OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

8

UNIDO MONOGRAPHS ON INDUSTRIAL DEVELOPMENT

01411

Industrialization of Developing Countries: Problems and Prospects

CHEMICAL INDUSTRY

UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

UNIDO MONOGRAPHS ON INDUSTRIAL DEVELOPMENT

Industrialization of Developing Countries: Problems and Prospects

MONOGRAPH NO. 8

CHEMICAL INDUSTRY

Based on the Proceedings of the International Symposium on Industrial Development (Athens, November–December 1967)

UNITED NATIONS
New York, 1969

ID/40/8

UNITED NATIONS PUBLICATION

Sales No.: E.69.II.B.39, Vol. 8

Price: $U.S.0.50 (or equivalent in other currencies)

Printed in Austria

Foreword

The International Symposium on Industrial Development, convened by UNIDO in Athens in 1967, was the first major international meeting devoted exclusively to the problems of industrialization of the developing countries. It followed a series of regional symposia on problems of industrialization held in Cairo, Manila and Santiago in 1965—1966 under the sponsorship of UNIDO and the United Nations regional economic commissions, and a similar symposium held in Kuwait in 1966 under the sponsorship of UNIDO and the Government of Kuwait.

The Athens Symposium was attended by some 600 delegates from 78 countries and by representatives of various United Nations bodies, international organizations and other interested institutions in the public and private sectors. It provided a forum for discussion and exchange of views on the problems and prospects of the developing countries which are engaged in promoting accelerated industrial development.

The Symposium devoted special attention to possibilities for international action and for co-operative efforts among the developing countries themselves, and explored the scope, means and channels for such efforts.

Studies and papers on a wide range of problems relating to industrialization were presented to the Symposium—by the UNIDO secretariat and by participating Governments, international organizations and observers. An official report, adopted at the Symposium, has been published by UNIDO.[1] Based on this documentation and the discussions in the meeting, the present series of monographs is devoted to the 21 main issues which comprised the agenda of the Symposium. Each monograph includes a chapter on the issues presented, the discussion of the issues,

[1] *Report of the International Symposium on Industrial Development, Athens 1967* (ID/11) (United Nations publication, Sales No.: 69.II.B.7).

and the recommendations approved by the Symposium. Some of the monographs deal with specific industrial[1] sectors; some with matters of general industrial policy; and others with various aspects of international economic co-operation. An effort has been made to make the monographs comprehensive and self-contained, while the various economic, technological and institutional aspects of the subject matter are treated within the context of the conditions generally prevailing in the developing countries.

Since economic, technological and institutional aspects are described with particular reference to the needs of the developing countries, it is felt that the monographs will make a distinct contribution in their respective areas. They are intended as a source of general information and reference for persons and institutions in developing countries concerned with problems of industrialization, and particularly with problems and issues of international co-operation in the field of industrialization. With this in view it was considered that an unduly detailed technical presentation should be avoided while at the same time enough substantive material should be offered to be of value to the prospective reader. For a more elaborate treatment of the subject, the reader is referred to the selected list of documents and publications annexed to each monograph.

The annexes also contain information on the areas in which UNIDO can provide technical assistance to the developing countries on request; a selected list of major UNIDO projects in the respective fields; and a list of meetings recently organized by the United Nations.

It is hoped that the monographs will be particularly useful to Governments in connexion with the technical assistance activities of UNIDO and other United Nations bodies in the field of industrial development.

This monograph has been prepared by Professor Thomas Vietorisz of the New School for Social Research, New York City, as consultant to UNIDO, in co-operation with the secretariat.

CONTENTS

LIST OF TABLES

Explanatory notes

Billion refers to thousand million.

Dollar ($) refers to US dollar unless otherwise specified.

Ton refers to metric ton (1,000 kg) unless otherwise specified.

One mill equals $0.001.

