other chemical lines as well. In addition, the shadow prices of the model, as before, can be used for the evaluation of individual investment projects which are not part of the model.[31]

In Manne's model of the key sectors of the Mexican economy, 32/ the

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28/ Chenery (1955:RID), Chenery and Kretschmer (1956).

29/ On the use of shadow prices in project evaluation, see for example, Chenery (1953:AIC; 1955:RID; 1958:DPP).

30/ Op. cit.

31/ Examples of such evaluations are presented in the reference cited.

32/ Op. cit.

/chemical industry

chemical industry is represented by some twenty separate commodities including sodium carbonate, caustic soda, chlorine, ammonium nitrate, sulphate and urea fertilizers, sulphuric acid, boric acid, ethylene, polyethylene, styrene, polystyrene, butadiene, synthetic rubber, carbon black, dodecilbenzene, tetraethyl lead; in addition, the major petroleum refinery streams also appear individually. Most of these commodities can be produced domestically or imported, and export is allowed as a possibility for some. The optimal programme of the model indicates that it is advantageous to produce domestically each of the above chemical commodities. In addition, as before, the shadow prices of the model can be used for the evaluation of further projects not included in the model.

3. Multi-level planning

It has been indicated earlier that the aggregation of economic processes or of economic resources in planning models reduces the degree of realism of these models. At the same time, there is a limit to the amount of detail that can be usefully included in a central decision-making model. In general, the criterion for inclusion or exclusion of additional detail is this: does the additional detail change in a perceptible way the key conclusion concerning the questions to the study of which the model was directed?

The analysis of more detailed questions is preferably to be undertaken at a lower level, with the aid of models and techniques specifically directed to the problems of an individual sector. These models need not necessarily be of the mathematical programming type. Feasibility studies, locational analyses or project engineering work may all contribute to the evaluation of the detailed choices that present themselves within a sector. Of course, formal efficiency models can be used wherever the data are available. In the chemical sector, much work has been done with models that describe the technology of the industry process by process and which permit the detailed description of many different kinds of industrial complexes which might be advantageous from the point of view

/of economic

of economic development.[33] Some of this work has utilized formal mathematical programming techniques.[34]

One of the reasons why sector analysis is often difficult to correlate with an economy-wide model is the presence of strong economies of scale at the level of individual processes which persist up to scales corresponding to the demand of very large markets (in the chemical industry, markets of entire subcontinents). It is only recently that the mathematical problems raised by such economies of scale have become accessible at all to formal analysis, and the respective methods are far from being ready for routine application. Thus, the effects of such economies of scale generally have to be considered at a less formal, more pragmatic level, and only the results of such a previous study are then incorporated into the more encompassing planning study of the sector.

An additional reason for the separation of economy-wide and sectoral planning studies relates to the availability of data. Planning data at a level of reasonably fine detail are almost never available from standard sources, and have to be generated for the specific purpose in hand. For example, the description of technology pertaining to the chemical utilization of a local raw material such as low-grade coal or an ore which has unusual kinds of impurities requires specific engineering studies even for a preliminary definition of the relevant planning coefficients. Or else, the consideration of a new chemical plant at an unusual location may require the simultaneous sketching out of the structure of new transport arteries and terminals whose planning coefficients depend on local conditions of topography and other variable factors. For this reason, even if a large collection of standard planning coefficients is

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33/ See Isard and Schooler (1955), Airov (1956), Isard, Schooler and Vietorisz (1959), Vietorisz (1961:PDC), UN-ECLA (1963:CIL), Manne (1964).

34/ Vietorisz and Manne (1963), Vietorisz (1963:IDP), Kornai et al. (1963).

/available, these

available, these cannot be used with any degree of confidence unless intermediate results based on them are checked and double-checked by technical experts at every stage of the planning process, and unless these same experts complement the data wherever gaps present themselves. In addition, the information incorporated in planning models has to be kept up to date as time progresses, technology changes, and previous plans are put into execution. This task is unwieldy and in fact next to impossible for others than those who are in day-to-day contact with the detailed problems of the sector in question. These considerations again call for a separation of planning responsibilities into two or more levels.

It is primarily for these reasons that the problems of planning in full sectoral detail cannot be solved by the formulation of ever larger mathematical programming models. If it is further considered that within each sector there is a regional breakdown, that the individual enterprises or projects again have their own additional detail, and within these, sub-processes, components, etc., all have further detail subject to economic decisions, it becomes quite evident that the suggestion of handling the full range of decisions by any single all-encompassing model simply begs the question. What is needed is an explicit modelling of the planning process that takes into account its inevitably decentralized nature and which attempts to make this decentralized decision-making process as efficient as possible.

There are several mathematical techniques of recent origin which analyse sets of hierarchical interconnexions that are in many ways analogous to those that arise in decentralized planning organizations. These techniques go by the name of "decomposition methods" in the field of solving mathematical programming problems.[35/] In applying to the process of planning the main ideas implicit in these methods, attention is

35/ Dantzig and Wolfe (1961), Dantzig (1963), Kornai and Liptak (1962), Mycielski (1963).

/focused on

focused on the type of information that is exchanged between upper and lower planning levels.[36] Typically, the upper levels communicate to the lower levels information pertaining to resource utilization in the form of quantitative resource allocations, or alternately, in the form of accounting prices ("steering prices") to be used in project evaluation. The lower levels, in turn, communicate to the upper levels either pricing information that reflects the tightness of the allocations received, or else the amount of sectoral resource utilization in regard to those resources for which steering prices had been centrally established as guides to allocation. This exchange of information between the upper level and the several lower-level planning units attached to it is utilized at each level to make adaptive responses that tend to improve the overall efficiency of the system.

The powerful decentralizing effect of this hierarchical system is due to the fact that not all resources are subject to central control, but only either the most critical ones, or else, representative aggregates of detailed resources. In the mathematically simplest case, it can be shown that the decentralized system tends to the same optimal programme as a corresponding fully centralized one;[37] in more complex cases, especially those involving aggregation and disaggregation steps which are of crucial importance for practical planning applications, many of the conceptual problems still await definite analysis. It appears to be a reasonable supposition that in such more complex cases, a balance can be struck between the economy of information flow on the one hand, and the theoretical improvement possible with a fully centralized decision-making system, on the other. In other words, cutting down the flow of information in the system makes it easier and faster to arrive at decisions at all levels, but the probable error due to an incomplete exchange of information is increased.

36/ See UN-ECAFE (1961:FID), Vietorisz (1963:SSE).

37/ Dantzig and Wolfe (1961).

/In regard

In regard to planning for the chemical industries, it can be concluded that it is essential to separate economy-wide planning decisions from decisions of secondary importance pertaining to the detailed structure of the chemical sector. Given an economy-wide planning model, the sectoral analysis can be interrelated with such a model in a way that will tend to produce mutual adjustments and cut down areas of planning error, even if the sectoral analysis is undertaken with the aid of less formal methods. In general, the overall model will produce allocations and steering prices of resources for the purposes of sectoral analysis; conversely, the sectoral planning studies will firm up the coefficients of the overall model and help to revise the initial sectoral allocations and steering prices.

4. Execution of Plans: Questions of feasibility and of policy instruments

No matter how carefully the consistency and efficiency of a plan has been studied and a seemingly optimal plan derived by models of interrelated hierarchical planning levels, all of this work will remain without solid foundation if questions of feasibility and practical execution do not permeate the entire planning process. Since many of the considerations under this heading are not yet readily amenable to formal treatment, and some perhaps never will be, the only way of incorporating them in the plans is to use the formally derived results at each stage of the planning process as merely a point of departure, and to modify them in line with judgement and experience. It will be noted that this prescription is an additional argument, and perhaps the most powerful one, in favour of decentralized planning, since judgement and experience have to be brought to bear on problems as near to their source as possible, rather than at some distant planning centre.

Under the heading of feasibility appear all the institutional and political factors with which every practising policymaker is familiar. To cite just a few, military considerations may dictate more self-sufficiency in certain branches of the chemical industry, such as explosives,

/than purely

than purely economic considerations would warrant. Or else, the accustomed minimum living wage and considerations of social equity exclude the direct application of a shadow wage rate to labour even if the latter would induce an efficient resource allocation, and compensating mechanisms have to be found to reduce the false allocation effects of such a minimum wage. Then again, the government may find it impossible to mobilize the resources that would be needed for supporting an optimal public investment programme. Many more examples could be cited.

Under the heading of policy instruments consideration must be given to the detailed effects of putting targets incorporated in plans into execution. Tax and tariff measures, foreign exchange policy, incentives for individuals and for enterprises, monetary and credit policy, public versus private investment, measures to be applied to foreign enterprise, and other policy areas have to be considered in this light.

All of the above institutional conditions and choices of policy instruments will reflect themselves in the parameters of the planning models which may be used, in ways which are not adequately quantifiable. Thus, a given wage policy or a tariff policy that is reflected in the level of real wages may lead to serious repercussions in the field of productivity and thus in the technical coefficients of the model; a change from one-shift to three-shift operation in large segments of the economy may lead to a significant drop in the capital coefficients of some activities; a given industrial development plan implied by a model may turn out to yield unacceptably low levels of employment, etc.

For the time being, only a few aspects of these questions are amenable to quantitative treatment. Some of the effects can be analysed by the efficiency models themselves, with only slight modifications; for example, the effects of planned and controlled prices or a minimum prescribed level of employment can be analysed by means of programming models. In other cases, behavioural relations can be modelled by means

/of "simulation"

of "simulation" techniques[38] which allow the following of highly complex interrelations in the economy through the simple technique of computing the direct effect of each change, one small step at a time. In this way, highly complex patterns of interaction can be traced out through the cumulative consequences of a very large number of small cause-and-effect changes which can be kept track of by means of modern computing equipment.

So far, only a few results of this kind of work have been published as applied to economic development problems in general, and none referring specifically to the development of the chemical industry. Nonetheless, the method is sure to attain considerable elaboration in the near future and is worthy of further attention.

C. Project Generation and Evaluation[39]

In an earlier section on decentralization, it has been indicated that economy-wide planning studies are in general not able to cope with the detailed issues that arise at the level of individual sectors. Planning studies and planning decisions within the sectors have to be organized and undertaken at a separate hierarchical level, coordinated with central planning studies and decisions, but invested with considerable autonomy.

An important aspect of planning work at the sectoral level is the translation of general growth targets for a sector into individual development projects, such as the expansion of existing productive facilities or the establishment of new ones, intensive efforts directed at raising productivity in some branches or introducing quality improvements in others, etc. As indicated before, there is a two-way communication between the sectoral planning process and the overall plan; while general targets are being translated into concrete development projects, the range and

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38/ See Holland (1962), Holland and Gillespie (1963), Rauner and Steger (1962), Duesenberry, Eckstein and Fromm (1960), Orcutt (1960) Shubik (1960).

39/ See the references relating to investment criteria cited in a footnote to Section I-B-2; also Hayes (1959), MIT Conference (1961).

/detail of

detail of these projects in turn reacts back on the overall plan and improves the definition of overall growth potentials.

Development projects may arise independently of the governmental planning process, e.g., they may be generated by the private sector of the economy; often, however, a particular stimulus is required, as a part of the planning effort, to bring forth the right kind of projects, correctly studied and presented in such a way that they will be reasonably easy to compare with competing alternative projects in the same sector or in other sectors. In any event, whether originated by the private sector or by the planning machinery of the government, the generation and evaluation of projects can be viewed from a unified point of view as an important part of the planning process that leads to growth.

From a wide variety of potential development projects, barely visualized and completely lacking in detailed definition, to the concrete engineering blueprints of a few selected projects, there is a series of stages through which most projects pass in the course of sectoral planning. Evidently, it would be wasteful of resources to prepare detailed engineering blueprints for the thousands upon thousands of potential projects which may be technically feasible at a given time and place; therefore, a series of selection steps is undertaken in the course of which the range of potential projects is progressively narrowed and the definition of surviving projects is at the same time progressively sharpened. Three typical stages are: (1) preselection, (2) feasibility studies, (3) project engineering.

1. Preselection

In this stage, the widest possible variety of projects is considered, but only on the basis of a few rudimentary criteria (capital, labour or foreign exchange intensity, markets, raw materials, economies of scale).[40] The emphasis at this stage is on being comprehensive and

40/ For a discussion of such criteria and a listing of relevant data, see Bohr (1954) and US-ICA (1958:MID).

/guarding against

guarding against the omission of potentially attractive projects which for some reason may appear unusual or unorthodox at first sight. In a systematic planning effort aimed at complementing the work of the private sector, special attention has to be paid to the kind of projects likely to be overlooked by private enterprise due to any of the following reasons:

(i) Unusually large financial requirements compared with customary firm size;

(ii) unusually advanced technology compared with prevailing standards;

(iii) integration between processes not customarily so integrated;

(iv) separation of sub-processes not customarily so separated; and

(v) technological requirements diverging sharply from those customary in the more advanced countries.

In the chemical industries, examples of any of these situations are quite usual. In a country characterized by small chemical firms engaged in mixing and packaging type operations, a project involving a large petrochemical complex is unlikely to be forthcoming from the private sector; likewise, where simple basic processes dominate, a sophisticated, computer-controlled gas reaction is less likely to be spontaneously considered than more conventional processes. The example of the advanced industrial countries will, in other cases, exercise a constraining influence on the visualization of alternatives: deviations in organization or technology will not be easily envisaged.

2. Feasibility studies

The second stage comprises feasibility studies, including locational analyses and process-analysis type approaches to individual industrial branches, possibly involving a programming model of a sector as a whole composed of reasonably well-defined individual processes or projects.[41/]

41/ For a general approach to feasibility studies, see Manne and Markowitz (1963), US-AID (1962).

/At this

At this stage, the compilation and refinement of the data advances hand-in-hand with a study of the preliminary results. In addition to the rudimentary criteria which had been used in preselection, in the second stage the principal inputs and outputs of each significant process are defined with sufficient precision to permit an approximate cost-revenue comparison at market prices as well as at social accounting prices.[42] In this regard, "precision" is taken to refer not only to the error associated with a particular input-output scheme, but also to the refinement of the description of a process or a project by means of a set of sub-processes which may be individually adjusted to prevailing conditions of demand and price, and to the disaggregation of resource categories into finer classes revealing more detail.

The point of view adopted in relation to the first two stages may be summarized by saying that in the preselection stage, a decision is taken with regard to allocating scarce resources to be used in feasibility studies, while in the feasibility studies themselves, the allocation concerns the conventional resources: primary factors, basic commodities, etc. The decisions relating to the selection between competing projects are taken at this stage or, in some cases, they may be deferred until detailed project engineering for a few selected projects has been completed. Since project engineering is far more cumbersome, time-consuming and expensive than a feasibility study, it is essential that a great deal of narrowing of the range of choice be undertaken at the feasibility-study level. It is equally essential that an adequate range of well-defined alternatives should be available at the feasibility-study stage, otherwise there will be nothing to select from, and decision-making will inadvertently be pushed back into the stage of preselection.

On the basis of the above, the central position occupied by feasibility studies in sectoral planning can be readily appreciated. Nonetheless, an

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42/ Social accounting prices may be the shadow prices of a mathematical programming model, or if no such model exists, they may be estimated. See Chenery (1955:RID; 1958:DPP).

/advance in

advance in this field is of relatively recent date, since its intermediate position has long placed it out of bounds both for the economist, more used to operating at a higher degree of aggregation or generalization, and the engineer, by training not accustomed to focus on indirect interrelations and repercussions between individual projects. In the chemical sector, nonetheless, a great deal of practically useful work is already available. It has been found easier to describe the technology of this sector (including the technology of other chemical-process type industries) than that of, say, the metal transforming industries. Perhaps this is in part due to the rapid evolution of the chemical industry which has made the feasibility study essential to private and some public investment decisions in the more advanced countries, thereby focusing the interest of chemical engineers on a compact description of technological alternatives, from a point of view which coincides largely (though not wholly)[43/] with that of the planner.

Details of technical-economic description and a critique of the method will be found in the Annex.[44/]

In spite of the relatively favourable situation in the chemical industry in regard to the availability of a suitable method for technological description and a fair collection of data, it is not possible in planning to rely exclusively on any compilation of numerical coefficients without the participation of technical experts in the planning process. This is especially true of new processes whose advantages and drawbacks are not yet clearly established. If technical coefficients are available concerning such processes,

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43/ One lacuna in the engineering data is the scarcity of information for making cost-benefit evaluations at social accounting prices. Cost components are often lumped together at prevailing market prices which may be wholly irrelevant to planning decisions.

44/ See also "Preinvestment Data Summary for the Chemical Industry" (Vietorisz, 1961).

/these can

these can be used to estimate an upper bound on the possible advantages to be gained from the use of the process, since they usually describe operation under smooth conditions, with no allowance for stoppages due to unexpected difficulties. When utilizing technically new processes, however, many unforeseen difficulties are certain to occur, therefore the advantages of the process, as measured under conditions of smooth operation, have to be balanced against the disadvantages of delays, stoppages, the shortfall in production due to the latter, and the resulting bottlenecks that may be experienced in other sectors. If a new process is estimated to be highly advantageous under projected smooth working conditions, it is often worthwhile to accept the attendant difficulties of putting it into operation; if, however, the advantage is only marginal, or if the economy is highly sensitive to shortfalls in the production of the sector in question, then the new process will often have to be eliminated from consideration and more conservative approaches will have to be relied on.

Questions such as these can rarely be resolved either by the economist or by the technical expert alone. On the one hand, the analysis of interactions within the economy is indispensable to predicting the repercussions caused by instability in the new process; on the other hand, the behaviour of the process itself cannot be anticipated without the aid of the technical specialist.

One possibility to be particularly guarded against in planning for the less developed areas is the shifting of the social cost of technical experimentation to these areas which cannot afford such a burden unless they derive a major direct benefit from the technical advance in question. Thus, the temptation should be firmly resisted to consent to the breaking in of an unproven process, when a contribution to the external financing of a project in an underdeveloped country is tied in with the choice of a particular technology. Examples of such tie-ins have not been completely unknown in the past and have on occasions resulted in considerable disadvantages to the areas in question. In such cases, the underdeveloped area accepts a gamble with a poor expectation of a favourable payoff to itself, and with most of the certain benefits going to outsiders.

/3. Project engineering

3. Project engineering

There is little to be said here about the final stage of project engineering other than the aspects already mentioned. It is worth noting, however, that the less developed areas find themselves at a great disadvantage in relation to the more industrialized countries in that the former rarely have top-quality indigenous engineering organizations capable of dealing with the complexities of substantial chemical-industrial projects. A foreign engineering contractor is, first of all, a drain on the foreign-exchange resources of an economy; then, he is also likely to be less aware of local technical requirements and opportunities than a first-class local organization would be. The result is that the foreign contractor often applies elements of his home experience to situations to which the former is not appropriate. It is well-known that many important engineering cost estimating methods are highly pragmatic and not based on well-analysed concepts. They work because situations are repetitive and the methods undergo a gradual evolution and adaptation. An indigenous engineering organization has the opportunity to acquire experience and adapt such pragmatic methods to local conditions.

An example of empirical methods is the use of estimating factors that are based on aggregated costs. In these factors technical relationships, which may be quite stable, are used in conjunction with particular local price ratios, which are highly variable. Thus the transfer of such a factor from one economic environment to another may lead to considerable error. For example, the automatic application of a conventional 6 per cent interest rate that is hidden in certain technical estimates, while quite all right for industrialized countries, can lead to totally unrealistic results in an underdeveloped area.

Further examples relate to such matters as capital versus labour intensity, and the adaptation of processes to local raw materials and local climatic conditions. In the chemical industries, the effects of labour inputs and of climate are likely to be of subordinate importance, because

/the range

the range of capital-versus-labour substitutability is inherently narrow,[45/] while adaptation to a wide range of climatic conditions has already occurred in the industrialized countries. Not so in regard to local raw materials, where considerable adaptation possibilities remain.