The following abbreviations are used in this monograph:

ECLA	Economic Commission for Latin America
FAO	Food and Agriculture Organization
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization
SBR	Styrene-butadiene rubber
PVC	Polyvinylchloride
c.i.f.	cost, insurance and freight

INTRODUCTION

The significance of the chemical industry for economic development

The chemical industry is one of the dynamic sectors of a modern industrial economy; on the average, it has a growth rate about two-thirds higher than that of the national economy as a whole. The chemical industry also expands faster than the average for all manufacturing activities. The food processing and textile sectors of manufacturing generally expand relatively slowly, but most other manufacturing sectors show growth rates of similar magnitude to that of the chemicals sector. The dynamism of the chemical industry, however, derives not only from its capacity for rapid growth but also from the rapid technological change that is one of the industry's outstanding characteristics. The nature of chemical processes and the range of chemical products are subject to continuous change. Consequently, expenditure on research and development and the influence of these activities on management decisions make the chemical industry one of the most "research-minded" of the industrial sectors.

A measure of the significance of the chemical industry in economic development is the increasing extent to which chemical processes and products penetrate the technology of other industrial sectors as the level of industrialization rises. This phenomenon is similar, both qualitatively and quantitatively, to the growth of electrification, mechanization and automation that accompanies technological progress, and independent development targets may be set for it, as for the others, in industrial development plans. Eventually, nearly all industries producing consumer goods need, directly or indirectly, the products of the chemical industry. In recent years, the chemical industry has also become to an increasing extent the producer of consumer goods made, for example, from plastics, synthetic fibres and synthetic rubbers.

In the standard industrial classification of the United Nations,[1] the chemical industry comprises the following branches:

[1] *International Standard Industrial Classification of all Economic Activities*, No. 4/Rev. 1 (United Nations publication, Sales No.: 58.XVII.7).

Basic industrial chemicals, including fertilizers, organic and inorganic chemicals, dyes, explosives, synthetic fibres, resins, plastics, rubbers, and nuclear materials;

Vegetable and animal oils and fats;

Paints, varnishes and lacquers;

Miscellaneous end-products, such as pharmaceuticals, cosmetics, soaps, polishes, inks, matches, candles and insecticides.

With the exception of fertilizers, which is the subject of a separate monograph in this series,[2] this monograph is concerned with the whole range of products of the chemical industry, although most attention is given to problems associated with setting up the manufacture of organic and inorganic industrial chemicals, including petrochemicals.

Simple chemical products such as paints and varnishes, soaps and polishes, are the first to be manufactured in the course of industrialization, generally followed by fertilizers, the chemicals associated with agriculture and some other end-products, with a limited integration back along the processing chain—resins, plastics and synthetic fibres. A diversified base of heavy industrial chemicals is not achieved until a much later stage. Only in developed countries is there complete technological independence in the sense of national capability to undertake research, development, and process engineering and a broad penetration of chemical processes and products into other industrial sectors.

Clearly, the chemical industry occupies an important place in the framework of industry as a whole, particularly when industrial development has progressed to a certain extent. It is not surprising that a growing number of requests are being received from developing countries for assistance in setting up or expanding various branches of this industry. The existence of a domestic market for certain products is generally self-evident, since they are necessarily imported if there is no domestic production. In that case the key question is whether the market is large enough to justify the minimum economic scale of production. Many countries have raw materials that can be turned to economic use in chemical processes and are thereby encouraged to examine the possibilities of manufacture.

It may be thought that the establishment of the manufacture of chemical products will give employment to a significant number of workers, but as a generalization this belief is not well founded. The

[2] Monograph No. 6: *Fertilizer Industry*.

chemical industry, especially the manufacture of basic heavy chemicals and petrochemicals, has a very low labour intensity and cannot be expected to contribute significantly to the absorption of surplus labour. Its development has to be justified in terms of import substitution to save foreign exchange and in terms of the contribution it can make to structurally balanced industrial development and general technological capabilities. Above all, a chemical industry can stimulate efficiency in the agricultural sector of a developing country. Even at quite an early stage in its growth, the chemical industry can produce fertilizers, pesticides and other chemicals that a country may not be able to afford to import. In the course of promoting the use of these products, it also helps to upgrade skills and raise the level of technology in agriculture.

Chapter 1 describes the world situation of the chemical industries, pointing out that the value of production is believed to have doubled between 1960 and 1970. The share of the developing countries in the total production is only about 5 per cent and is increasing very slowly. *Per capita*, the production in the developing countries averages only one eleventh of the world average. Both in the developing countries and in the world as a whole, production expanded less rapidly in the second half than in the first half of the 1960s and still lower growth rates are foreseen in the 1970s.

Consumption of chemical products in the developing countries is higher than production, about one third of consumption needs on the average being met by imports.

Production and import statistics, when examined in relation to population and *per capita* income, show that on a *per capita* basis the value of chemical production may be expected to increase by 1.66 per cent for every 1 per cent increase in income, while *per capita* imports rise almost exactly in step with *per capita* income. The influence of population size on chemical production and imports is not as great as that of the income level but is nevertheless significant.

A reasonably well-developed chemical industry is both its own principal supplier and best customer. This is due to the processing chains that involve many intermediate steps in the transformation of chemicals. The other main markets of the chemical industry are agriculture and the textile, food, rubber and paper industries. In the course of industrial development, there are changes in the relative importance of the various branches of the chemical industry, the share of basic organic chemicals and plastics increasing while that of soaps and simple chemical products decreases.

Chapter 2 describes some of the characteristic features of the chemical industry and examines some of the products. The relationship between the size of the market and the minimum scale of economical production for various products has a critical effect on the prospects for developing the chemical industry in any given country. Economies of scale are particularly marked in the case of the basic heavy chemicals. Their production can be developed, therefore, only to the extent allowed by the over-all development of the country. Economies of scale usually impose less stringent constraints, however, on the production of most end-products. The nature of the economies of scale is examined in detail, particularly as they arise in the production of basic chemicals. The conclusion is reached that, at present levels of income in most developing countries, only the organization of a regional or sub-regional market would give the volume of demand necessary to manufacture most basic chemical products, even at minimum economic scales.

The largest group of material inputs into the chemical industry, at least in the developed countries, consists of intermediate chemical products. The most important group of raw material inputs is a miscellaneous group of organic origin (excluding petroleum-based hydrocarbon) used mainly for consumer products such as soaps, paints, oils, fats and waxes. Generally speaking, the supply of these raw materials poses few serious problems. The extent to which inorganic minerals, hydrocarbons and carbon raw materials from which to manufacture basic heavy chemicals are available is, however, a much more critical consideration. The technical and economic factors involved are discussed in some detail.

The linkages are examined between the chemical sector and the engineering sector that supplies its processing equipment. The importance is stressed of ensuring, through co-ordination of development policy, that local engineering enterprises can furnish an increasing proportion of the equipment required by the chemical industry.

Compared with other industrial sectors the chemical industry employs a low percentage of unskilled labour and a high percentage of skilled and technical manpower, and the total numbers employed are relatively small. The possibilities of capital-labour substitution are limited, partly because the chemical industry appears to offer fewer choices of alternative processes than other industries, and partly because modern technology has developed in industrialized countries under the pressure of high wage rates and relatively cheap access to capital.

Chapter 3 examines some issues of policy that have to be decided in the course of developing the chemical industry, for example the role of planning at different stages of this development. At the outset there is little interrelation between individual projects or between chemical projects and those in other industries so that planning may be restricted to a general promotional role. As the range of locally manufactured end products widens the most important issue raised is whether to rely on importing intermediate chemical products or, at least in some cases, to integrate backwards to heavy chemicals. Only if investment in new chemical projects is centrally co-ordinated can the conflicting considerations that arise at this stage be properly balanced from the point of view of the national interest. As development progresses the main issue is when and how to build up a diversified heavy chemical base. At this stage the scope for planning is much greater. The smaller the markets to be served, the more difficult it is to resolve these issues because of the economies of scale in the production of heavy chemicals. At this stage it also becomes important to co-ordinate research and development activities. When the chemical industry of a country has reached full development and is technologically independent, experience shows that some measures of co-ordination are still advantageous, even where there is no resort to actual programming of sectoral development.