In concluding the present section, which has dealt with the relation between chemical-industry planning and economy-wide planning, it is noted that the emphasis has been on target setting and pricing problems, that is, on the more technical issues of planning as distinguished from institutional problems. Among the latter, policy questions relating to a wide range of fields as well as problems of organization for planning have been largely bypassed. The reason for this choice of emphasis was the intention to focus on those areas of planning in which there has been the greatest recent progress in regard to planning instruments. At the same time, it is to be stressed that planning is an art rather than a science; when the available theoretical methods have been pushed to their limit, there remains and probably there will always remain a wide discretionary range within which the planner and policymaker must exercise judgement based on experience rather than rely on formal methods of attack. The objective of theory is to permit these qualities to operate at a higher level rather than to be absorbed in the consideration of problems which are capable of theoretical treatment and thus, of a simple and often mechanical solution.

The next set of questions to be taken up pertains more particularly to the planning problems within the chemical industry itself.

45/ See Section II-D.

PART II

PARTICULAR FEATURES OF THE CHEMICAL INDUSTRIES AND THE PLANNING PROBLEMS ARISING WITHIN THIS SECTOR

A. Markets and economies of scale

The extent to which the development of the chemical industries is promising or not in a particular economy depends critically on the size of the market in relation to the scales of economical-sized plants. In most branches of the chemical industry, this relationship is unfavourable for all but the largest of the less developed areas when attention is restricted to individual national markets. In combined markets the relationship becomes more favourable.

Since this problem is one of the most crucial ones for the development prospects of the chemical industry in these countries, it merits detailed analysis from several angles, a task to which the present section is dedicated.

1. Inter-industry linkages and chemical demand

The demand for the products of the chemical industry in general depends to an unusual degree on the development of an economy as a whole rather than on the development of only a few selected industries.

This conclusion is suggested by a qualitative survey of the principal markets of this industry which comprise households and governments as well as industries producing finished, intermediate and capital goods. (See Table II-A-1).

The qualitative impression of a widespread diffusion of chemical demand throughout the economy is supported by statistical measures.

(a) A substantial fraction of the sales of the chemical industry goes to other industries rather than to final demand. Table II-A-2 shows the percentage share of interindustry demand in total demand for a set of 29 industries, taken from input-output tables that had been made

/Table II-A-1

Table II-A-1

PRINCIPAL MARKETS OF THE CHEMICAL INDUSTRY

Sales oriented to consumption include drugs and pharmaceuticals, cosmetics and soaps, household chemicals and photographic materials, In addition, at one remove but still strongly oriented to final consumption are sales to the following industries:

- processed foods:	acids, cleaning fluids, preservatives, disinfectants
- textiles:	alkalis, detergents, dyes, bleaches, resins and adhesives for sizing, synthetic fibres
- leather:	tanning agents, dyes, bleaches
- printing and publishing:	inks

Intermediate sales to other sectors or industries which are less closely oriented to final consumption:

- agriculture:	fertilizers, agricultural control chemicals (insecticides, herbicides, pesticides), chemicals for animal husbandry (feed additives, veterinarian drugs, disinfectants)
- pulp and paper:	pulping chemicals, bleaches, adhesives
- glass, ceramics:	sodium sulphate, additives
- lumber and wood products:	wood preservatives, resins and adhesives, paint and varnish, bleaches, stains
- metallurgy:	pickling acid (steel), sodium hydroxide (aluminum), flotation chemicals, leaching agents, additives
- petroleum refining:	sulphuric acid, alkalis, solvents.

/Table II-A-1 (Cont'd)

(Table II-A-1, cont'd).

Sales oriented to capital goods and consumer durables. These are intermediate sales to other industries on current account, but they are oriented to capital investment or investment in consumer durables:

- construction:	roofing materials, paint and varnish, adhesives, plastic components. (See also lumber and glass in intermediate group above).
- electrical machinery:	plastics for wire insulation, insulating bases and shapes
- transport equipment:	batteries, plastic for seals and trim, paint and varnish
- household appliances and furniture:	plastic components, enamels. (See also lumber and wood in intermediate group above).

/consistent for

consistent for four different countries.[46] The table has been arranged in the order of increasing average percentage share by industries. It can be seen that the chemical industry appears toward the high end of the spectrum, indicating a high proportion of interindustry demand to total demand:[47] of the order to two-thirds on the average. Thus, chemical demand depends on the productive structure of the economy as much as on a high level of per capita income and consumption. The latter, of course, also has important indirect effects, precisely by way of interindustry linkages.

(b) Interindustry sales are less sharply concentrated for the chemical industry than for many other industries. In other words, the chemical industry has moderately strong forward linkages to many industries rather than overwhelmingly strong ones to a few industries. This is illustrated by Table II-A-3 in which the concentration of interindustry demand is measured by means of the percentage share of total interindustry sales going to the four largest markets of a given industry. The data are based on the 50 x 50 input-output table for the United States for 1947.[48] It can be seen that the chemical industry has the lowest percentage figure in Group I which comprises the extractive and manufacturing industries except fabrication and metal transforming. Thus the chemical industry has stronger interindustry linkages to its secondary markets than other industries in this group.

Group 2 has an average concentration figure of 58 per cent which is slightly above the value for chemicals; however, in this group there is a large scatter and some industries have percentages well below the one for the

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46/ Chenery and Watanabe (1958); also Chenery and Clark (1959, Chap. 8).

47/ It should be noted that the figures given in the table understate interindustry linkages to the extent that these result from sales on capital account rather than on current account. The difference is particularly important for capital-goods industries such as machinery.

48/ Evans and Hoffenberg (1952).

/Table II-A-2

Table II-A-2

SHARE OF INTERINDUSTRY DEMAND IN TOTAL DEMAND

(Percentage)

Products	Japan	Italy	Norway	United States	Average
1. Shipbuilding	6	0	4	22	8
2. Processed foods	17	7	6	19	12
3. Industry n.e.c.	20	10	12	29	18
4. Trade	20	11	21	18	18
5. Transport equipment	22	5	15	33	19
6. Apparel	17	3	35	29	21
7. Transport	24	18	9	36	22
8. Machinery	33	22	9	28	23
9. Non-met. miner. prod.	31	25	19	35	28
10. Services	32	40	33	31	34
11. Leather and products	47	32	28	32	35
12. Printing and publ.	29	0	51	64	36
13. Lumber and wood prod.	35	43	29	40	37
14. Rubber products	56	40	16	48	40
15. Fishing	14	35	66	48	41
16. Grain mill products	13	49	68	66	49
17. Textiles	50	57	46	64	54
18. Electric power	59	58	40	59	54
19. Non-met. minerals	52	51	68	52	56
20. Coal products	84	53	46	60	61
21. Chemicals	70	71	46	65	63
22. Iron and steel	75	88	39	70	68
23. Paper and products	80	75	43	79	69
24. Agriculture and forestry	74	70	61	73	70
25. Petroleum products	79	78	81	47	71
26. Non-ferrous metals	67	94	49	82	73
27. Metal mining	98	85	59	96	85
28. Coal mining	97	101	85	64	87
29. Petroleum and nat. gas	95	100	N.D.	97	97

Source: Chenery and Watanabe (1958).

Note: 1. Industries ordered by increasing share of interindustry demand in total demand, average for the 4 countries.

2. Since sales on capital account are reported as an element of final demand in input-out-put tables, the percentages shown understate the linkages of capital-goods industries to other industries.

/Table II-A-3

Table II-A-3

MARKET CONCENTRATION FOR INDUSTRIES

United States Interindustry data (1947, 50 x 50 table)

	% Top 4 Markets
1. Extractive and manufacturing industries except fabrication and metal transforming	
1. Agriculture and fisheries	92
2. Food and kindred products	91
3. Tobacco manufactures	95
4. Textile mill products	81
5. Apparel	88
6. Lumber and wood products	77
7. Furniture and fixtures	68
8. Paper and allied products	70
9. Printing and publishing	75
10. Chemicals	53
11. Products of petroleum and coal	69
12. Rubber products	67
13. Leather and leather products	76
14. Stone, clay and glass products	64
15. Iron and steel	63
16. Non-ferrous metals	65
Average	75
2. Fabrication and metal transforming including machinery and transport equipment	
17. Plumbing and heating supplies	84
18. Fabricated structural metal prod.	82
19. Other fabricated metal products	46
20. Agr. mining and constr. machinery	46
21. Metalworking machinery	51
22. Other machinery (except. electric)	36
23. Motors and generators	54
24. Radios	75
25. Other electrical machinery	57
26. Motor vehicles	87
27. Other transport equipment	52
28. Professional and scientific equipment	46
29. Misc. manufacturing	36
Average	58
3. Services	
30. Coal, gas, electric power	63
31. Railroad transportation	32
32. Ocean transportation	71
33. Other transportation	37
34. Trade	51
35. Communications	56
45. New construction and maintenance	33
Average	49

/Notes to Table

(Notes to Table II-A-3)

Source: US Interindustry Table, 1947 data, 50 x 50
Ref: Evans and Hoffenberg (1952).

Method: The percentage figure given relates the sum of the top 4 interindustry market flows to the total interindustry flow, both measured in millions of dollars. Interindustry markets are taken to be columns 1 - 45 of the cited table, excepting column 43 (undistributed). Total interindustry flow was computed as total gross output minus the sum of cols. 46 - 50 (final demand).

Critique of the percentage figure as a measure of differential market concentration: This measure is to be regarded as merely a rough indication of the difference in market dispersion between industries. It is intended to capture differences in the degree to which the development of an industry depends on the development of only a few other key industries, versus on development of the economy as a whole.

The data are most solid for group 1. In group 2 the undistributed amount is at times disturbingly large, diminishing the usefulness of comparisons; moreover, a considerable part of interindustry transactions, namely those on capital (rather than on current) account, are not included in the comparison, since such transactions appear as an element of final demand. In group 3, items 31 (railroad transportation) and 33 (other transportation) have disturbingly large undistributed flows.

/chemical industry.

chemical industry. Since many of the industries in Group 2 sell to other industries on capital account rather than on current account, and since the capital-account transactions are condensed into one component of final demand in the input-output tables, the effect is to leave a large part of the combined interindustry flow undistributed. This tends to make the figures of Group 2 less reliable. On general grounds, one would expect this group to show less concentration than Group 1, due to the above-mentioned sales to almost all industries for net investment and replacement purposes.

Group 3 comprises the more important services. Here again, a lower degree of concentration can be expected, since services such as transport, power and communications are inputs to most of the other sectors of the economy.

In sum, the chemical industry tends toward the type of widespread interindustry linkages which characterize the investment-goods and service sectors rather than toward the more sharply concentrated linkages typical of other manufacturing and extractive sectors.

The consequence of the widespread distribution of chemical demand as opposed to its concentration in particular markets is that this industry as a whole tends to develop only in step with the general development of the economy. In other words, there is less scope here than in other industries characterized by more concentrated demands to create a market by the simultaneous expansion of one or two other key industries.[49/]

The above observations, which relate to the chemical industry as a whole, need not necessarily be true of individual chemical products; the demand for these could be more concentrated and yet leave the demand for the industry as diffuse as observed.

49/ An example of the latter kind in another sector would be the establishment of a cement industry to serve a large hydroelectric, road, or other construction programme where the expansion in the cement and the construction sectors was mutually dependent and jointly planned.

/Table II-A-4

Table II-A-4 presents some end-use patterns for three basic inorganic chemicals taken from the economic development plans of Taiwan, India and Japan.[50] It can be seen that the degree of concentration for these chemicals is indeed quite high; for example, for sulphuric acid, the main use (fertilizer) accounts, on the average, for some two-thirds of demand, and for caustic soda and soda ash, the main use is typically one-third or more of total demand. These basic chemicals, moreover, are the ones of most widespread use; there are many other important chemical products, such as heavy organics, whose demand distributions are even more concentrated.[51] This is particularly true of chemical intermediates which are utilized in processing chains leading to specified end-products. Many substances (such as e.g., dimethyl terephthalate) are used entirely for conversion to one other product, in this case, dacron (terylene) synthetic fibre.

In spite of the greater degree of concentration observed for individual chemical products than for the industry as a whole, there are only a few products that are tied to other sectors showing a sufficient degree of structural flexibility to permit their development with a certain degree of independence from the growth of the economy as a whole. Such sectors can be used, together with their complementary chemical processes, as particularly dynamic factors in the planning of development. The most important group of such products comprises fertilizers and agricultural control chemicals. The production of these can indeed be expanded at an accelerated pace when tied to a general agricultural expansion and technification programme. Another example is synthetic rubber, closely tied to the assembly of automobiles and trucks. Further examples, however, are likely to be of minor importance: e.g., tetraethyl lead, tied to

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50/ UN-ECAFE (1963).

51/ For demand distributions in the United States and technical data relating to over one hundred important chemical products, see Faith, Keyes and Clark (1957).

/Table II-A-4

Table II-A4

CHEMICAL END-USE PATTERNS

(Percentages)

Products	Taiwan			India		Japan		
	1956	1961	1966	1961	1966	1955	1960	1970
Caustic soda								
Pulp and paper	43	40	30	22	24	13	13	15
Rayon and synthetic fibers	-	10	18	25	29	47	34	20
Soap	16	12	7	20	15	6	5	3
Chemicals	7	9	8			21	31	42
Textiles	11	9	11	22	16			
Aluminium	9	5	7	2	6	2	3	4
Petroleum refining	2	1	10					
Vegetable oil				2	1			
Other	12	14	9	7	9	11	14	16
Soda ash								
Glass		44		29	29			
Pulp and paper		21		3	3			
Chemicals		12		30	31			
Textiles				5	3			
Laundries				29	30			
Food		23						
Other				4	4			
Sulfuric acid								
Fertilizer	92	86	93	46	73		65	52
Iron and steel				11	5		3	3
Petroleum refining		3	2	2	1		2	3
Rayon yarn and fiber	4	6	2	13	9		9	8
Chemicals				12	7		10	14
Other	5	5	2	16	5		11	20

Source: UN-ECAFE: Ind. Prog. in the ECAFE Region (1963), Annex.

/petroleum refining

petroleum refining, or other specialized chemicals required by the glass, paper or metallurgical industries.

In general, the demand for the important chemical products originates in a number of different end uses. In Figure II-A-1 the end-use pattern for ethylene and its derivatives is shown, based on United States data for 1954-55. There are eight major end-uses which are taken into account. All of these end uses, with the possible exception of synthetic rubber (as mentioned above) depend, either directly or indirectly, on an overall balanced growth of the economy as a whole rather than on the unbalanced expansion of one or two particular sectors. In this way the network of interconnexions between chemical processes tends to diffuse the demand for many basic chemical products, even though the particular product may have a forward linkage directly only to a few other products.

2. The nature of economies of scale

The fact that the chemical industry is characterized by a lack of concentration of interindustry linkages and consequently by a dependence on the demand generated by the level of development of the economy as a whole is particularly significant when viewed in relation to the pronounced economies of scale prevailing in most branches of this industry.

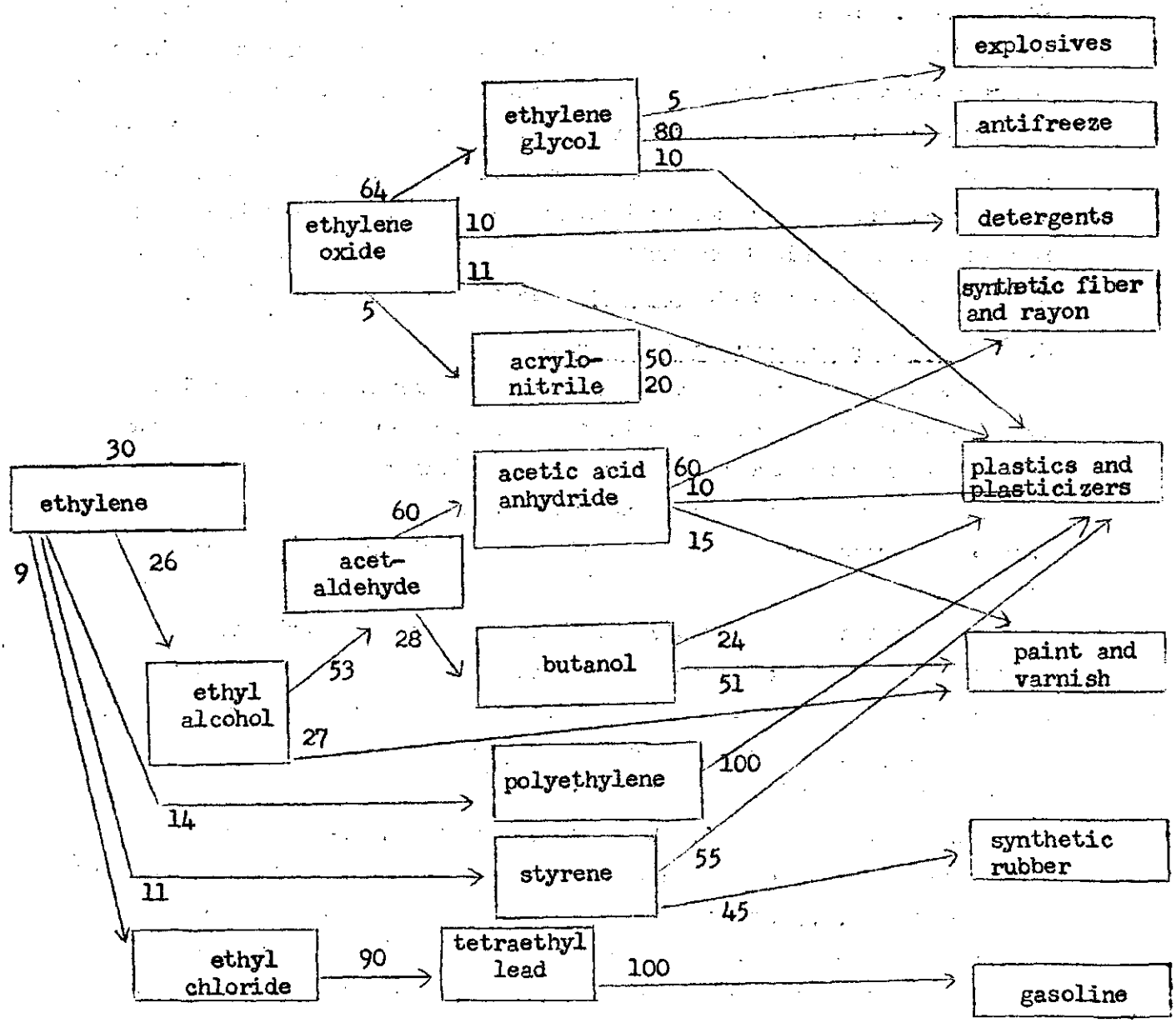
The most important source of these economies of scale is the reduction of unit fixed investment required as productive capacity increases. In addition, there is also a sharp reduction of unit labour requirements, but as labour costs typically represent only a small fraction of production costs in most chemical processes (and especially the basic ones), the contribution of this factor is relatively minor. Some economies may also present themselves in raw material and utility[52/] requirements, e.g., improvements in the recovery of auxiliary chemicals, but these are seldom of sufficient importance to produce significant errors in relation to an assumption of strict proportionality of such inputs with scale.

52/ Steam, power, fuel.

/Figure II-A-1

FIGURE II-A-1

END-USE PATTERN: ETHYLENE
US, 1954-1955



Source: Faith, Keyes and Clark (1957).
Note: Numbers on arrows indicate percent of total outflow.

/Description

Description

The variation of the capital and labour coefficients of entire processes can be described satisfactorily[53] for many purposes by means of the fractional-power relationship.

$$\frac{C_1}{C_2} = \frac{S_1}{S_2}^{\phi}, \quad 0 \leq \phi \leq 1,$$

where C_1 and C_2 are capital or labour inputs (total not unit) at specified scales; S_1 and S_2 are the corresponding scales; and ϕ is an exponent that varies from process to process and is between 0 and 1. Typically, the exponent for capital is in the range 0.6-0.8, that for labour, in the range 0.2-0.4.

Using C_1 and S_1 as variables and C_2 and S_2, and ϕ as parameters, the logarithms of the variables plot as straight lines for constant ϕ. Therefore, on double logarithmic paper the respective factor inputs give scatter diagrams that can be correlated by means of the indicated relationship on the assumption of constant ϕ. The value of ϕ is the measured slope of the correlating line. It can be seen that ϕ can be interpreted as the elasticity of a factor input with respect to scale; thus it measures the percentage change in the factor input in response to a one-percent change in scale.

The application of this relationship to entire processes is based on the fact that essentially all components of a chemical plant (vessels, towers, piping, heat exchangers, pumps, etc.) exhibit this same relationship between size and first cost, with the value of the exponent ϕ clustered close to 0.6 in most cases. Very extensive collections of cost correlations for components are available.[54]

53/ See Annex 1; also Vietorisz (1961:PDS), UN-ECLA (1963:CIL).

54/ Aries and Neuton (1955), Chilton (1960), US-Bureau of Mines (1949).

/While the

While the data on entire chemical processes are much more scarce and at times only a few points may be available to derive the parameters for a given process, this large body of underlying data increases very considerably the confidence which may be attached to estimates of cost trends based on a minimum of specific information.[55/]

Core/ancillary distinction

A further consideration in the application of correlations to describe economies of scale in the chemical industry is the distinction between core processes and ancillary processes. The latter include for example power and steam generation, water purification and waste disposal, maintenance, repair and replacement, materials handling, in-plant transport, storage, laboratory services, etc.[56/] In assembling data for describing the technical structure of a process, a variable amount of ancillaries may be found to be included in the raw data; in particular, the investment figures may vary according to how much allowance has been made for the requirements of such ancillary processes. In general, the costs due to ancillary processes tend to be proportional to fixed investments and to direct operating labour; thus they give rise to further economies of scale in addition to the costs which are directly related to investment, i.e., interest charges and depreciation allowances, and the direct wage bill. In the technical description of a process, the ancillaries are typically not separated from the core process explicitly, but allowance is made for them in the cost estimates in the form of "indirect production costs" and similar accounting items.[57/] The net result of these estimates in one study[58/] was a combined annual charge of almost 20 per cent against fixed investment, exclusive of interest.

55/ See Chilton (1956), Isard, Schooler and Vietorisz (1959), pp. 52-58; UN-ECLA (1963:CIL).

56/ For a more complete listing, see Vietorisz (1961:PDS); see also Section II-D-2.

57/ See Annex 1, Sec. 4.

58/ Isard, Schooler and Vietorisz (1959) p. 59.

/Meaning of

Meaning of scale limits

Considering the existence of fractional-power correlations presented in the previous section, the question arises what significance should be attached to the frequently employed concept of "minimum economical scale." Evidently, to the extent that the function holds over the entire range of outputs, one cannot speak of a strict minimum, but only of a range where the diseconomies of small-scale become "excessive", whatever that is taken to mean. At times there is a technical minimum scale below which equipment is not commercially available, but most chemical processes are technically capable of being run smaller scales all the way down to pilot-plant and bench scales. At the other extreme, the technical maximum scale may be determined, again, by equipment availability or such considerations as the difficulty of transporting and erecting outsize equipment, difficulties of maintaining process control, etc. The estimates of "maximum" scale usually refer to a combination of these factors and are to be interpreted loosely, as new records with regard to size are being established with the progress of time. In practice, the estimated maximum scales can be taken to signify the approximate limit to which the economies-of-scale function holds.

Economies of scale in relation to factor inputs

In discussing economies of scale from the point of view of economic development it is important to note the extent to which they involve the basic primary factors, especially capital, labour and foreign exchange. In regard to capital, the amount of this factor tied up in a process is largely proportional to fixed investment;[59/] in other words, the effect of using excessively small process scales is to raise the capital-output ratio for the economy as a whole and thus to slow down overall growth. As shown above, in the chemical industry the most important source of

59/ Capital is also tied up in inventories and other working capital.

/economies of

economies of scale is fixed investment; thus, small-scale chemical industries will tend to produce the above unfavourable effect. This is not necessarily the case in other industries. For example, in the metal transforming industries small-scale (short-series) production will reflect itself primarily in higher labour requirements and only secondarily less efficient capital utilization: thus to the extent that an economy operates with a labour surplus, this diseconomy will have a less unfavourable effect on the overall growth rate than a diseconomy due primarily to low capital productivity.

The importance of fixed investment in regard to the economies of scale in the chemical industry, however, has further consequences. Original investment in plant and equipment, and replacements due to the limited lifetime of capital goods, which have a relatively short life span in the chemical industries,[60/] imply a constant flow of requirements for machinery and equipment. In most underdeveloped countries this class of commodities is in chronically short supply, and often it has to be largely imported. Thus, the low productivity of this scarce resource implies either an aggravation of the shortage of domestic output, or a burden on the balance of foreign exchange. In either case, the ultimate effect is to create further constraints on the potential growth of the economy. Once again, in other industries where diseconomies of small-scale production show up primarily in the guise of low labour productivity, their retarding effects on growth will be far less pronounced as long as there is a surplus of labour. Contrariwise, under conditions of high rates of growth where the manpower base is the ultimate limiting factor, the relative disadvantage of the small-scale operation of the chemical industry disappears, and all diseconomies of small scale become equally binding with regard to the rate of growth.

60/ See Section II-C-1.

/3. Markets

3. Markets versus economies of scale: orders of magnitude

In order to give an approximate idea of the economies of scale in the chemical industry compared with the demand that can be expected at the levels of income of underdeveloped countries, suffice it to say that in most basic chemical lines a subcontinental market is required to provide the demand for a reasonable sized plant. In Table II-A-6 some numerical examples are presented to ilustrate the orders of magnitude involved.

For sodium hydroxide and sodium carbonate, the yearly per capita consumptions at per capita income levels of 100 U.S. dollars amount to approximately one-half kilogram. The approximate minimum economical plant sizes estimated for these two chemicals are 20 000 and 175 000 tons per year, respectively; thus, the populations required to support such minimal plants are 36 million persons for sodium hydroxide, and 343 million persons for sodium carbonate. Considering now larger plants, it is estimated that economies of scale in these two lines of production ("Maximal plants") persist up to 150 000 and 825 000 tons per year, respectively. The populations required to support such plants at the indicated per capita income level would amount to 273 million and 1 617 million, respectively; in other words, such plants would be utterly out of reach for all but the very largest individual countries.

At higher per capita income levels, the picture becomes progressively more favourable. The populations required to support a minimal sized sodium hydroxide plant at income levels of 200, 300, and 600 US$/capita are only 18, 12 and 6 million persons, respectively. A similar decrease is noted for sodium carbonate.

A further example is the production of synthetic rubber. The estimates presented here assume that the entire demand for rubber tires is supplied by synthetic rubber which, of course, overestimates the potential of a given market. Even so, the markets required to support the production of a minimal sized plant are between 90 and 18 million persons at income levels of 100-300 US$ per capita; maximal plants require markets ten times larger.

/Table II-A-6

Table II-A-6

POPULATION REQUIRED AT DIFFERENT INCOME LEVELS TO SUPPORT MINIMUM AND MAXIMUM SIZE CHEMICAL PLANTS

	100	200	300	600
	(Income: US$ per capita)			
Sodium hydroxide (electrolysis)				
Consumption, KG/CAP, YR	.55	1.10	1.66	3.39
Required population, 10^6 persons:				
for min. plant (20 000 TON/YR)	36	18	12	6
for max. plant (150 000 TON/YR)	273	136	90	44
Sodium carbonate (solvay)				
Consumption, KG/CAP, YR	.51	1.35	2.40	6.45
Required population, 10^6 persons:				
for min. plant (175 000 TON/YR)	343	130	73	27
for max. plant (825 000 TON/YR)	1 617	611	344	128
Rubber tires for vehicles				
1. GRS rubber process				
Consumption of rubber (assume 100 per cent synthetic), KG/CAP, YR	.20	.55	.98	2.76
Required population, 10^6 persons:				
for min. plant (18 000 TON/YR)	90	33	18	7
for max. plant (180 000 TON/YR)	900	330	180	65
2. Butadiene raw material				
Consumption for synthetic rubber, KG/CAP. YR	.16	.44	.78	2.21
Required population, 10^6 persons/yr:				
for min. plant (27 000 TON/YR)	169	61	35	12
for max. plant (230 000 TON/YR)	1 438	523	295	104
3. Styrene raw material				
Consumption for synthetic rubber, KG/CAP, YR	.04	.11	.20	.55
Required population, 10^6 persons (assuming 50 per cent of production goes to synthetic rubber):				
for 1/2 min. plant (Min=14 000 TON/YR)	175	63	35	13
for 1/2 max. plant (max=90 000 TON/YR)	11.25	409	225	82

Source: Demand projections in Vietorisz and Szabo (1959) and UN-ECLA: Chemical Industry Study (1963:CIL).

/This, however

This, however, is not the only consideration because some of the intermediates of the synthetic rubber process, e.g., butadiene, require larger scales than the end process itself. Thus butadiene, which represents 80 per cent of the raw material needs of synthetic rubber, requires a supporting market approximately twice as large as the final process step. While in the case of many chemical intermediates the scale problem can be attacked by the joint utilization of an intermediate chemical by several subsequent processes - this is the basis for considering chemical processes grouped in complexes, as will be discussed presently - in the case of butadiene, there is no practically significant alternative use, so that the indicated scales constitute an effective constraint on the consideration of synthetic rubber production.

In general, the economies of scale have to be considered separately for each link in a processing chain or a network of such chains. Thus in the conversion of ethylene to final products, each processing step has to be scrutinized from this point of view. (See Figure II-A-1.) Additional processing steps involved in the production of cooperating chemical intermediates which are not shown in the table have to meet similar requirements.

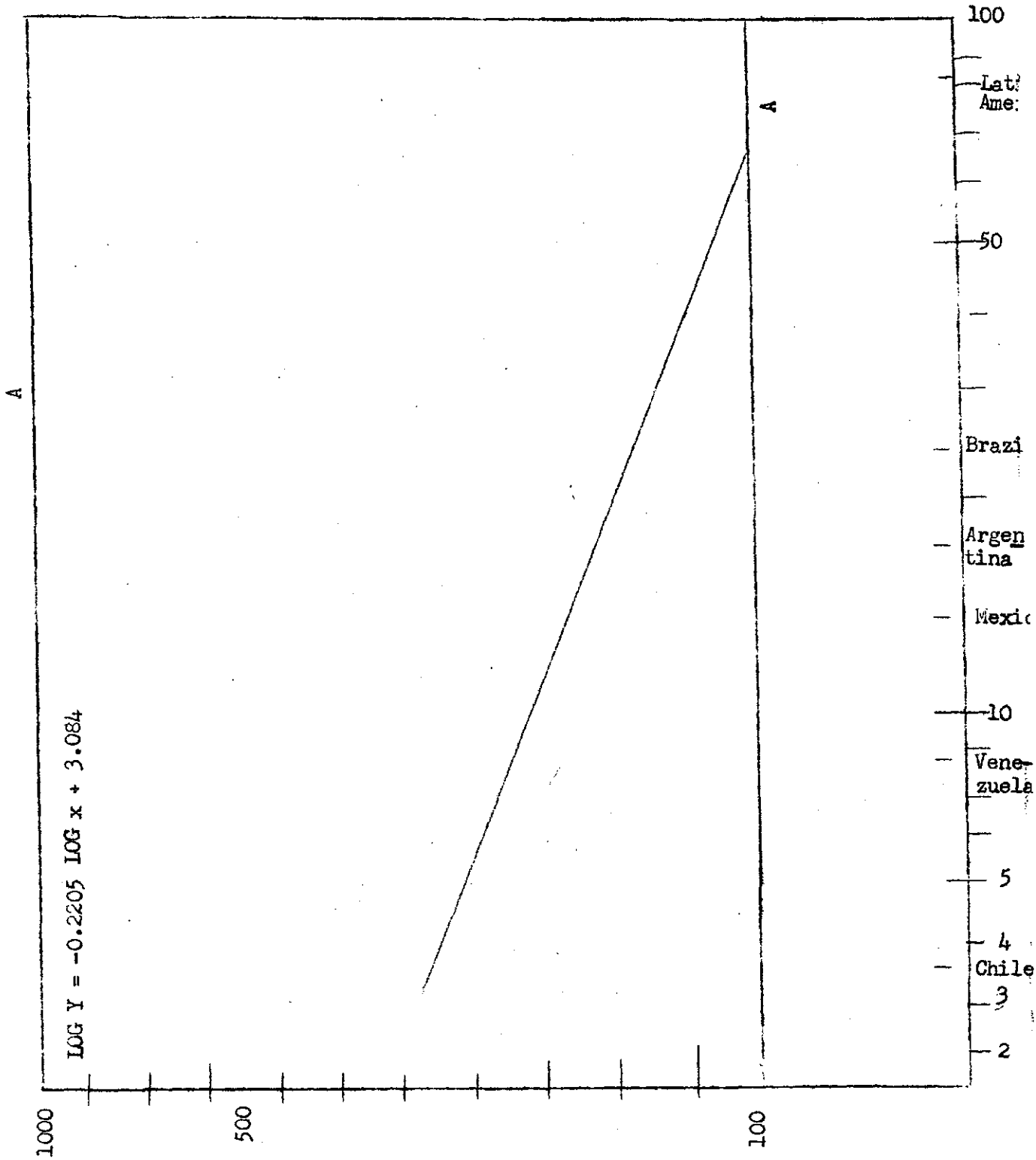
As a further illustration of the orders of magnitude of economies of scale in relation to markets, Figures II-A-2 and II-A-3 are presented which refer to Latin American markets.[61/] In Figure II-A-2, the generally declining tendency of production costs is shown as a function of the extent of the market. The diagram refers to 36 basic chemical products; for each, the production cost in a national market, at the scale of that market, is graphed as a percent of the production cost <u>at the same location</u>, but at the scale of the entire Latin American sub-continental market embracing the twenty republics. It is seen that there is considerable scatter between individual chemical products, and there are also gross deviations from the trend due to local factors, but the trend is unmistakable. It should be noted that the end-point representing the sub-continental market is a legitimate part of the correlation, as it refers to 180 individual points (5 countries, 36 products for each). The diagram indicates clearly that in

61/ These figures have been taken from Vietorisz and Szabo (1959).

/FIGURE II-A-2

FIGURE II-A-2

Latin American Chemical Markets: Production Cost-Scale Correlation



Notes to Figure II-A-2

1. Horizontal axis: country and regional income projections for 1965, in 10^9 US$.
2. Vertical axis: ratio of production costs at the scales of **national** markets to production costs at same locations at the scale of entire **regional** market, percent.
3. Number of chemical products covered: 36.
4. Point **A** represents the reference point for all ratios. By definition, the production cost of each of the 36 products at each of the 5 alternate locations is taken as 100% at the scale of the entire regional market.
5. Source: Vietorisz and Szabo (1959).

this group of basic chemical products production costs keep declining all the way up to the scale of the sub-continental market. In relation to underdeveloped countries in other regions of the world, it should be observed that the average income in Latin America for 1965, the year of this projection, was estimated for this study[62] as slightly over 400 dollars; thus the region is toward the upper end of the spectrum of underdeveloped countries, and the persistence of economies of scale up to a population of over 200 million, at these income levels, implies their persistence up to even larger market sizes at lower income levels.

The following graph (Figure II-A-3) gives more detail in regard to individual products.[63] Each point in this double logarithmic graph refers to a chemical product, and indicates its relative production cost (in terms of the price of the imported product at US port of origin) both at the scale of the Chilean market and at the scale of the Latin American regional market. (See notes to Figure II-A-3.) Production costs at the scale of the Chilean market are generally higher than the US market price, as indicated by the centering of the scatter above the horizontal 100 per cent line; production costs at the scale of the Latin American regional market are generally lower than the US market price, as indicated by the centering of the scatter to the left of the vertical 100 per cent line. The trend of the scatter can be fairly represented by the line with a 45° slope, at a constant distance above the reference line, indicating a constant ratio between Chilean and Latin American regional production costs. This ratio is 2.25; thus, subject to a wide margin of variation in the case of individual chemicals, production costs at the scale of the Chilean market tend to be 125 per cent higher than at the scale of the Latin American regional market.[64]

62/ These figures are taken from Vietorisz and Szabo (1959) and do not represent official United Nations estimates.

63/ Same source as above.

64/ From the expression for economies of scale,

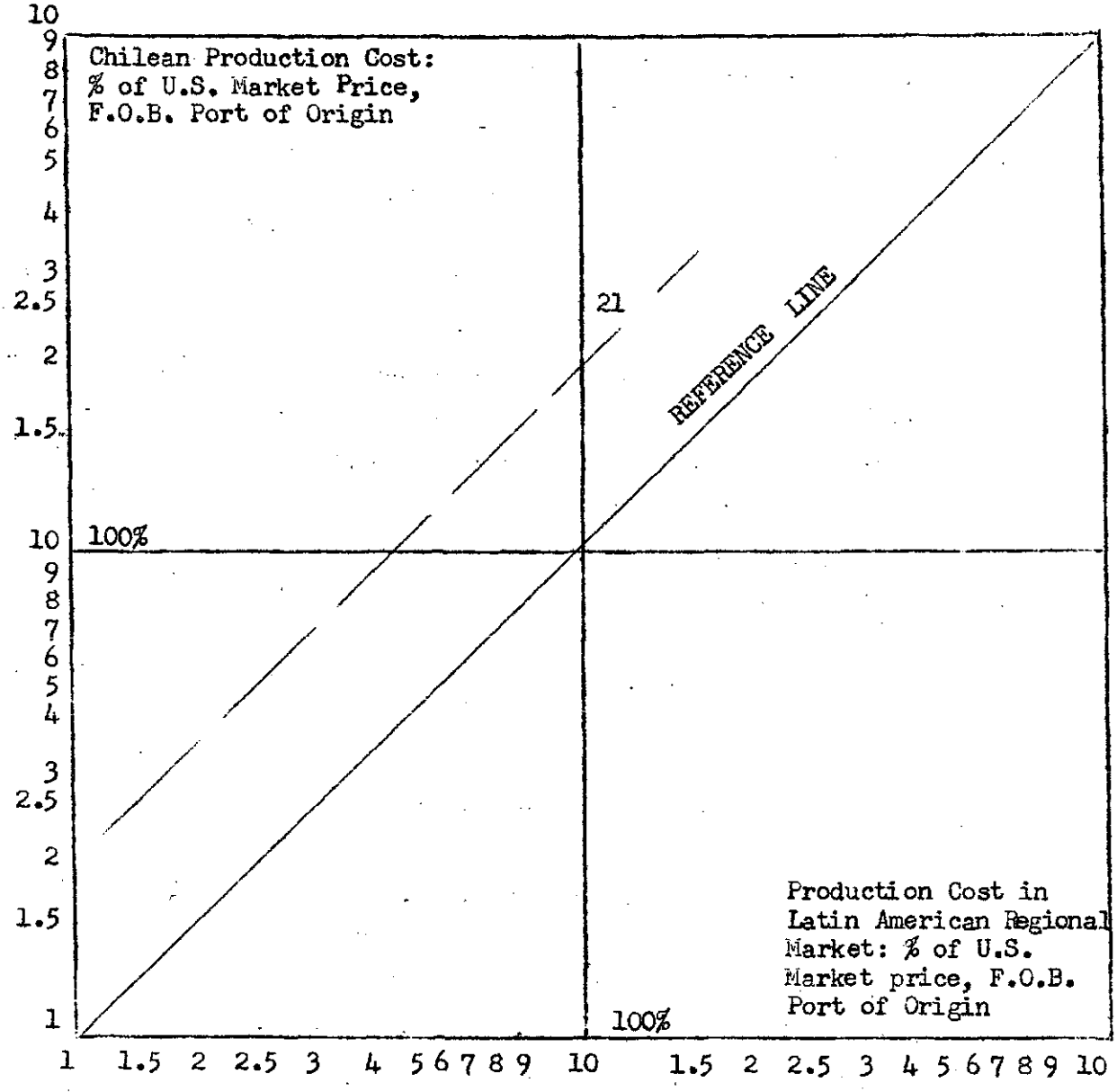
$$(C_1/C_2) = (S_1/S_2)^f,$$

we can derive a constant ratio between C_1 and C_2 on the assumption that both (S_1/S_2) and f are approximately constant. In fact, there is a variation due to differences in these as well as in the effects of input costs not subject to economies of scale.

/FIGURE II-A-3

FIGURE II-A-3

Relative Production Costs of Chemicals:
Chilean Market vs. Latin American Regional Market



Notes to Figure II-A-3

1. Source: Vietorisz and Szabo (1959).
2. The production cost of ecah product as a % of US market price f.o.b. port of origin can be read off the graph, both for the scale of production corresponding to the Chilean national market and representing the vest productive location for this country and at the scale of the Latin American regional market, and representing the best productive location within the region as a whole.
3. The chemical products covered are the following: 1. Sodium carbonate; 2. Triple superphosphate; 3. Bicalcium phosphate; 4. Cellulose acetate; 5. Ammonium sulphate; 6. Acetone via cumene; 7. Ammonium nitrate; 8. Synthetic rubber; 9. Vinyl Chloride; 10. Silicon carbide; 11. Acetone via isopropanol; 12. Polystyrene; 13. Dodecyl benzene; 14. Caustic soda; 15. Phenol-formoald.resin; 16. Sodium tripolyphosphate; 17. Urea-formaldehyde resin; 18. Carbon black; 19; Polyethylene; 20. Polyvinyl acetate; 21. Propylene tetramer; 22. Methanol; 23. Vinyl chloride; 24. Butadiene; 25. Ethylene; 26. Ammonia; 27. Formaldehyde; 28. Chlorine; 29. Styrene; 30. Phenol; 31. Vinyl acetate; 32. Isopropanol; 33. Acetaldehyde; 34. Acetic acid.

The graph shows, product by product, the diseconomies of small-scale production for serving small markets. In the case of each commodity, the demand estimate allows for the interaction of different chemical processes in regard to the joint utilization of intermediate products required for satisfying the demands originating in final consumptions as well as in other sectors of the economy.[65/]

4. Methods of attack upon the economies-of-scale squeeze

The graphs just presented point directly to one of the major avenues of attack upon the problem presented by insufficient national markets in relation to diseconomies of small-scale production, namely, international economic integration. Before turning to this option, some other possibilities will be explored.

(a) Exports to the world market. The first possibility is competitive entry into the world market. This possibility is invoked in many instances when, upon projecting the demand for chemical products in a given national market, it is encountered that these fall short of the needs of economical production.

If all the smaller underdeveloped countries of the world were to set their hopes upon such exports, many of them would have to be disappointed even if the larger markets could be successfully penetrated. The latter outcome however is far from being probable. Those countries which practice some measure of economic planning are usually bent upon developing their own chemical industries, while the markets of countries with predominantly free-enterprise economies are controlled by well-entrenched oligopolies which fight the loss of substantial market shares to newcomers.

65/ It should be noted that the graphs of Fig. II-A-2 & II-A-3 by themselves offer no conclusive indication of the advantages of regional economic integration, since they represent only production costs, with no reference to the costs of transport. It so happens, nevertheless, that in the case presented economies of scale generally dominate transport costs all the way up to the scale of the entire subcontinental market. (See the references cited.)

/The nature

The nature of the latter markets deserves some further comment.[66/] As many of the sales of the chemical industry are to other companies in the same industry and since the nature of chemical production requires assured supplies in large volumes and subject to close delivery schedules, a network of intercompany informal and contractual relations tends to be established which effectively regulates access to markets. A further factor tending to stabilize relationships between firms is the fact that additional investments, due to the prevalence of economies of scale, tend to be large percentage additions to existing total capacity in the production of any one product. Thus, uncoordinated investments entail the risk of substantial idle capacity, a situation which all market participants have a strong interest in avoiding. Whenever there is such substantial idle capacity, price competition becomes keen, and profits tend to be squeezed. Instead of this form of competition, firms generally prefer to engage in two other forms of competition to which the technology of the chemical industry is particularly well suited: competition in regard to improved processes, and competition in regard to new products. In order to participate successfully in the latter forms of competition, a firm has to build up a research and development establishment. The accumulated experience of such establishments, and the scale at which they have to be run, act as a further discouragement to potential new entrants. Finally, the firms in the industry exercise considerable collective political power and are in a position to originate protectionist measures (tariffs, quotas, etc.), if the situation calls for it. In the United States, for example, the chemical industry is one of the most protectionist-minded of the industrial groupings.

The oligopolistic structure of the industry extends beyond national boundaries and in the past has frequently given rise to international market allocations and related agreements.[67/] There is no reason to expect a basic change in this institutional structure in the foreseeable future.

66/ On the institutional structure of the chemical industry, see the following general references on industrial economics: Adams (1954), Alfelder and Michl (1957), Burn (1958), and the following more specific studies: Allen (1960), Bohmfalk (1952), Manzoin (1952), Markham (1958), Phillips (1960), Backman (1964).

67/ For some examples, see Adams (1954:IPS) p.190. On international cartels in general, see also Mayall (1952), Plummer (1952).

/In spite

In spite of the apparent stability of the oligopolistic structure described above, it is not invulnerable to attack, provided that a special situation exists which can be exploited by antagonists whose economic power is commensurate with that of the firms in the chemical industry. Such a situation has arisen recently in the form of the entry of oil companies into the petrochemical markets. This entry was backed by a number of sources of strength: control of raw materials, large marketing organizations, well-established research and development operations in closely related fields of science and engineering, and great financial strength. The result of this entry has been a struggle for markets, with the creation of considerable overcapacity and a fall in the price level of a number of important chemical commodities.

It would be a serious mistake to conclude, nevertheless, that what the giant oil companies could do, a small newly-established producer in an underdeveloped country can do likewise. In the case of the latter, most if not all of the sources of strength enumerated above would be missing. The best that might be hoped for is that some small new producers may find a temporary crack in the market structure and may enter certain markets as allies of one or other of the giant companies. Even for this, the long-run possibilities are not particularly encouraging, because after the lapse of some time it is generally in the interest of both the old and of the new market participants to terminate the struggle and to settle down to the usual pattern of market control on the basis of the new lineup of market shares.

In sum, the attempt to solve economies-of-scale problems in the planning of the chemical industries by risking a competitive entry into the world markets amounts to a gamble with generally poor prospects. Chemical exports on a substantial scale, as a general proposition, cannot be hoped for unless some special situation can be successfully exploited, or else, unless it is based on joint planning between several countries, as indicated below.

(b) Industrial complexes. Failing a reliance on exports, the attempt to overcome the economies-of-scale squeeze has to be concentrated on possibilities that can be realized by efficient planning of the development of this industry within the national economy.

/The tool

The tool of such planning is the consideration of industrial complexes which tie together separate processes into more efficient combinations. The sources of efficiency are these:

(i) Common use of output. Processes are tied together which utilize the same chemical intermediate commodity in subsequent processing steps. In this way the output of a given process is shared between several successive processes, and the scale of the base process can be increased. Example: (see Figure II-A-1) while one or the other of the end uses of ethylene may not be sufficient to justify its production, the simultaneous consideration of several or all end uses can raise the scale sufficiently to allow economical production.

(ii) Common exploitation of raw materials or utility inputs: Processes are tied together which rely on the same raw material or utility input. In this way the scale at which the raw material or utility is exploited or produced will be raised, and its cost will fall. Typical raw materials of the chemical industry which come under this heading are: sodium chloride (salt); nonmetallic minerals; and petroleum refinery streams. Among the utilities, power is of the greatest importance for many chemical and other production processes. Generating power at a sufficient scale to obtain really low unit costs (of the order of .003 to .004 US$ per KWH) can be achieved only, if at all, by concentrating electrochemical and electrometallurgical processes into a single complex.[68/]

(iii) Locational concentration of petroleum refining activities which yield petrochemical feed streams: The processes for the reforming of naphtha for aromatics production, the extraction of ethylene from cracking gases, the recovery of byproduct hydrogen for chemical utilization, the recovery of sulphur from desulphurization units, the separation of n-butane

68/ In large hydroelectric developments (over 300 000 KW) at exceptionally favourable sites, power may be available at a cost of 3 mils per KWH. Thermoelectric power stations operating on natural gas that would otherwise be flares may (on optimistic estimates) attain the 3 mil level at 50 000 KW, and the 2.5 mil level at 200 000 KW installed capacity. By comparison, the power needs of integrated production units serving the demand of the entire Latin American regional market projected for 1965 are as follows: caustic-and-chlorine electrolysis complex: 142 000 KW; phosphoric acid complex: 250 000 KW; aluminum: 263 000 KW; minor electrochemical and electrothermal processes: 26.000 KW. Source: Vietorisz and Szabo (1959).

/and n-butylene

and n-butylene from the $C_3 - C_4$ cut for butadiene production, and others, cannot be operated efficiently unless the feed streams are available in sufficient quantity. Since many of these streams are narrow cuts obtained as a byproduct of the refining operation, their quantities are rather rigidly determined by the nature of the crude and the distribution of the refinery products that are to be obtained. In this situation, the existence of a single 5-million ton/yr refinery as against five 1-million ton/yr refineries[69/] which are widely dispersed, can make the difference between a low-cost, efficient process or a high-cost, inefficient one. (Of course, the needs of the chemical industry constitute only one of many considerations in relation to the planning of the location of petroleum refineries.)

(iv) Merging of ancillary processes serving several (possibly unrelated) core processes. The operation of ancillary processes represents a considerable fraction of production costs, and these processes themselves are subject to economies of scale. As mentioned before, in chemical processes these economies of scale are often taken into account without specifically separating the analysis of individual ancillary processes from that of the core process; thus, the costs of the ancillaries as a group are estimated as percentages based on fixed investment and direct operating labour. This procedure is, however, not sufficiently precise for the cases when the feasibility of an industrial complex may hinge on the merging of the ancillaries. In fact, the ancillaries of chemical processes may sometimes be merged satisfactorily with the ancillaries of processes in other industries. Thus, the generation of power may be shared with a steel mill, a cement factory, or even with the general power supply of a city; the generation of steam may be shared with a paper mill or a sugar mill; transport terminals with loading and unloading facilities may be shared between a wide class of industrial processes; repair, maintenance and even some replacement may be shared with any of the chemical-process type industries which employ similar operations and thus have similar kinds of process equipment.

69/ 1 million tons/yr of crude oil are equivalent to approximately 20 000 barrels/day.

/(v) Merging

(v) Merging of social-overhead type processes and services for an industrial complex. Less closely tied to an individual process than the previously mentioned ancillary operations, these processes and services are nevertheless of the same general nature; they are required to make the operation of the core processes possible. They include labour training and related activities that tend to establish pools of specialized skills (including administrative and managerial ones) in a geographical area; the development of general transportation and communications serving an area; the provision of housing and other community facilities.

Many of the cost savings that can be planned for by the merging of ancillaries and of social-overhead type processes and services appear in the economic literature under the heading of "external economies".[70] This concept, derived from the observation of predominantly private-enterprise type economic systems, takes into account the fact that the establishment of a given productive enterprise often reduces the costs of production for other productive activities. In the absence of planning, however, the operation of external economies is haphazard and the resulting cost reductions may not be appropriated effectively for stimulating additional growth. For example, important cases exist in which economies of scale would be obtained only by the joint operation of two interrelated processes neither of which is capable of operating profitably in the absence of the other[71] and thus cannot historically precede the other; in such a situation joint planning of the two is the only way to establish a profitable complex. Another example relates to the merging of ancillaries for processes which are typically carried out under separate organizational entities in the more industrialized countries: here the integration of the separate core processes into a complex is left out of consideration due to commercial considerations and simple adherence to tradition, and the potential external economies never have a chance of coming into effect. An illustration is the

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70/ See, for example, Rosenstein-Rodan (1956, 1961), Chenery (1959:IID), Vietorisz (1963:IDP).

71/ Such a case involving the iron and steel sector is analysed by Chenery (1959). This case applies to the interaction of entire processes comprising core and ancillary subprocesses.

/ancillary machine

ancillary machine shop capacity encountered in steel mills which is required for the routine maintenance of the heavy rolling equipment and includes machine tools with exceptional specifications in regard to the size and weight of work pieces. This ancillary capacity could be utilized effectively, from the technical point of view, in the maintenance and replacement operations of many chemical-process type industries which also have needs for heavy machining, as well as in certain autonomous lines of metal transforming activity. There is, nevertheless, often a considerable resistance to the administrative complications and interference in the main activity that would result from making this capacity available for the purposes mentioned, because no allowance has been made from the very beginning for this joint utilization as part of the planning of the operation of the steel mill.

Another illustration referring more specifically to the chemical industry is the establishment of a chemical plant in Viet-Nam studies by the United States International Cooperation Administration.[72/] Separate feasibility studies undertaken for calcium carbide, caustic soda, and fertilizers, each showed a market too restricted for economical production. It was found, however, that if the manufacture of fertilizers was combined with the manufacture of heavy chemicals such as the ones for which the feasibility studies had been undertaken individually, and placed under a single management at a single location, ancillaries including steam, power, water supply, railway, shops, office, laboratories, maintenance and general services could be used in common, and the resulting economies rendered the complex attractive enough for promotion to private investors.

In sum, the industrial complex approach serves to identify the most efficient way of combining productive processes in such ways that economies are realized by the interaction of the individual processes which would not be available to the latter considered in isolation. In almost all instances, some chemical processes exist which become attractive when investigated in the context of an industrial complex approach. Nonetheless, economies of scale in the end apply to complexes as much as to isolated plants; thus when all the extra efficiency has been achieved by means of the industrial complex

72/ US-ICA (1959), p.73.

/approach of

approach of which the latter is capable, the resulting complexes will continue being more attractive in larger market areas than in smaller ones, up to markets of subcontinental dimensions.

(c) Joint planning in common markets. This leads back to the starting point of the present section: the advantage of joint planning in economic areas embracing more than a single country. Regional markets can, in principle, be planned for by the same techniques as national ones, provided that institutional obstacles can be cleared away. The differences between exports to the world market and exports to another part of a market with jointly planned production are very great and very much in favour of the latter, provided that the joint planning arrangements can be assumed to be stable. This, of course, is the crux of the problem.

The advisability of joint planning of chemical-industry development in regional markets is one of the key conclusions of this paper. It will be taken up again in the closing section.[73/]

73/ Conclusions: Sec.3.

/B. Raw materials

B. Raw materials

1. General survey

The principal raw materials of the chemical industry are listed in Table II-B-1. In relation to the sectoral origin of these raw materials, reference is made to Table I-B-1, where the input coefficients of the chemical industry have been listed for five different countries. It can be seen that the important suplying sectors include agriculture, forestry and fishing which, together with processed foods and paper, account for most of the group of "raw materials of organic origin". "Hydrocarbons" are supplied by the extractive sector, petroleum-and-natural gas, as well as by the petroleum products section; "carbon" (except for petroleum coke) is supplied by the coal mining sector. "Other minerals" originate largely in the nonmetallic minerals sector. The approximate input percentages in Table II-B-1 have been based on these identifications of the raw materials list with the supplying sectors, and have been taken as the averages of the first four countries in Table I-B-1.

It can be seen that the various raw materials including electric power represent one quarter of total inputs; another quarter is accounted for by the chemical industry itself, which is thus its own principal supplier. With transport, trade and services (and some minor inputs not shown), these interindustry purchases add up to some 60 per cent of the total inputs, the rest being components of value added. Purchases of machinery and equipment and of construction on capital account are part of final demand and do not appear in current-flow input-output tables; nevertheless, they constitute one of the main interindustry linkages of the chemical industry.[74] Together, these data give an approximate picture of the importance of raw material inputs in relation to other inputs.

It is evident from the table that the raw materials of organic origins have a leading role. The reason for this is that in the definition of the chemical industry for input-output purposes, end-chemical products of large volume, such as soaps and cosmetics, paints and varnishes, oils, fats and

74/ For more detail on this estimate, see section II-C on capital goods inputs.

/Table II-B-1

Table II-B-1

Chemical industry: raw materials and other inputs

			Input coeff. %
A.	Raw materials		
1.	Hydrocarbons:	Petroleum, natural gas, liquified pet. gases, fuel oil	1.3
2.	Carbon:	Coal, lignite, graphite, coke, petroleum core	1.2
3.	Other minerals:	Sulphur, salt, limestone, phosphate rock, potassium salts, fluorspar, sand, pigment minerals	0.5
4.	Raw materials of organic origin	Cellulose, oils and fats, waxes, naval stores, bones and hides, molasses, agricultural wastes	18
5.	Other:	Metals and ores	2
6.	Electric power		2
			25
B.	Intermediate commodities and other inputs		
1.	Chemicals		25
2.	Transport, trade and services		7
3.	Machinery and equipment (capital account)		18 75/
4.	Construction	(capital account	9 76/

Source: Shreve (1956) and Table I-B-1.

75/ Based on a 6 per cent growth rate of the economy. See Table II-C-2.

76/ See last note to Sec. II-C-1.

/waxes are

waxes are included which have large raw material inputs in this group.[77] The comparative importance of the group is considerably less as far as the basic heavy chemicals and chemical intermediate products are concerned.

2. Overestimate of advantages conferred by raw material availability

In relation to the advantages conferred by raw material availability on the development prospects of the chemical industry in a country, the first and most important observation is that the former are often greatly over-estimated in a first-blush appreciation of industrial development possibilities. A good raw material is helpful, but the size of markets is generally far more critical. In addition, optimistic anticipations based on local deposits of this or that raw material often fail to take into account quality, accessibility and opportunity cost.

An example will illustrate the illusions that may exist in the above regard. In a particular country, known to the author, some persons concerned with development pinned great hopes on the availability of sulphur deposits as a basis of sulphuric acid manufacture; the latter was expected to usher in an era of other chemical process developments. Upon investigation, it turned out that the deposits were located thousands of feet above sea level in the high mountains, at a large distance from the nearest transport arteries, and completely underdeveloped. They were of the kind of mineral that had to be mined by excavation methods rather than being brought to the surface by drilling and the injection of steam, as is customary with the high-grade sulphur deposits encountered in the United States and Mexico. In other words, the exploitation of the former deposits would have implied large investments, and production costs considerably higher than the world price level. Moreover, even if it had been possible to produce sulphur at a low cost, this would not, as of itself, have guaranteed low-cost sulphuric acid production; neither would the latter, if realized, necessarily have had much of a stimulating effect, taken by itself, on the general development of the chemical industry.

Another illustration relates to the local availability of crude oil or natural gas. It is often mistakenly assumed that such resources guarantee

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77/ See the definition of the industry under "Coverage", p.8.

/good prospects

good prospects for a domestic petrochemical industry. Nothing could be further from the truth in the many instances where local hydrocarbons constitute only part of the domestic fuel supply, and the import price based on the world market (which sets the level of social valuation for the resource) happens to be high.

3. Opportunity costs

The example just mentioned raises the issue of opportunity costs versus the costs of exploitation in the assessment of the economic value of local raw material deposits.

(a) The cost of exploitation, measured at market prices or social accounting process, is an adequate criterion of the value of a raw material if the latter has no alternative uses. For example, in the Magallanes region at the Southern extreme of the South American continent,[78] by-product natural gas is obtained in limited quantities together with petroleum production. While much of this gas has until recently been reinjected underground to improve crude oil recovery, eventually the amounts which are most economical for this purpose will fall short of the amounts produced. Ordinarily, this gas would be used as domestic and industrial fuel, complementing other fuels. At the given location, however, there is only one city of any substantial size, Punta Arenas, whose fuel needs will be exceeded by the available gas. Other major population centres are over a thousand miles away, across difficult terrain or by sea. If the amounts of surplus gas were spectacular, as in the Gulf of Mexico-Caribbean basin or the Persian Gulf area, it would be worthwhile considering the export of the gas either by large-diameter pipeline or by criogenic technology overseas.[79] Both of these alternatives, however, require scales far above the scale limit set by gas availability. Thus, the surplus gas has no alternative use other than the one that might be given to it by establishing petrochemical or other natural-gas based industries at this location. For this reason, the social value of the gas can be set at its marginal cost of exploitation, without any allocation of joint costs from crude oil production. In other words, the value is the extra cost incurred when utilizing this gas, as compared to the cost that would be incurred if the gas were flared.

78/ Source: Vietorisz and Szabo (1959), Chap.III-1-A.

79/ The United Nations Centre for Industrial Development is engaged in a study concerning the application of criogenic technology to the utilization of excess natural gas.

/Another example

Another example is the exploitation of salt (sodium chloride) from solar evaporation of sea water in hot, arid climates. The export possibilities of this commodity are poor since it is practically a ubiquity, and domestic uses other than for the processes whose raw material needs require its exploitation are minor. Thus, having no important alternative uses, salt is valued at the cost of exploitation. Another example in this class is limestone.

The cost of exploitation is the proper criterion for valuation also in those cases where a raw material is exported, but due to restricted competition exports are institutionally limited to a smaller amount than could be supplied at the world market price. In such a situation, the f.o.b. export price overstates the economic value of the resource, since withdrawing a quantity for domestic production will not curtail the export revenue derivable from it. An example is the production of crude oil. In a number of situations oil companies may prove out a field and subsequently cap part of the wells, holding the productive capacity in reserve for future use. Whenever this is the case, the cost of production (including allowances for exploration and test drillings) is the proper criterion of social value rather than the f.o.b. export price. Examples of lesser importance to the chemical industry include nonferrous metal ores and iron ore.

(b) Opportunity costs are the best criterion of valuation whenever the raw material has alternative export or domestic uses. For example, fuel oil has to be valued at the c.i.f. import price whenever imports supply a substantial fraction of total demand even though the major portion may be of domestic origin, with production costs well below the import prices. This is so because withdrawing part of domestic production for chemical-industry utilization will entail increased imports. Only if part of the production is available for export, over and above domestic needs, will the valuation fall below the import price. If the surplus is small in relation to the world market total, and can be disposed of on the world market at going prices, the proper valuation is the f.o.b. export price. If the surplus is large and forms a considerable share of the world market, then exports will no longer be possible in unlimited quantities at the going price, and the valuation will drop to the production cost, as indicated in the previous section.

/The same

The same criterion of valuation applies when a raw material is supplied for domestic use from several alternative sources. In this case, it is not necessarily the production cost at the supply point of a chemical plant which determines the proper social valuation, but rather the price determined by the marginal source of supply (domestic production or imports) from the point of view of the market as a whole.

While the above criteria of opportunity cost have been derived from idealizations of the workings of free-market economies, they apply to allocation decisions under planning, provided that economies of scale and indivisibilities do not have all-pervasive effects upon the particular markets under study.[80/]

4. Sub-marginal raw materials and contingency planning

Domestic sources of some particular raw materials require further consideration from the point of view of contingency planning. Such planning aims at a flexible adjustment of the economy as a whole to unforeseen contingencies, such as, e.g., a sudden foreign exchange squeeze due to world market fluctuations. The raw materials in question are those whose costs of exploitation are above the market price or social accounting price; and those which are of too low grade to be exploited under current market (or planning) conditions.

(a) Those raw materials whose costs of exploitation are particularly high will not be able to compete with better sources. The high costs may be due either to the geological nature of the deposits, e.g., in the case of coal, deep situation, narrow or broken seams, or in the case of crude oil, deep wells, small scattered fields or inadequate porosity; or they may be due to the inaccessibility of the deposits to available transport routes. In the latter case, the production of a particular raw material has at times to be evaluated in relation to the opening up of an entire frontier region by means of the provision of transport routes and other forms of social overhead capital. Such considerations exist, for example, in the case of a mineral-rich frontier zone like the Guayana region in Venezuela. Thus, where an entire region is being opened up, the cost of access to a particular raw material

80/ When the production costs of raw materials or other inputs fall substantially as a result of an increase in demand, no actual or idealized price system will be capable of signaling correct allocation decisions, and the costs of the complex of interrelated activities have to be studied as a whole rather than in a decentralized fashion. See Chenery (1959:IID) and Vietorisz (1963:IDP).

/cannot be

cannot be charged entirely to the cost of exploitation, since the expenditures in question also generate autonomous growth in the region as a whole.

In evaluating the costs of exploitation, particular attention has to be paid to cost items whose value is typically understated at market prices, in particular, investment and replacement costs associated with extractive or production machinery, and fuel costs.

(b) Those raw materials which are of too low grade to be exploited under current conditions are similar to the former group. Whereas the former lead to high costs directly in their exploitation, the latter lead to high costs in their subsequent utilization.

Submarginal grade raw materials may be of insufficient concentration, or they may contain excessive amounts of impurities. In both cases, existing technology may require some modification to cope with such raw materials. It has already been mentioned in another connexion that the engineering know-how required for such technological adaptations is not locally available in many underdeveloped countries, and thus the chances of successful adaptations for these raw materials are less than for the submarginal raw materials of the industrialized countries which are under constant study with a view to a technological advance that will render their utilization attractive. This situation places the underdeveloped areas at a disadvantage with regard to the more industrialized countries, since raw-materials technology has become inherently biased in favour of the geology of the latter.

The raw materials of high cost and low grade mentioned under the foregoing two headings have considerable significance for planning, because they can be utilized as a second line of defense against unforeseeable contingencies. Under the heading of flexibility in economy-wide planning,[81] it has already been mentioned that the likelihood of foreign-exchange or similar crises may render such a second line of defense highly desirable. A prudent raw materials policy within economic planning will carry the utilization of high-cost and low-grade resources somewhat beyond the margin that would apply under stable average expectations. The accent of this policy is on the ability to expand the exploitation of these resources substantially within a short period of time at reasonable additional cost.

81/ Sec. I-A-3.

/Thus, for

Thus, for example, the open-pit mining of low-grade coal near transport routes with adequate reserve capacity, coupled with standby coal-firing equipment in selected heavily fuel-intensive industries (e.g., power generation) can be used as such a second line of defense. Normally, the scale of this mining activity would be low and reliance would be placed on fuel oil; under stress, however, coal could in part replace fuel oil. The fixed economic burden of such a policy would be the investment in the mine and the standby mining and coal-firing equipment. During periods of crisis, there would also be the variable cost of forced production in the mine as well as any additional deterioration in process equipment due to more corrosive coal fuel gases.

Areas in which such a defensive raw materials policy may conceivably apply within the chemical industry include the following:

- coal versus fuel oil as a general-purpose fuel
- coal versus fuel oil as a raw material for ammonia and methanol synthesis
- pyrites as a source of sulphur versus elemental sulphur
- low-grade domestic phosphate rock versus imports as fertilizer raw material
- cellulose from domestic fibrous plants versus imported pulp
- ethyl alcohol from agricultural raw materials versus ethyl alcohol from ethylene
- acetylene from calcium carbide versus petrochemical acetylene.

It should be noted that the last two options imply more than just a shift in raw materials; they tend to displace a whole chemical complex based on a particular fundamental process. In this connexion it needs to be pointed out that the raw materials requirements of petrochemical processes tend to be quite small compared with the general fuel requirements of an economy, and thus not too much is gained by economizing on the former.

There is, however, a related area in which considerations of contingency planning play a role of first importance, namely the choice between integrated chemical complexes including the necessary basic processes, and the establishment of the later states of production alone based on the import of heavy chemical intermediates. If the latter option is chosen, the domestic chemical industry will rely heavily on imported raw materials which can in no way be replaced by domestic substitutes on short notice. In other words, a foreign-exchange squeeze will encounter a totally inflexible demand on the

/part of

part of such productive processes, and the only choices will be between import of raw material supply or curtailment of production. Whenever possible, such rigidities must be avoided in planning. Nonetheless, if the basic processes are subject to more stringent economies of scale than the terminal steps, the planner may find himself facing a serious dilemma. Since this problem raises some fundamental questions concerning the entire philosophy of development of the chemical industries, its discussion is put off until the final section of this paper.[82/]

5. Particular raw materials: the price of caloric value

An excellent survey of the technical and economic problems relating to individual raw materials of the chemical industry will be found in the ECLA chemical-industry study for Latin America.[83/] The grouping of raw materials in this study corresponds closely to the one given in Table II-B-1 above. Among the inorganic raw materials, sulphur, salt, limestone and phosphate rock are identified as the most important ones, and are discussed individually. Among the organic raw materials, hydrocarbons and carbon are distinguished from other raw materials of organic origin. One difference in emphasis between the study cited and the estimates given earlier in this paper refers to the importance of the latter class of raw materials. Whereas the ECLA chemical study finds them of subordinate importance, the estimates in Table II-B-1 assign a large weight to this group. This divergence can be reconciled if it is noted that the definition of the chemical industry for the purposes of the input-output tables which were the source of the present estimates is wider than that used in the ECLA study, and includes a number of related industries which are heavy users of the type of raw material in question.

There is one respect in which the above excellent survey of raw material problems merits further amplification, namely, in regard to the price level of the caloric value of fuels at different geographical locations. The importance of the latter is attested by the fact that it has been found in a number of locational studies of the chemical industry, including the ECLA study cited above[84/] that the locational advantages of this industry depend largely on

82/ See conclusions, Sec. 3.

83/ UN-ECLA (1963). Characteristics of principal raw materials: Chap. 4, pp. 113-129; raw material prices: Chap. 3, pp. 102-104, Annex XV, pp. 287-292.

84/ See also Isard and Schooler (1955), Airov (1956), Isard, Schooler and Vietorisz (1959).

/the balance

the balance between three factors: economies of scale, transport costs, and the price of caloric value at a given location.

The price of a calorie of heating value serves as a meaningful index to measure the effect of a number of factors that have a strong influence on chemical production costs. Thus, the generation of steam or power, or the direct use of fuel play a role in most chemical processes and form an important part of total costs. In addition, petrochemical feed streams vary in price in close relation to the price of a calorie. Thus, it is of interest to consider in detail the geographical structure of fuel prices. In general, this structure is determined by the interaction of the price of three basic fuels: fuel oil, natural gas and coal.

The geography of fuel prices is reasonably stable in the long run. A simple and convenient analysis of the bases on which long-term predictions of the world fuel price structure can be made is due to Dwyer (1958).[85/] The key assumption, based on the observation of the historic behaviour of fuel markets, relates to the equalization of delivered fuel prices in two key markets: the U.S. Eastern seaboard, represented by the focal point of New York, and the industrial zone of Northwestern Europe, represented by the focal point of Rotterdam. Three alternate assumptions can be made in regard to the long-term interrelation of these two focal points with the key supply zones in the Caribbean and Persian Gulf petroleum fields and the Eastern United States coal mining area (see Figure II-B-1):

(a) Fuel prices are equalized in New York where the price level is determined by the delivered cost of U.S. coal. The price in the Caribbean and the Persian Gulf equals New York minus transport; the price in Rotterdam equals Persian Gulf plus transport. (Maximum Persian Gulf price level).

(b) Fuel prices are equalized in Rotterdam where the price level is determined by the delivered cost of U.S. coal. Caribbean and Persian Gulf prices equal Rotterdam minus transport. (Minimum Persian Gulf price level).

(c) U.S. coal and Caribbean fuel oil are equalized in New York where the price level is determined by the delivered cost of U.S. coal; Caribbean

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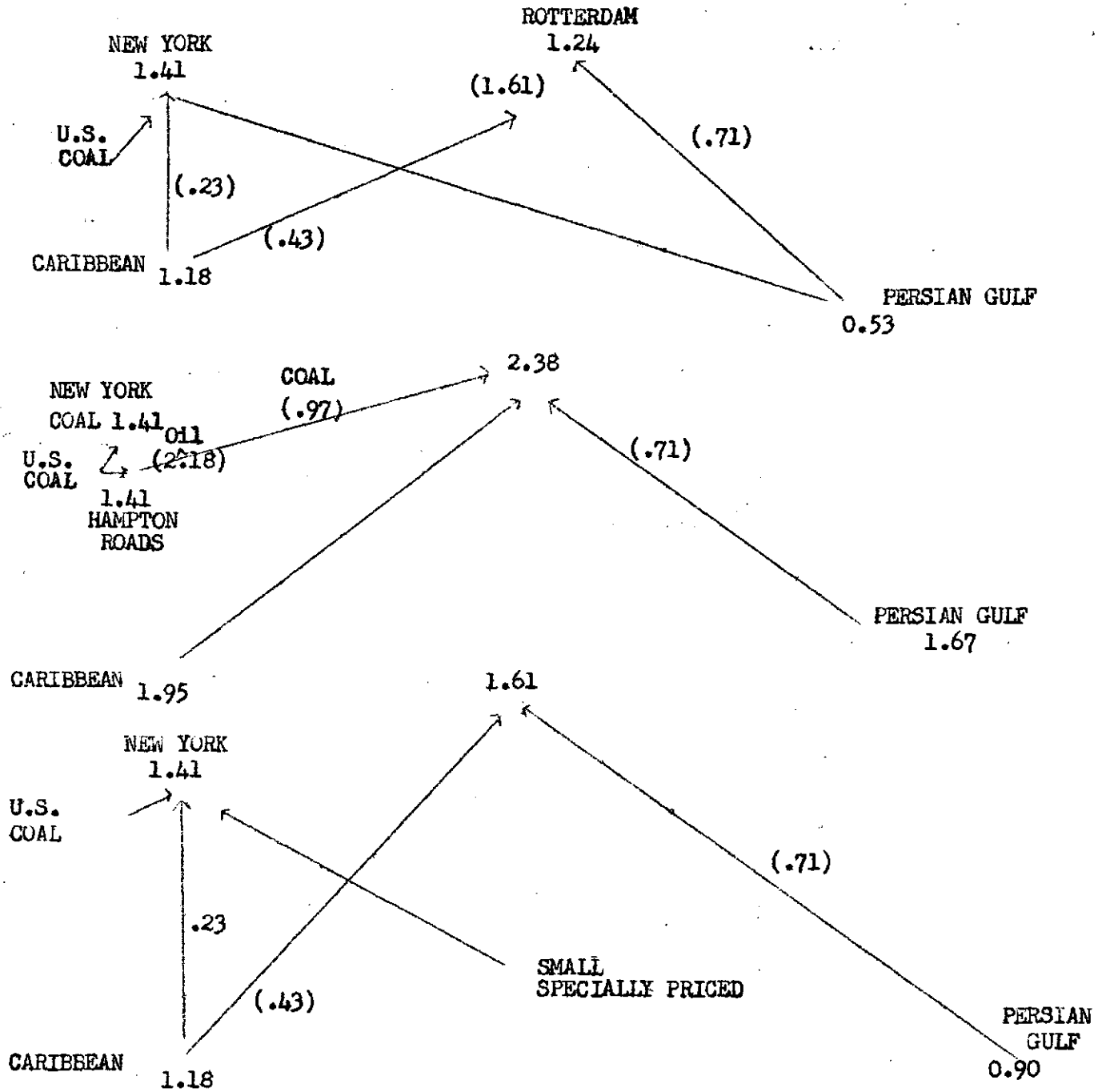
85/ The most complete and up-to-date economic analysis of the world fuel market and the oil and natural gas industries will be found in Adelman (1962, 1964).

/FIGURE II-B-1

FIGURE II-B-1

World Fuel Price Structures

US$ Per 10^6 Kcal



Source: Based on Dwyer (1958).

Note: 10^6 Kcal = 0.631 bbl of fuel oil = 0.142 met. ton of coal.
Basis of figures: U.S. coal price $10/long ton in New York.

/and Persian

and Persian Gulf fuel oil are equalized in Rotterdam. Caribbean price equals New York minus transport; Rotterdam price equals Caribbean plus transport; Persian Gulf price equals Rotterdam minus transport. (Intermediate Persian Gulf price level.)

The first of these assumptions is consistent with large, systematic movements of U.S. coal to Western Europe; the second, with large shipments of Persian Gulf crude to the United States. These are extreme assumptions, of a low order probability, on the following grounds. In Western Europe, there has been a progressive displacement of coal by oil, in spite of the fact that local coal production has been heavily subsidized. In the face of this loss of markets by local coal, it is hard to visualize major shipments of U.S. coal at a relatively high cost. The opposite assumption, involving large, price-determining shipments of Persian Gulf crude to the U.S., appears to be unlikely in the near future in the face of a strict quota system protecting continental producers. Thus, the third, intermediate assumption appears to be most probable.

Given an assumption concerning the above basic interrelations, the world fuel price structure can be mapped out easily by means of interrelations between the secondary supply areas and the focal markets on the one hand, determining a complete set of prices at all supply points; and the division of all markets between supply points on the other hand, based on lowest-cost delivered price. If the third of the former assumptions is used as a basis for this mapping, the first and the second assumptions can be used to set realistic limits to possible variations.

In the mapping of the world price structure, transport costs play a basic role. Dwyer analyses the several factors which influence the structure of tanker transport costs, taking into account existing shipping capacity of relatively low average tonnage, the size limitation imposed on ships passing through the Suez Canal (which is the main link between Western Europe and the Persian Gulf), and the trend toward the construction of tankers of much higher tonnage. He concludes that the so-called SCALE No.2 rates[86/] which are widely used as a standard of reference in world shipping, are likely to form a suitable basis for projecting the future trend of long-term shipping

86/ London Tanker Brothers Panel (1954).

/costs. The

costs. The structures presented in Figure II-B-I are based on these rates. In addition, transport costs for natural gas by pipeline[87/] are also needed to relate the fuel costs at or near gas fields to the world fuel price structure. Price equalization based on caloric content can be safely assumed whenever there is a large enough amount of gas available to allow for its use as a general industrial fuel, in addition to premium-type uses, such as in consumer markets. Thus, prices at the gas field are estimated as the price at the focal seaboard market, where equalization with fuel oil takes place, minus pipeline transport cost.[88/] Prices derived in this fashion may have to be modified downward, as discussed above in Section II-B-3, whenever local fuel (natural gas or fuel oil) production is large enough to enter the world market under conditions of oligopolistic market constraints rather than competitively.

An example of price determination for natural gas and fuel oil which illustrates how these two prices can diverge at a given location concerns the Gulf of Mexico.[89/] Assuming price equalization based on caloric content in the New York market, the price of natural gas in the Texas Gulf is New York minus pipeline transport cost of about one dollar per million kcal; the price of fuel oil at the same location is New York minus tanker shipping cost of 23 cents per million kcal. The price of natural gas at the Texas Gulf location is considerably below that of fuel oil, since fuel oil can be shipped from this area overseas to New York at a much lower cost per unit of caloric value than the overland pipeline shipping cost of natural gas.

The values of refinery products other than fuel oil, to be used as petrochemical raw materials, are determined by the alternative uses of these products. The value of reforming naphtha for aromatics production, for example, is determined by its alternative use as a motor fuel; the value of a C_4 stream[90/] for conversion to butadiene is determined by its alternative use as liquefied petroleum gas, as a gasoline additive, or as an industrial fuel, depending on which is the marginal use. It should be noted that in each of these cases, the alternative use can be taken to set a realistic

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87/ See Cookenboo (1955), Isard and Schooler (1955).

88/ The focal markets for North American natural gas is New York.

89/ Isard, Schooler and Vietorisz (1959), p.103.

90/ Butanes and/or butylenes.

/opportunity cost

opportunity cost only if there are no oligopolistic market restraints. A typical example of the latter is encountered in the case of gasoline. In the marketing of refinery products, gasoline tends to be relatively highly priced and fuel oil tends to be priced relatively low; for this reason, gasoline markets are shared under carefully balanced institutional arrangements of an oligopolistic nature whereas fuel oil markets are more competitive. If in a country the marketing or export of gasoline is limited under this kind of institutional arrangement, its opportunity cost is overstated, as noted in section II-B-3 above.

The importance of the price of caloric value to the planning of the chemical industries is due to the fact that this factor is the strongest among the various influences that tend to tie the location of the basic processes of this industry, i.e., the production of homogeneous chemical products of large tonnage or value, to specific geographical points. Contrariwise, economies of scale are totally neutral between alternative locations. Transport costs are less than completely neutral, since they tend to give some advantage to central locations from which products can be distributed to various markets at relatively low costs. Among the other factors of production, labour plays a subordinate role due to low absolute inputs, as will be pointed out in the sequel; steam, fuel, thermoelectric power and petrochemical feed streams are closely related to the cost of caloric value and their locational effects are effectively represented by the latter. Among other raw materials, salt and limestone are near-ubiquities at the regional level. This leaves sulphur phosphate rock, raw materials of organic origin, and hydroelectric power as other factors tending to localize the industry to geographically specific points; however, only the last one of these approaches in importance the role of the price of caloric value, and that only for a selected group of electrochemical and electrothermal processes. As a result, the rational locational pattern of basic chemical production is dominated, to a large extent, by the price of caloric value.

/C. <u>Equipment</u>:

C. Equipment: Relation to the metal working sector

In planning the development of the chemical sector, a particularly important linkage occurs with the metalworking sector. For the present purpose, this sector is defined as including all metal products, machinery, electrical and transportation equipment. The linkage is due first, to new investment and second, to the replacement of machinery and equipment in chemical plants.

1. General orders of magnitude of linkage

(a) The order of magnitude of the linkage to the metalworking sector[91] can be appreciated by reference to Table II-B-1 in the previous section, in which raw materials and intermediate product inputs occur side by side with inputs of machinery and equipment. When the economy grows at the rate of 6 per cent per year, the latter are of the order of 18 per cent of the value of total current flow inputs, i.e., only slightly less than all raw materials inputs, or the inputs of all chemical intermediate products participating in interindustry transactions. Therefore, the linkage to the metalworking sector is one of the important determinants of the development prospects and the planning of the chemical industry.

It should be noted that the figure illustrating this linkage should be taken only as approximate, because it depends heavily on the particular structure of the economy from which it is taken. The rate of growth of the chemical sector influences the need for new investment inputs, while the plant and equipment already in existence determines replacement inputs. In developing economies in which the chemical plants in existence are of relatively recent origin, the replacement inputs are temporarily of a minor character; however, if much of the existing capacity has come into being at approximately the same time or if one or two plants account for a large fraction of the capacity in a country, the replacement inputs, when they come due, can constitute a sudden heavy input need.

(b) The lifetime of chemical plant and equipment in the basic chemical processes[92] varies from about ten years upward to twenty years and perhaps more. An approximate idea of average service lives can be obtained from

91/ This estimate is derived in sub-para. (d).

92/ Production of homogeneous chemical products of large tonnage or value. See "Coverage", p. 8.

/depreciation figures.

depreciation figures. The U.S. Treasury Department has produced a tabulation of allowable depreciation rates for tax purposes: these, however, have been criticized as excessively low, i.e., they imply an excessively long service life.[93] It has been argued that even in those cases where the physical life of the equipment is quite high, technical progress and consequent economic obsolescence often causes equipment to be replaced before it is worn out. The criterion for replacement in the absence of technical progress is the balance between progressively increasing maintenance and repair costs and technical inefficiencies on the one hand, and the cost of capital tied up in new plant and equipment, on the other. Technical progress tends to shorten the economical life, by introducing an additional consideration in the above balance, namely the cost of economies foregone when the old equipment continues in use rather than being replaced by new and more efficient equipment.[94]

A selection of pertinent data applicable to developing countries will be found in the ECLA chemical industry study, in the form of depreciation allowances whose reciprocal can be taken as the approximate service life.[95] These depreciation allowances range from 6 per cent (sulphuric acid, formaldehyde, superphosphate) to 10 per cent (nitric acid, acetylene), thus giving approximate service lives ranging from 17 years down to 10 years. In another study of recent data for a developing area, a 10-year service life was allowed for caustic soda production.[96] A longer life expectancy for fixed capital stock in the chemical industry (21-25 years) is given by Grosse:[97] this, however, is an average that includes buildings and other construction with considerably longer service lives than machinery and equipment.

93/ US - Treasury Dept. (1955); Ryan (1958).

94/ For discussions of the problem of economical equipment replacement policy, see: DOMAR (1953), Alchian (1952), UN-Div. Ind. Dev. (1961:UIE).

95/ UN-ECLA (1963:CIL), Annex XIV: see activity tables for individual chemical processes.

96/ Manne (1964), page 9. This compares with an 11-year life (9 per cent depreciation) in the ECLA study. Manne's estimate is not independent, because he has relied on the ECLA figures, but he has applied checks to the same.

97/ Grosse (1953) Table 10, p. 224.

/The average

The average service lives referred to above of course do not mean that at a given date the plant collapses and must be replaced: as already mentioned, the replacement decision is forced by mounting current cost, and can be advanced or retarded to some extent; nontheless, large extensions of the service life beyond the economic optimum (calculated in the absence of technical progress) can lead to serious cost inefficiencies. It should also be noted that while the average service lives refer to the key components of a process plant, individual components and equipment classes of a subsidiary nature have their own service lives which can differ from the average for the plant as a whole. Such components can be replaced individually. Often, key components when near the end of their economic lives are replaced by their technically improved versions which can lead to the installation of new subsidiary equipment; it is also common for replacement and expansion to be integrated into a single operation.

(c) Expansion of capacity implies new investment rather than replacement; nevertheless, for the reasons mentioned above, the division between these two categories is not as sharp as the two terms might imply. The distinction also tends to be blurred by the fact that different components or equipment classes often have capacities which are not perfectly coordinated, because standard sizes of equipment (e.g., pumps, heat exchangers) are often used which have different effective capacities in relation to a given chemical process; also, these capacities are often not sharply defined, but vary with the load which is imposed on the process (e.g., the capacity of piping can be increased with the pressure differential that is applied, at the cost of additional pumping energy requirement). Given the fact that different process components have differing capacities, one of these capacities will constitute an effective limit for the process as a whole. If this bottleneck capacity is increased, the slack in the others will allow the effective capacity of the process as a whole to be increased, until the next bottleneck becomes effective. In this way, "unbalanced" expansions are possible. For a given capacity increase, an unbalanced expansion (if feasible) requires fewer resources than a balanced expansion.

/(d) In

(d) In order to estimate somewhat more closely the components of the linkage with the metalworking sector, replacement and new investment flows have to be related to the capital coefficient for the industry. The most up-to-date collection of capital investment data referring to individual chemical processes will be found in the ECLA chemical industry study.[98/] These data are totals for fixed capital, without a breakdown by sector of origin. Less recent data but with finer breakdown have been compiled by the Harvard Economics Research Project.[99/] Further data by individual process or industry branch will be found in Grosse, "Capital Requirements for the Expansion of Industrial Capacity", originally published in 1953 and recently republished.[100/]

When applying such data to the estimation of capital coefficients for the industry as a whole, several problems have to be confronted. Some of these relate to the proper weighting of individual coefficients, others to the statistical basis for reporting the ratio for comparison with other data. The relevant problems are discussed in a report by the United Nations Centre for Industrial Development: "A Study of Equipment-Output Ratios", three different estimates of the equipment requirements of the chemical industry for the U.S., U.K., and Japanese data will be found in the same source.[101/] These figures are reproduced in Table II-C-1 together with some additional figures derived from other sources.

As can be seen from the table, there is a large scatter among the data even after price corrections and approximate adjustment to an inter-industry sales basis. Some of this scatter is due to the difference in the

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98/ UN-ECLA (1963:CIL) Annex XIV, Tables. These data have been compiled by updating a collection of chemical activity vectors in Isard, Schooler Vietorisz (1959), Tables 3-6; the latter collection, in turn, goes back to Isard and Schoder (1955), Appendix A and B.

99/ Cristin, Cameron and Carter (1953).

100/ Grosse (1953:CRE).

101/ UN-Centre for Industrial Development (1961:SER), Table 2.

/the coverage

the coverage of fixed assets: thus, as discussed in the UN-CID (Centre for Industrial Development) study[102] the U.S. data refer only to machinery (ISIC[103] class 36-38), the U.K. data comprise all "plant and equipment"; whereas the data in cols. 11-12 of Table II-C-2 comprise all fixed assets. Even allowing for these factors, the scatter is still so large that the data can be used only for establishing orders of magnitude. One conclusion which emerges from the consideration of comparable data for several industries[104] is that the chemical industry has relatively large requirements of equipment: on the basis of the U.S. and U.K. data this industry is exceeded as an equipment user only by pulp and paper, petroleum and basic metals; whereas on the basis of the Japanese data, it is exceeded only by petroleum.

On the basis of the data of Table II-C-1 it has been decided to use the following estimate for defining orders of magnitude: for balanced new investments including balanced additions to existing capacity, the capital requirement embodied in goods originating in the metalworking sector is estimated as one dollar per unit of interindustry sales of the chemical industry (including such sales to the chemical industry itself). This decision is based on the judgment that the more recent data of columns 8-13 are inherently more trustworthy than the older data of the first columns;[105] within the range of the more recent data, however, the above estimate is probably on the low side. Thus, the importance of the linkage of the chemical industry to the metalworking sector is probably understated by this estimate.

102/ Op.cit.

103/ United Nations International Standard Industrial Classification, see United Nations Statistical Office (1958:ISI).

104/ UN-CID (1961:SER), Table 2.

105/ The figures in columns 1-7, 8 and 13 all originate in the input-output study group of W.W. Leontief; however, columns 8 and 13 represent work based on more recent sources which can be taken to supersede earlier material.

/Table II-C-1

Table II-C-1

SUMMARY OF DATA FOR THE ESTIMATION OF EQUIPMENT RATIOS FOR THE CHEMICAL INDUSTRY

	1	2	3	4	5	6	7	8	9	10	11	12	13
Coefficient	.23	.21	.23	.22	.22	.08	.22	.54	2.2	.61	1.25	2.02	.61
Year	1939	1939	1939/40	1939/40	1939	1940	1938/39	1953	1954/55	1955	1939/52	1958	1947
Country	United States	United States	Austral	Nether-lands	Canada	Mexico	South Africa	United States	United Kindom	Japan	United States	United States	United States
Coverage	United States 30, 34, 42, 66, 67			EQ4				ISIC 36-38	Plant & equipment	Equipment	Total fixed assets		Equipment
Nature of coefficient	Gross average equipment capacity ratio	Depreciated value of equipment per value of output						Equipment requirement for expansion of output on value Added basis	Replacement cost new estimates for insurance on value Added basis	Net average equipment output ratio on value Added basis	Replacement cost, new, total fixed assets, ratio to sales		Equipment requirement for expansión of output, per annual output, straight average of 65 processes
									Adjusted to 1962 prices				
Coefficient	.29	.26	.29	.27	.27	.10	.27	.65	2.7	.74	1.98	2.12	.96
									Adjusted to Interind. Sales Basis				
Coefficient	?	.26	.29	.27	.27	.10	.27	1.14	4.74	1.30	1.98	2.12	?
Comment	Adjustment for capacity utilization								Assumed 57% value added				Adjustment for captive output
	1A	1B	1B	1B	1B	1B	1B	2	2	2	3	3	4

Sources: 1A Grosse (1953: SCU), Table 1, sum of coefficients in industry group of origin N° 30, 34, 42, 66, 67.
1B Op. cit., Table 6.
2 UN-CID (1961:SER), Table 2. Estimate for United States based on Harvard Economic Research Project data.
3 Lynn and Howland (1960).
4 Cristin, Cameron and Carter (1953), Table 1. Based on Harvard Economic Research Project Data.

Notes: 1. All price adjustments based on wholesale price index series in United States Bureau of Census (1953:HSU) and (1963:SAU). Chemical prices refer to "chemical and allied products", equipment prices are taken as the average of "metals and metal products" and "machinery and motive products".
2. The coefficients of Grosse (cols. 1-7), the United States estimate from the UN-CID report and the average figure of col. 13 all originate directly or indirectly in work proposed by the input-output study group under the direction of W.W. Leontief.

/Using the

Using the above estimate, on the basis of an average 12-year service (8 per cent depreciation) and on the assumption of a uniform spread of replacement expenditures over time, the linkage due to replacement is .08$ per $ of sales; with a growth elasticity of 1.66 for the sector as a whole,[106] the linkages that result on the basis of growth rates of the economy ranging from 2 to 8 per cent, vary from 11 to 21 per cent. (See Table II-C-2).

Table II-C-2

Chemical - Metalworking Linkages[107]

growth rate for the economy, percent	2.0	4.0	6.0	8.0
growth rate for the chemical industry, percent	3.3	6.6	10.0	13.3
machinery and equipment flows:				
replacement	.080	.080	.080	.080
expansion	.033	.066	.100	.133
Total	.113	.146	.180	.213

2. Effects of linkage

The effects of the linkage of the chemical industry to the metalworking sector depend on whether there exist domestic industries falling within this sector.

(a) If no domestic metalworking industries exist, the flows indicated in Table II-C-2 above constitute a large foreign exchange requirement and an important offset to the foreign exchange savings effected through the replacement of chemical imports by domestic production. Moreover, the flows

106/ See Sec. I-A-1.

107/ An order of magnitude for construction flows can be derived in a similar way. Grosse (1953:SCU), Table 1, gives a construction coefficient of .14 that is consistent with the sume of coefficients originating in his groups 30, 34, 42, 66 and 67 (see notes to Table II-C-1) and which has the value of .23 (see Table II-C-1). If the ratio of the two capital requirements can be accepted as correct, the construction component corresponding to the previously utilized equipment/sales ratio of 1 dollar will be 0.61 dollar. With a twenty-year lifetime, this gives depreciation flows of 0.030; while the expansion rates of the chemical industry postulated in Table II-C-2 give corresponding construction flows for expansion of 0.020, 0.040, 0.061 and 0.081, respectively. The third of these, corresponding to a 6 per cent growth rate of the economy, has been accepted as the basis of the construction flow coefficient included in Table II.B.1.

/presented in

presented in the table refer to normal size plants in the United States; thus if the scale of operations of a plant in a developing area is substantially smaller, the capital requirements per unit of output will rise, and thereby the burden on the balance of payments will increase.

Since replacements are not tied to a strict time schedule, in times of foreign exchange shortage replacements can be put off under the pressure of other expenditures which are more rigidly determined. If so, the result will however be excessive repair and maintenance requirements. Since these requirements in part also represent inputs originating in the machinery and metalworking sectors (e.g., spare parts) they will again lead to foreign exchange needs, but the latter are now rigidly determined rather than flexible. Thus a country which tends to put off replacement expenditures due to foreign exchange problems will create not only inefficient (higher-cost) general operating conditions in the chemical industry, but will also induce additional and rapidly increasing foreign-exchange needs for repair and maintenance materials whose procurement cannot be put off without drastic effects on production.

(b) If some domestic capacity exists in the machinery and metalworking sectors, the picture is more favourable. Some repair and replacement of relatively simple process equipment components (tanks, vessels, towers, piping) will now become practicable; and with an increasing capacity and diversification of the metalworking sector, the percentage of the flows in this linkage that can be supplied from domestic sources will increase.

Chemical processes differ substantially in the degree to which they use simple rather than complex fabricated components. A few spot estimates for five processes for Chile (a country having considerable metal transforming capacity) have shown a spread of the order of one third to two thirds of the total value of process equipment that could eventually be procured from domestic sources.[108/] In an ECLA study of the basic equipment industries of Brazil, it was found that 64 per cent of the needs of an expansion programme of the petroleum refining and petrochemical industries could be covered from domestic sources.[109/] The latter case is, however, exceptional, because

108/ UN-ECLA Chemical Industry study group, verbal communication.

109/ UN-ECLA (1963: MIM).

/Brazil has

Brazil has an unusually large domestic market and a highly developed metal transforming and machinery sector. For smaller countries with per capita income levels in the 100-300 dollar range, it appears reasonable to assume that the percentage of machinery and equipment that could be supplied to the chemical industry for replacement and expansion from domestic sources will vary from one third downward to near zero.

There are two factors that militate against easy import substitution in regard to chemical plant and equipment. First, as increasing percentages of capital requirements are substituted, the more and more sophisticated components have to be produced domestically. Such components are often produced by fabrication techniques utilizing specialized or outsize metal-working equipment which typically has enormous capacities in relation to the demand generated by the chemical industry alone, or even by the entire manufacturing sector of a small developing country in the above income range. Secondly, the processes utilized by the chemical industry, and therefore the equipment and machinery needs of the same, are in constant flux due to rapid technological progress, and the accumulated skills and know-how needed for keeping abreast of these developments require a large technical-engineering organization such as the smaller developing countries cannot effectively maintain on their own.

In sum, (i) equipment and machinery requirements are translated into either foreign-exchange or domestic-supply needs; (ii) the latter are highly sensitive to the effects of economies of scale, first in regard to fabrication of specialized or outsize components and second, in regard to the engineering know-how that is needed for keeping up with technological change.

It should be added in conclusion that while the problem of the linkage of the chemical industry to the metalworking and machinery sector is often very difficult to attack satisfactorily, a considerable part of the gross capital investment (both for replacement and for expansion) takes the form of construction and of installation of machinery and equipment.[110/] Import substitution in regard to these flows is far simpler and easier than that in regard to machinery and equipment, and should in all cases be tackled energetically, since failure to do so will result in a largely unnecessary burden on the balance of payments.

110/ See Table II-B-1, and the last note to Sec. II-C-1.

/D. Employment

D. Employment

It has been stated earlier that the chemical industries are poor providers of jobs, particularly unskilled ones, for solving the often very serious problem of underemployment in developing countries. In this section, some orders of magnitude will be established concerning this problem, and some further issues will be discussed, including economies of scale in regard to labour inputs, capital-labour substitution possibilities, and others.

1. Orders of magnitude of labour inputs

(a) General. The chemical industry is near the lower end of the spectrum of industries in regard to unit labour costs. Some data demonstrating this point are presented in Tables II-D-1 and II-D-2. In Table II-D-1, wages are shown as percent of value of product, based on the U.S. census of manufactures for the year 1947. These data have been converted to millions of man-hours per million dollars' worth of product at 1962 prices, using wage and wholesale-price statistics. As seen, industrial chemicals as a group have a labour coefficient, in the above units, of .087. Paints and varnishes, and synthetic rubber (both included in the chemical industry under a broad definition),[111] have even lower coefficients, of .048 and .050, respectively. This compares with coefficients in the .094 - .189 range for textile products and .162 - .213 range for machinery and machine tools.

Table II-D-2 presents similar labour coefficients taken from input-output tables for the U.S. The coefficients for 1939 have been converted to 1962 prices using a wholesale price index for chemical and allied products. In this tabulation, also, the chemical industry appears near the low end of the range, with a coefficient of .013. These coefficients have historically shown a pronounced downward trend, as the table clearly indicates.

The coefficients for the chemical industry calculated from the two sources differ considerably. This is probably due in part to the definition of the industry and to the kinds of labour included under the heading of wage payments. Nevertheless, the main conclusion is established that the chemical industry shows a relatively low degree of labour intensity.

111/ See "Coverage", p.8.

/Table II-D-1

Table II-D-1 (Part 1)

Labour costs and labour coefficients

Low labour cost industries	Wages as percent of value of product (1947)	Labour coefficient 10^6 MHRS/10^6 $(1962)
Flour milling	3.4	.022
Cane-sugar refining	4.8	.031
Cigarettes	4.9	.032
Petroleum refining	6.0	.039
Meat products, except poultry	6.3	.041
Liquor, distilled	7.1	.046
- Paints and varnishes	7.5	.048
- Rubber, synthetic	7.8	.050
Medium labour cost industries		
Beet sugar	11.4	.073
Leather tanning	12.2	.079
Aluminum, primary	13.0	.084
Baking, bread	13.4	.086
- Chemicals, industrial	13.5	.087
Paper and paperboard	13.6	.088
Pulp	13.6	.088
Canning and preserving	14.3	.092
Baking, biscuits and crackers	14.4	.093
Clothing, work shirts	14.6	.094
Women's and children's undergarments	15.0	.097
Liquorm mail	15.0	.102
Frozen foods	16.6	.107
Clothing, men's shirts	18.8	.121
Cement	19.5	.126
Rubber, tires and tubes	20.1	.129
Rayon and related woven fabrics	20.4	.131
Cotton, broad-woven goods	21.2	.137
Woolen and worsted manufacturing	21.7	.140
Women's and misses' dresses	21.8	.140
Cigars	22.0	.142
Clothing, men's and boys' suits and coats	23.5	.151
Shoes	24.5	.158

/Table II-D-1 (Part 2)

Table II-D-1 (Part 2)

High labour cost industries	Wages as percent of value of product (1947)	Labour coefficient 10^6 MHRS/10^6 $(1962)
Special industrial machinery	25.1	.162
Glass, containers	25.3	.163
Rubber footwear	29.4	.189
Full-fashioned hosiery	29.4	.189
Machine tools	33.1	.213
Glass, pressed and blown ware	37.0	.238
Pottery and related products	42.4	.273
Shipbuilding and repairing	43.9	.283

Note: Classification of industries and first column of figures taken from U.S. Int. Coop. Adm. (1958:MID), Exhibit VII-6. Labour coefficients for 1962 were calculated on the basis of wage rates for the chemical and allied industries; value of product was adjusted to 1962 prices. Both wages and prices were taken from U.S. Bureau of Census data - see ref. (1963: SAU) and (1953: HSU): for wages, Table 311 and series D-634; for wholesale price index, Table 469 and Series E-32.

/Table II-D-2

Table II-D-2

Labour coefficients of the chemical industry

10^6 MHRS/10^6 U.S.$

		1939 Prices			1962 Prices
		1919	1929	1939	1939
1.	Agriculture and food	.31	.24	.19	.100
2.	Ferrous metals	.07	.04	.04	.019
3.	Automobiles	.09	.04	.03	.017
4.	Metal fabricating	.08	.05	.04	.023
5.	Non-ferrous metals	.12	.07	.04	.021
6.	Non-metallic minerals	.10	.05	.04	.023
7.	Petroleum and natural gas	.03	.03	.02	.009
8.	Coal, coke and mf. gas	.05	.04	.04	.018
9.	Electric utilities	.10	.08	.05	.026
10.	Chemicals	.06	.03	.02	.013
11.	Lumber, paper, print. and pub.	.12	.07	.06	.032
12.	Textiles and leather	.11	.08	.08	.040
13.	Transportation	.12	.11	.12	.061

Source: Leontief (1953): Studies in the Structure of the American Economy, Chapter 2, Tables 1-3, pp. 24-26.

Note: Source data in 1939 prices have been recalculated to 1962 prices using the following price indexes of the U.S. Bureau of Labour Statistics for wholesale prices of chemical and allied products: 1939 = 50.8, 1962 = 97.5, base 1957-59 = 100.0.
See U.S. Bureau of Census (1953:HSU), Series E 32 and
" " " " (1963:SAU), Table 469.

/In order

In order to form an approximate idea of the number of jobs generated by a given volume of chemical production, the above coefficients may be applied directly to the volume of production. The resulting labour inputs will have the correct order of magnitude, as illustrated by figures taken from a recent Latin American chemical industry study[112/] (see Table II-D-3). The total manpower needs for 46 basic chemical-industry products which in the aggregate represent some 25 per cent of total chemical industry demand, have been estimated at 20 million man-hours per year on the assumption that production takes place in integrated plants serving the entire market of the twenty republics; on the assumption of separate plants for individual national markets, the sum of labour requirements for five principal national markets is estimated at 50 million man-hours per year.[113/] The value of production being estimated at some 550-600 million US.$, the resulting labour coefficient is in the range .033-.091, i.e., in the range of the coefficients presented earlier.

If the latter manpower needs are converted to the number of jobs generated, they yield 10 000-25 000 jobs, depending on the degree of regional integration. By comparison in the year 1965, the target year of these projections, the labour force in Latin America will increase roughly by some 2 million persons.[114/] Thus the ambitious chemical-industry expansion and import substitution programme envisioned in these projections would at best utilize barely one percent of the labour force <u>increase</u> of a <u>single</u> year.

A final illustration is provided by the ECLA industry study for Peru.[115/] In this study, a projection is prepared from 1955 to 1965: the total increment of the economically active population for these years is estimated in round figures as 1 million persons. Of these, the projection assigns roughtly 10 per cent, or 100 000 persons, to the manufacturing industries

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112/ Vietorisz and Szabo (1959), summary tables of calculations.

113/ Includes direct operating labour plus indirect labour used in the chemical processes and their ancillary operations.

114/ Based on a population of 225 million persons, a 2.5 per cent rate of increase, and a 35 per cent labour force participation rate which has been intentionally underestimated.

115/ UN-ECLA (1959:IDP).

/proper excluding

proper excluding handicrafts.[116] Of this number, again 10 per cent or some 10 000 persons are assigned to the chemical industry[117] which is the third largest source of new jobs in this projection, following right after the metalworking industries (broadly defined) and the food industry. It would appear that the role of the chemical industry as a provider of new jobs is more important in this projection than the previous evaluations would have indicated. It should be noted, however, that first, the scales of production for serving this single national market are small, and the unit labour inputs are consequently high; and second, in this industry there is a large possibility of once-over expansion through import substitution, a possibility which does not exist in other industries such as food or textiles and which will not recur in future expansion programmes of the chemical industry. In spite of these factors, the total labour absorption for the 10-year period is only 1 per cent of the labour force increase for the same period. Evidently, the promotion of this industry primarily with a view to providing new jobs is less than promising.

(b) Skilled and technical manpower. In regard to skilled labourers, the chemical industry tends to be in the low range; contariwise, in regard to technical and professional manpower as well as managerial and clerical personnel, it has relatively high requirements.

In the ECLA industrial study for Peru referred to above, the chemical industry appears approximately in the lowest quartile of industrial branches covered; for the base year and the target year of the projections, the percent of skilled labourers to total labourers was estimated as 15 per cent and 27 per cent respectively. This compares with about 80 per cent for apparel, 50 per cent for furniture, 30-40 per cent for textiles and about 25 per cent for metal manufactures and machinery.[118] A similar picture emerges from the ECLA study for Argentina[119] where the chemical industry is

116/ Table 31, p.43 (Spanish edition).

117/ Op.cit., Table 239, p. 301 (Spanish edition).

118/ UN-ECLA (1959:IDP) Table 240, p. 301 (Sp.ed.).

119/ UN-ECLA (1959:EDA) Vol. 2, Part B, Annex, Table 94, p. 247 (Sp.ed.).

/the lowest

the lowest of 8 industrial branches in regard to the percent of skilled labourers, which is in the range of 12-15 per cent. It should be noted that what constitutes a "skilled" labourer is subject to some latitude of definition, but the above figures offer a valid comparison between industries.

In regard to technical and professional manpower, the chemical industry is one of the highest users among the branches of the manufacturing industry. In a recent survey of Japanese data prepared for the United Nations,[120] the chemical industry appears with 3.9 per cent based on total employees, exceeded only by printing and publishing, and followed by machinery (2.9 per cent) and primary metals (2.5 per cent). In the ECLA Peru and Argentina studies cited above, the chemical industry again appears at or near the top, together with machinery and transport equipment, and in the case of Argentina, also with petroleum. The percentage estimate of technical and professional employees is somewhat higher for the Latin American countries than for Japan: 4-6 per cent for Peru, and 6-8 per cent for Argentina.[121]

For the case of Japan, data are available also on the percent of managerial and clerical employees, in regard to which the chemical industry ties for first place with printing and publishing with some 25 per cent of total employees.[122]

Whether the manpower training needs represented by the chemical industry become a significant element in the development planning of an economy depends on the importance of the chemical sector in a particular development programme. As an indication with regard to orders of magnitude, in the ECLA industrial development study of Peru the expansion of the chemical industry was assigned a substantial role: it was allocated 20 per cent of all industrial investments;[123] at the same time, its share of newly-trained technical and professional manpower was estimated as 20 per cent, of newly-trained skilled labourers as only 7.5 per cent.[124]

120/ Okita (1963), Table 3.

121/ Peru: UN-ECLA (1959:IDP), Table 242, p. 303; Argentina: UN-ECLA (1959:EDA), Table 95, p. 248.

122/ Okita (1963), Table 3.

123/ Op.cit., Table 244, p. 304.

124/ Op.cit., Tables 241 and 243, pp. 302-303.

/2. The

2. The role of labour inputs in development planning

(a) Labour inputs in the chemical industry are subject to economies of scale which are even more powerful than those characterizing the requirements for fixed capital. Correlations of labour inputs indicate an elasticity with respect to scale of the order of 0.2.[125] Thus, large increases in scale will correspond to small increases in labour requirements. Since the number of workers per shift is an integer and since many processes require only a handful of operators[126] large capacity ranges will be characterized by identical numbers of workers per shift.

Notwithstanding these powerful economies of scale, their effect on the planning of development is slight, since they operate on an input which is small in absolute magnitude. Thus, the relatively large labour inputs associated with small scales of production will constitute a much smaller disadvantage for developing countries than the diseconomies of small scale due to fixed capital requirements. It has to be noted, in addition, that labour tends to be an overvalued resource; thus, at social accounting prices, the disadvantage is even smaller than at market prices. Conversely, if one of the objectives of development is taken to be the creation of job opportunities, the economies of scale in the use of labour may be regarded as a disadvantage, because they will permit the expansion of capacity (if associated with the replacement of old capacity) without a significant expansion of employment.

(b) The possibilities of capital-labour substitution[127] in the chemical industry are limited both actually and potentially: actually, because the modern chemical processes which have been developed in the industrialized countries are adjusted to the high wage rates prevailing there; and potentially, because in the chemical industry there appears to be less

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125/ Wessel (1952).

126/ See technical data in UN-ECLA (1963:CIL) (chemical industries study), Annex XIV tables.

127/ For a general discussion of the merits of labour vs. capital intensive processes, see UN-Bur.Ec.Aff. (1958:CII), with extensive literature citations. For a discussion of technical substitution/adaptation possibilities, see UN-Centre Ind. Dev. (1963:APE), with literature citations.

/room for

room for substitution on technical grounds than in other industries, especially the ones characterized primarily by mechanical transformation processes.

Since there is very little quantitative information available in regard to this problem it will be instructive as a background for judgement to survey the principal operations which characterize the chemical industry and other industries in which chemical processes play a major role.[128/]

(i) Operations characterized by a dependence on basic physical processes are at the lower end of the range of capital-labour substitutability,[129/] since in these operations the possibility of human intervention is quite limited. These include fluid flow, heat transfer, evaporation, humidification/dehumidification, gas absorption, solvent extraction, absorption, distillation and sublimation, and drying. Many of these operations are typically performed under continuous operating conditions, but there is perhaps some possibility of replacing the latter by batch processes. Such a replacement may conceivably lower the unit capital requirements: (e.g., if fluids were carried in containers rather than being pumped through piping) but it is very doubtful that capital requirements would diminish faster than unit capacity when going from continuous to batch operation.

(ii) Passing to a higher degree of substitutability, we encounter operations characterized by a combination of physical transformation and mechanical control. The latter include mixing, centrifugation, classification, filtration, screening, crystallization, disintegration and materials handling. Due to the element of mechanical control involved, there is a range of discretion in regard to these processes in the substitution of labour for automated operation. Most of these processes have originally been operated batchwise, utilizing simple equipment, and continuous operation has been introduced gradually by means of automation and redesign. While the technical possibility of capital-labour substitution in regard to these

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128/ See Shreve (1957), Chap. 1, for a list of processes and operations.

129/ The use of human beings as prime movers (primary energy sources) has been abandoned a long time ago and will not be considered as an option in capital-labour substitution in the chemical industries.

/processes is

processes is greatly superior to that characterizing the previous group, it is still not clear whether the reduction of capital requirements when passing from continuous to batchwise operation would not be more than compensated by a reduction of capacity and a deterioration of control and quality.

(iii) Process control. The control of such process variables as temperature, pressure, flow rate, concentration, etc., has traditionally been performed by human operators, and has only recently come under consideration from the point of view of automation. The control of chemical processes by means of computers is a distinct technical possibility, but since the range of substitution here is opposite from the one of concern to underdeveloped countries, it is of lesser interest from the present point of view. It should be noted that neither the potential savings nor the expansion of technology into new areas permitted by this advance (e.g., close control of unstable gas reactions which is impossible by hand) is likely to lead to major changes in the near future.[130/]

(iv) Core versus ancillary parts of a process.[131/] Most of the operations considered heretofore, with the possible exception of materials handling, usually belong to the core of a chemical process. Ancillary processes or operations, as distinguished from the core, are related less closely to the primary transformation taking place in the process, and are more in the nature of auxiliary sub-processes or complementary operations which, while essential, can for many purposes be considered separately. Although there is no firm dividing line between the core and the ancillaries, it is clear that such processes as steam and power generation, water treatment, sewage and waste disposal, air purification, central supply of compressed air, vacuum heating and lighting to several process areas can be classed as ancillary processes. In regard to capital-labour substitution, these are analogous to the core processes in that they can be broken down into the three types of operation discussed above (physical-process dependent operations, physical transformation/mechanical control type operations, and process control) with their capital-labour substitution possibilities depending on the characteristics of the latter operations.

130/ Vietorisz (1963:PCH), Sec. 38-39.

131/ For a discussion of this distinction, see for example: Malmgren (1959), Vietorisz (1963:PDC).

/(v) In

(v) In addition to the above ancillary processes, there exists a group of ancillary operations which are complementary both to core processes and to the ancillary processes listed above. These include maintenance and repair, storage and inventory handling, most kinds of materials handling, internal transport, the operation of external transport connections including loading and unloading, laboratory and technical inspection, fire and police protection, the operation of employee services including first aid, washroom and cafeteria services, and office services. The above ancillary operations are characterized by a good deal of mechanical activity and a large element of control. This is equally true, e.g., of maintenance and fire fighting, the giving of first aid and the driving of fork lift trucks and the other operations listed above. These operations are typically labour intensive and have become subject to automation only relatively recently. It is primarily in regard to these operations that capital-labour substitutability of a significant degree exists in chemical processes.

In the absence of a technology developed in the direction of economizing capital inputs by labour substitution in the chemical industry, it is difficult to establish orders of magnitude for this potential without detailed engineering studies of individual processes. The following is, therefore, merely an attempt to apply a reasonable conjecture.

In a tabulation by the Harvard Economics Research Project[132/] a percentage distribution of equipment expenditures is given for a number of chemical processes by categories of "process equipment" and "auxiliary equipment". Within the class of "auxiliary equipment", the categories "conveyors and conveying equipment" and "mechanical measuring and controlling instruments" have been summed and an average percentage figure was derived which turned out to be 6 per cent. This composite category is, however, both too broad and too narrow at the same time. On the one hand, it includes non-substitutable capital, especially under the heading of instruments; on the other hand, it does not allow for the substitution possibilities that might present themselves in regard to some of the ancillary operations (e.g., maintenance) or some of the core operations combining physical transformation

132/ Cristin, Cameron and Carter (1953).

/and mechanical

and mechanical control (see ii above). Nonetheless in the absence of better data, the above figure may be taken to define an order of magnitude; thus the estimate may be ventured that the amount of capital that can be economized by means of capital-labour substitution is perhaps of the order of 5-10 per cent; while any hope of substituting as much as 25 per cent of equipment by the use of labour-intensive techniques certainly appears to be greatly exaggerated in the light of the above considerations.

E. Research and development[133/]

The chemical industry is one of the most dynamic branches of the manufacturing industries: it is characterized by rapid technological change and the emergence of new and improved processes as well as new and improved products. A measure of the pace of historic change is the ratio of sales of new products not in existence at an earlier date to total current sales. In regard to this measure taken over the 1956-1960 period in the United States, the chemical industry, with a figure of 16 per cent, ranks third, following aircraft, ships and railroad equipment (35 per cent), and fabricated metals and instruments (17 per cent).[134/]

The rapid technological change of the chemical industry is made possible by large expenditures on research and development. Table II-E-1 summarizes some data taken from United States practice which permits a comparison of different industries from this point of view. It can be seen that the chemical industry is near the top of the list in regard to all indicators, including total expenditures on research and development, ratio to value added or sales, and professional manpower utilization.

The principal source of this table, apart from the Statistical Abstract of the U.S. Bureau of the Census, was a recent study of research and development in the United States by the National Industrial Conference Board.[135/] This reference contains much additional detail which is useful from the point of view of the chemical industry: thus it distinguishes

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133/ For a recent survey of research and development in the U.S. see Terleckyj and Halper (1963). See also US-NAT'l Sci. Foundation (1957, 1958).

134/ Terleckyj and Halper, Table 19.

135/ Terleckyj and Halper (1963).

/between classification

between classification by industrial group and actual destination of research and development effort (i.e., not all research and development undertaken by chemical companies goes into chemical and related products, and conversely, some other companies also do research in the chemical field[136]); it furnishes some breakdown by major chemical product group;[137] and gives expenditure breakdowns by professional manpower, supporting manpower, non-payroll and other categories.[138]

In regard to economic development planning in the chemical industry, research and development gives rise to the following problems:

- Manpower training
- Economies of scale in research and development
- Adaptation of technology to local raw materials and other local conditions including desired capital/labour substitution.

(a) The order of magnitude of the manpower training needs may be appreciated by reference to the coefficients and ratios given in Table II-E-1. Professional research and development personnel, as seen in the table, is of the order of 3 per cent of total employees, with an additional 7 per cent for supporting personnel. If these coefficients are transferable from the United States to a developing country, they allow the estimation of total manpower pools required and, by comparison with current availability, lead to estimates of training requirements.

(b) The extent to which the United States coefficients may be applicable to other conditions can be better appreciated by reference to some other pertinent facts of U.S. practice. Chief among these is the high degree of concentration of research and development activities among a small number of companies. Among 20 major branches of manufacturing for which data have been compiled[139] the lowest concentration index (the percentage share of the 4 top companies in total research and development expenditures)

136/ Op.cit., Table 16.

137/ Op.cit., Tables 11, 16.

138/ Op.cit., Chap. 5.

139/ Op.cit., Table 24.

/Table II-D-3

Table II-D-3

LATIN AMERICA CHEMICAL STUDY MANPOWER NEEDS

(Millions of Mhr/yr)

	Chile	Argentina	Brazil	Venezuela	Mexico	Latin America Reg.	Total of countries
1. Sodium carbonate solvay	1 277	1 782	1 693	1 122	1 877	1 380	
2. Caustic bicalcium phosphate complex	560	847	1 091	605	801	3 124	
3. Superphosphate tripoly-phosphate complex	251	562	839	458	337	1 926a/	
4. Silicon carbide	87	124	132	102	123	167	
5. Nitrogen complex	210	502	710	343	392	2 164	
6. Urea and phenol/formaldehyde complex	420	-	528	480	502	662	
7. Cellulose acetate, PVA, PVC complex	4 219	5 424	6 012	4 179	5 004	8 630	
8. Polyethylene-polystyrene-butadiene complex	477	733	880	639	781	1 492	
9. Carbon black	45	56	67	51	58	137	
10. Dodecyldenzene-propylene tetramer complex	111	180	204	116	172	252	
11. Acetone-isopropyl alcohol complex	152	203	240	166	211	320	
12. Alumina-aluminum	1 744	3 574	3 017	2 878	-	4 322	
Total 1 - 11	7 809	10 413	12 396	8 261	10 258	20 254	49 137
Total 1 - 12	9 553	13 987	15 413	11 139	-	24 576	-
Jobs - Estimated at 2 000 Mhr (yr. Job)							
Total 1 - 11	3 900	5 200	6 200	4 100	5 100	10 100	24 600
Total 1 - 12	4 800	7 000	7 700	5 600	-	12 300	-

Source: Vietorisz and Szabo (1959), summary tables in Annex V.

Note: The above estimates are based on direct operating labour plus and allowance of 75% for indirect labour manhours.

a/ Not integrated.

/Table II-E-1

Table II-E-1 Comparisons

UNITED STATES RESEARCH AND DEVELOPMENT

	Research and development expenditure (millions of dollars) 1960	Value added (millions of dollars) 1960	Percentage of expenditure Value added	1 per cent of expenditure Sales	Scientific and engineering: Research and development Manpower (thousands of persons) 1960	Scientific and engineering: Manpower coefficient Persons / (millions of dollars) Value added	Professional research + development (Employment as percentage of total employment)	All research and development (Employment as percentage of total employment)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Aircraft and missiles	3 631	6 599	55.0	17.7*	85.4	12.9	7.3	24.1
2. Electrical equipment and communication	2 406	20 174	11.9	10.5	72.2	3.6	3.7	10.2
3. Chemical and allied products	986	14 347	6.9	3.8	34.4	2.4	3.3	7.2
4. Machinery	932	14 383	6.5	3.6	31.7	2.2	1.8	5.1
5. Mobilization vehicles and other transportation	864	11 848	7.3	NA	18.7	1.6	NA	NA
6. Instruments	396	3 819	10.4	7.5	13.8	3.6	3.8	9.2
7. Petroleum refineries and extraction	290	5 136	5.6	1.1	8.9	1.7	1.6	3.7
8. Primary metals	160	13 350	1.2	.8	5.5	.4	.4	.8
9. Rubber products	120	3 773	3.2	1.8	4.6	1.2	.6	1.3
10. Fabricated metal products	118	10 320	1.1	1.6	4.3	.4	.5	5.1
11. Food and kindred	102	19 721	.5	.3	5.5	.3	.2	.4
12. Stone, clay and glass	96	6 394	1.5	NA	NA	NA	NA	NA
13. Paper and allied	56	6 554	.9	NA	2.5	.4	NA	NA
14. Textiles	32	5 669	.6	NA	1.2	.2	NA	NA
15. Lumber, wood, furniture	9	3 456	.3	NA	.6	.2	NA	NA

Source: (1) United States-Bureau Census (1963: SAU), Table 738, p. 545.
(2) " " " Table 1 095, p. 780-1, and Table 438, p. 327.
(3) Calculated.
(4) Terleckyj and Halper (1963), Table 33.
(5) " " , Table II.
(6) Calculated.
(7) Terlne - 63-RDG, Table 33.

* Aircraft and parts.

/is 31 per cent

is 31 per cent; for the majority of branches, it is in the range 40-60 per cent, and for a few it is substantially higher, e.g. for motor vehicles, 88 per cent; for scientific and mechanical measuring instruments, 78 per cent; for rubber products, 86 per cent. These figures compare with 60 per cent for industrial chemicals, 52 per cent for other chemicals, and 41 per cent for pharmaceuticals; i.e., the chemical industry is in the middle range of concentration with regard to research and development. While average in comparison with other industries, this concentration is still very high in absolute terms.

A high degree of centration suggests, even though it does not prove conclusively, that there are strong economies of scale in the operation of research and development establishments. This creates a considerable problem for smaller countries in the planning of their chemical industrial development, because it indicates that the manpower coefficients derived as averages for U.S. industry cannot be simply applied to chemical-industry outputs that are scaled down in proportion to local demand. Certainly the small markets of many developing countries will not support the kind of decentralized research and development effort characterizing the large chemical market of the United States. If such research can be undertaken at all locally, it has to be considered as a single centralized effort, and has to be planned as such.

(c) The advantages of local research and development establishments include ease in the adaptation to local raw material conditions and to capital/labour intensities as locally required; the conservation of foreign exchange which would have to be spent on research and development contracted in foreign countries; and perhaps most importantly, the maintenance of the competitive position of local industry in relation to the advancing level of technology characterizing the world chemical market. While many basic chemical plants can now be purchased and erected on a contract basis through internationally known engineering firms, such plants may become rapidly obsolescent unless serviced and kept up to date by a continuing and substantial research and development effort. The planning of such an effort jointly with the planning of the physical investments in chemical plant and equipment is crucial, because unlike the original plant, the research and development service cannot be readily purchased on the world market.

/CONCLUSIONS

CONCLUSIONS

1. Planning methodology

In order to give focus to the many themes touched upon in this report, it is relevant to ask: what can be done and what cannot be done within the present limits of knowledge, in regard to the planning of the chemical industries at the national level?

(a) First, approximate priorities can be established in regard to the expansion of the chemical sector as a whole or the undertaking of major chemical projects. These priorities concern the allocation of investment funds and the establishment of policies of import substitution and possibly of promotion of new exports. In taking decisions concerning these matters, the chemical sector or the respective projects have to be measured against the opportunities afforded by other sectors. The principal tool for defining these priorities is the modelling of the economy as a whole by means of linear programming and its extensions. In such models, the chemical sector appears as one activity or a small group of activities. The model may answer certain questions directly, such as the desirable scales of expansion of domestic production and imports in the sector, or it may be used indirectly to evaluate more detailed investment projects which are not a part of the model. The latter application is made possible by the social accounting ("shadow") prices contained in the solution of the model. While the use of linear programming models in economic planning is still experimental, progress in this field is rapid, and there are several examples of successful formulations.

(b) Second, in regard to the structure and location of chemical activities at a more detailed level, considerable empirical material is available which can be used directly in studies of the sector covering a particular geographical area. The technical coefficients describing this sector are far better developed than those describing most other sectors of the economy, and they permit the formulation of feasibility studies based on the major components of production cost, both at market prices and at social accounting prices. Such feasibility studies may answer questions concerning the comparative advantage of a process at a given location; the number and location of plants for serving a given market area most

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efficiently, the interaction of geographical location patterns and the time-phasing of construction, the interaction of several individual processes by means of raw materials, end products, or processing chains, and other related questions. These studies provide a concrete background for decisions concerning the commissioning of highly costly project engineering work.

2. Economies of scale and common markets

In regard to substance rather than method, the principal conclusion of the report is the overwhelming importance of economies of scale and the disadvantage of serving restricted markets. The chemical industry, especially its basic branches, requires sub-continental markets for efficient operation. The penalty of small-scale production is paid in terms of a loss of capital productivity, in particular, of capital embodied in machinery and equipment. Insofar as this represents an import requirement, the result will not only be a deterioration of the capital-output ratio (and, therefore, of the growth potential) of the economy in question, but also a debit on the foreign exchange balance, and, therefore, an adverse consideration in relation to import substitution. Joint planning of the expansion of the chemical industries in common market areas of sub-continental dimensions is clearly indicated.

The difficulties of such a course of action are, however, great. Joint planning involves supra-national cooperation of a kind for which there are few successful precedents. Opposition will be based on fears concerning the viability of already-existing chemical industries if exposed to the competition of a common market; the uncertainties of submitting development decisions to the discipline of international consultation; the uncertainties of the indefinite maintenance of the political atmosphere during which the supra-national planning effort has been initiated; the opposition of governing groups jealous of their prerogatives and fearful of a fall in their prestige and power in the case of fargoing economic integration; and ideological arguments involving national sovereignty. At the very least, it is to be expected that any country joining such a supra-national common planning effort will attempt to make very sure that it is receiving its proper share of the benefits of economic integration.

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While the former points are too elusive to be dealt with in a technical paper of the present kind, it is noted in connection with the last point that basic chemical industry location is dominated to a large extent by the geographical price structure of caloric value.[140] Accordingly, in a common market, low-fuel-price areas will have a heavy advantage over other areas. While several such low-fuel-price areas may exist and thus there may be possibility of distributing the major chemical complexes between them, this will still leave many areas with no benefit of integration, if such a benefit is thought of as "capturing" some of the large-scale, integrated basic plants.

The problem is further complicated if the large countries in the common market are also high-fuel-price areas. In this case, the latter countries are often in a position to "go it alone", since they can offset their high fuel prices against economies of scale achievable in their extensive markets. In the case of Latin America, for example, Brazil is in the latter position in relation to the low-fuel-price areas of the Caribbean basin and the Magallanes zone at the Southern extreme of the continent. Undoubtedly, a powerful inducement is needed to make such a country consider economic integration.

It is submitted that joint planning of the chemical industries alone is no answer to these problems, since an attempt to spread this industry all over the participating countries will cancel many of the benefits of large-scale production. What is needed is joint planning of the entire industrial base of the supra-national region, for if this is undertaken, it will always be possible to allocate large-scale production units to all participating countries. The reason for this is simple: there are a good many important industries that are largely "footloose", i.e., they can be established almost anywhere and they will achieve their economies of scale independently of location. After the industries which are tied to specific locations have been allocated to their most desirable geographical zones, the footloose industries can be utilized for working out a pattern of mutually satisfactory regional compensations and for making sure that the

140/ See Section II-B-5.

/process of

process of joint development will leave none of the individual countries behind the rest. Industries particularly suited to purposes of compensation are the branches of the metalworking-machinery-transport equipment sector.

Thus, a mechanism is available that is entirely adequate for solving the technical problems of economic integration and joint supra-national industrial development planning: if countries will take advantage of it or not is a matter that only these countries themselves can decide.

3. Chemical industry development in restricted markets

In the absence of joint supranational planning, the smaller under-developed countries may still not want to give up the advantages of establishing an industrial base of their own. What prospects do the chemical industries offer from this point of view?

The two governing considerations in this regard are: economies of scale on the one hand, and the diffuse end-use pattern of chemicals on the other. The first of these compels an attempt to increase the scale of production to the largest extent possible; but the second largely precludes doing so on the basis of the selective, accentuated growth of some sectors.

Not all branches of the chemical industry share this dilemma to the same extent. Thus, "simple" chemical manufactures (soaps, cosmetics, polishes, inks, candles, matches, etc.) are hardly subject to economies of scale at the national level and can easily be established under minimal conditions of per capita income and country size.

Vegetable and animal oils and fats, as well as paints, varnishes and lacquers also tend to fall in this group. In regard to these branches of the chemical industry, import substitution has clear advantages, since foreign-exchange savings will greatly outweigh newly generated foreign-exchange requirements, and there will be a substantial addition to national income. All of these branches, however, fall outside of what is generally defined as an "industrial base".

Those branches which properly belong to the industrial base are also the ones for which the dilemma is the sharpest: heavy industrial chemicals including heavy organic intermediates. These all show strong economies of scale, and their demand is spread out over the chemical sector and often over other sectors as well. If these branches are established at low scales,

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they will suffer the corresponding capital and foreign-exchange diseconomies; yet if their requirements are to be raised by a selective promotion of end uses, this will often clash with the overall goals of economic development. With a given productive structure, the needs for chemicals are largely fixed and under a normal pattern of development, additional requirements depend on the growth of the economy as a whole rather than on the growth of particular sectors. Therefore, if additional demand is to be created, the only way to do so is to stress end-chemical uses oriented to consumption. This creates two biases: one in favour of consumption as against investment; the other in favour of high-grade consumption intensive in the use of chemicals (synthetic fibres, plastic goods, rubber tires for vehicles, detergents) as against popular consumption. If these biases are held to be undesirable, their implications on heavy-chemical development must be faced.

Fertilizers constitute a possible exception to the former generalization. While their production requires heavy chemical processes, their demand can often be raised to a level that allows minimum economic scales to be reached, without prejudicial effects on the course of development as a whole. The growth and technification of the agricultural sector is one of the fundamental goals of economic development, and a moderate increase in the stress on this sector, due to an attempt to raise the scales of production of chemical fertilizers, will cause no harm. There is, however, a limit on how far this course of action can be pushed. The use of fertilizers is related to other aspects of agricultural progress (irrigation, improved organization, mechanization) which depend on general progress in the economy as a whole and in the industrial sector in particular.

A possible escape from the dilemma posed by heavy chemical processes is offered by importing the heavy chemical products and establishing certain sophisticated end-chemical production branches that can be more properly regarded as forming a part of the industrial base of a country than the simple chemical manufactures and related branches listed earlier. Such end-chemical processes include synthetic fibres, plastics, rubber, detergents, dyes and pharmaceuticals. While some of these, especially synthetic rubber, are subject to as strong economies of scale as basic industrial chemicals,

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and thus offer no better prospects than the former, there are others which are far less affected by economies of scale and yet whose production is characterized by the kind of advanced technology and complex organization associated with basic industrial progress. If such branches can be established at the production scales associated with the normal pattern of intermediate uses and final consumption that is characteristic of the level of development of the country, (i.e., without an undesirable stress on high-grade consumption for the sole purpose of raising production scales in the processing chain) this offers many of the advantages of industrialization without the drawbacks mentioned earlier.

Nonetheless, such a strategy also creates new risks, due to the instability of the foreign-exchange earnings of most underdeveloped countries. The intermediate chemical needs of domestic end-chemical processes create a rigid foreign exchange demand that cannot be cut without reducing the level of activity of these processes; but such a reduction implies unemployment, the under-utilization of capital resources, and a cutback of supplies available to other sectors for their input needs, i.e., dyes, plastics, adhesives. If the respective domestic production processes did not exist, flexibility would be greater on two counts. First, the kinds of consumption that have a relatively low priority could be reduced without creating unemployment and capital under-utilization. Second, in the absence of such processes domestic producers in other sectors would adjust their productive structures in ways calculated to reduce their dependence on inputs which would now be imported ones; e.g., they would tend to use wooden components instead of plastic ones, glues instead of adhesives, etc., in marginal uses. The net result would be a greater flexibility of foreign exchange needs.

In this case as in others, the increases of benefits under stable average conditions have to be balanced against the additional flexibility afforded by a strategy that guards against undue risks, and thus the planning of the chemical industries for restricted markets has to tread a middle ground between two undesirable extremes. These are: on the one hand, an over conservative approach that unnecessarily restricts the

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development of this industry in order to avoid risks; and on the other hand, a development policy that overstresses the chemical industry in comparison with other industries whose development is equally essential or more essential to overall economic growth, for example, branches of the metalworking-machinery sector. An excessive stress on chemical development may manifest itself in two ways: the establishment of basic heavy chemical industries with severely adverse conditions in relation to economies of scale; or the establishment of end-chemical processes with an excessive reliance on imported chemical intermediates. The disadvantages of the latter two courses of action are compounded when they create a bias in favour of high-grade consumption, for the sake of providing outlets for the corresponding chemical production processes.

/ANNEX 1

ANNEX 1

The description of technology

(1) The technological data for many chemical processes have been organized by employing the "activity vector" concept. An activity is defined here as the basic technological element of the integrated industrial complexes, i.e., a process of chemical transformation with inputs and products which are easily identifiable and unique. Conventionally, it may be represented by a column of figures. For example, the process for producing ammonia from natural gas may be expressed in the following form:[141]

Resource	Unit	Amount
Ammonia	Ton	1.
Natural gas	10^3 m^3	1.5
Caustic soda	Ton	.004
Power	KWH	120.
Water	m^3	25.

Mathematically, these vectors represent strictly determined ratios between the inputs and products of a specific technical process, assumed to be constant. When a technical process allows a variable composition of raw materials or a variable distribution of products, the whole series of variations may be expressed by means of an adequate number of individual activity vectors.

(2) The vector described above includes only those inputs which expand proportionally,[142] as production grows. Certain inputs, however, vary in a non-linear fashion. The most important of these are: fixed capital investment in buildings and equipment (referred to hereafter simply as "investment") and direct operating labour (referred to hereafter simply as "labour").

141/ Source: UN-ECLA: The Chemical Industry in Latin America (1963).

142/ The inputs of steam, water and fuel gas are not, strictly speaking, proportional to scale in the chemical industry. However, in general studies (though not in the preparation of individual projects), they may be considered as such with an allowable margin of error.

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In considering this latter point, it is assumed that the ratio between investment or labour inputs, on the one hand, and plant size, on the other, can be expressed in the following equation:

$$C/C_o = (S/S_o)^f$$

where C_o is the input of the productive factor at the base production scale (reference scale) S_o; C is the input of the labour or investment which is to be estimated for the production scale S, and f is an empirically determined exponent which may fluctuate numerically between the limit 0 and 1.

The exponent f being known for each process - on the basis of practical experience in the chemical industry - the economies in unit investment and labour requirements resulting from any increase in production scales may be measured, always provided that basic information is available on investment and labour inputs for at least one given plant capacity. These exponents, together with the technological coefficients relating to those inputs which change proportionally as production rises, must be known in advance and can then be incorporated into a "technology matrix" for the chemical industries. In the case of ammonia, the data pertaining to the non-linear labour and investment requirements are the following:143/

Concept	Unit	Amount
Reference scale (capacity)	10^3 Ton/yr	280.
Labour	10^3 Mhr/yr	134.
Exponential labour coefficient	dimensionless	.4
Investment	10^6 US$	33.4
Exponential investment coefficient	dimensionless	.81
Minimum economic scale	10^3 Ton/yr	30.
Upper limit of validity of exponents ("maximum scale")	10^3 Ton/yr	360.

143/ Source: Vietorisz and Szabo (1959). In the ECLA chemical study, op.cit., data for typical plant capacities are given instead of the exponential function derivable from the former.

/The last

The last item refers to the upper limit of the segment of the curve along which the exponential coefficients are valid for establishing the functional relationship between the non-proportional inputs and the size of the plant. Above this scale, unit labour and investment requirements can often be assumed to remain constant. Conversely, below the minimum economic scales, the validity of the exponential coefficients must be carefully examined in each case. Both the lower and the upper scale limits are to be regarded only as approximate.

With the above information and using the equation previously described, it is possible to calculate the capital and labour inputs for any plant capacity within the capacity range defined by the last two items.

(3) The calculation of investment and labour inputs required for various plant sizes permits the estimation of certain accounting costs which may be expressed as percentages of these two items. Following the established practice in the United States chemical industry, costs such as supervision, payroll overhead, plant maintenance, equipment and operating supplies, indirect production cost, general office expenditure, insurance, capital charges and depreciation may be calculated by expressing them as suitable percentages of fixed investment and/or labour (in which originally only direct labour is included). Supervision is reckoned for this process as 25 per cent of direct labour. Payroll overhead, which includes the cost of such things as paid holidays, vacations, liability insurance, pension and social security contributions, etc., is also reckoned as a percentage of direct labour, usually 15-50 per cent. Plant maintenance is estimated as 3 per cent per year of fixed investment, while equipment and operating supplies are taken as 15 per cent of maintenance. Indirect production costs are calculated as representing 50 per cent of the total of direct labour, supervision, plant maintenance and equipment and operating supplies. General office expenditure is reckoned as 10 per cent of the same total used for calculating indirect production costs. Depreciation is taken as 8 per cent of fixed investment.

/The interest

The interest rates taken as basis for the calculations for underdeveloped countries may fluctuate between 10 and 15 per cent, possibly even higher.[144]

(4) Finally, to complete the process of cost estimation, in addition to fixed investment, the requirements of working capital must also be taken into account. An often acceptable approximation for this purpose is to estimate a fixed per cent of the value of sales for each process, e.g. 20 per cent for ammonia.

A more exact procedure for the estimation of working capital is to allow for an amount sufficient to cover direct production costs during a period that may vary from one to three months:[145] The direct production costs included under this heading comprise raw materials, utilities and services, labour and supervision.

The problems which arise in organizing and using such data are discussed in "Pre-Investment Data Summary for the Chemical Industry".[146] They comprise such issues as the proper level of detail at which the description of a process or a set of related processes by means of

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144/ Instead of the more detailed breakdown of accounting costs, the ECLA chemical study (op.cit.) estimates 80-100 per cent of direct labour plus supervision for "general costs". These do not include supervision, maintenance, and depreciation which are specified individually in the study cited. Except for these items, the figures in the text are taken from Vietorisz and Szabo (1959). (In the case of supervision, there has been a slight modification.) See also Isard, Schooler and Vietorisz (1959), 58-61.

In addition to the costs included above, the ECLA chemical study (op.cit.) also includes under proportional costs an item for catalizers, auxiliary chemicals and royalties, which is reckoned at US$ 2.0 per ton of ammonia. This item is not a true technical coefficient, but is rather in the nature of an accounting item that happens to be proportional to scale.

145/ UN-ECLA: Chem. Ind. Study (1963), Annex XIII, p. 244.

146/ Vietorisz (1961:PID).

/individual activities

individual activites should be undertaken; the separation of technical data from prices in the derivation of coefficients; the degree to which the assumptions of proportionality or constant exponents in the economies-of-scale function, are empirically justifiable; the interpretation of coefficients from an economy-wide point of view as average or best-practice data; the transferability of coefficients from one geographical location to another; and many others. On balance, it is found that the existing technical-economic method of description is adequate for planning purposes at the level of early feasibility studies, but needs to be complemented by expert technical advice for more definitive studies, and eventually has to be translated into concrete action by means of fully technical project engineering work.

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