Integration of markets on a regional or sub-regional basis will nearly always make possible a more rapid development of the chemical industry. The negotiation of such arrangements has proved difficult, however, since each country is more anxious to produce a given product for the whole region than to import products made elsewhere in the region. Projects have therefore to be planned so as to compensate each country adequately. It may sometimes be possible to do this within the context of the chemical industry alone, but it will usually be more efficient to include other industrial sectors in a joint planning operation. The engineering sector lends itself well to the process of compensation, because its geographical location is only slightly restricted by economic and technical factors.

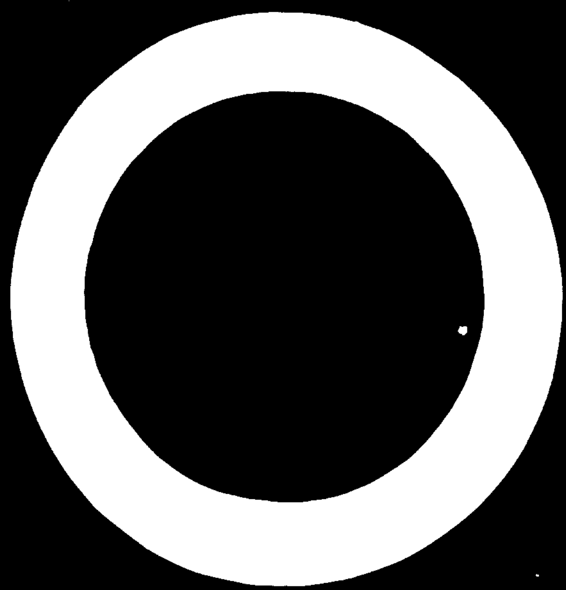
Two aspects of the balanced growth of industry are examined: balance between the chemical industry and other sectors and balance in the geographical distribution of the chemical industry. It is concluded that the manufacture of the simpler end-products can be accelerated almost regardless of the growth of the economy as a whole while certain products such as fertilizers and pesticides can be developed rapidly only if there is a parallel development in the agricultural sector. In the case of basic chemicals, development cannot proceed faster than the economy as a whole. While geographical dispersion of the manufacture of light chemical products is generally possible and even desirable, the opposite is true of heavy basic inorganic and organic chemicals. For a number of reasons the manufacture of heavy chemicals is more efficient in industrial complexes than in isolated plants.

When and to what extent backward integration should be undertaken in the chemical industry of a developing country are questions of great complexity. The interaction of technical issues and problems of foreign exchange availability are examined.

The importance of domestic availability of the main raw materials used in the manufacture of chemicals is much greater in some branches of the chemical industry than in others. It is explained that in certain circumstances it is important to value raw material resources on the basis of opportunity cost rather than on the basis of exploitation cost.

The more advanced the development of the chemical industry becomes, the more pressing is the issue of indigenous versus foreign technology. While a developing country may have no real choice but to rely on foreign technology in the earlier stages, reasons are given why this is unlikely to lead to adoption of the most suitable technology for local conditions. A long-term effort in research and development is required before any country can hope to become technologically independent. In parallel with this effort, the technical level of process engineering design and manufacture must be improved. It is recognized that there are formidable difficulties in finding the highly qualified personnel and the finance necessary to achieve success in this field. In practice there are various compromises between a fully imported and a fully indigenous chemical technology. These include the purchase of patents and licensing of individual processes, as well as joint ventures between foreign and domestic enterprises.

Financial and pricing policies must have regard to the structure of the world market for chemical products, the extent to which the enterprises set up in developing countries are joint ventures, and the degree to which production is to be oriented towards export. A relatively small producer in a developing country is extremely unlikely to be able to penetrate the world market, except on the basis of measures of regional integration, trade agreements or joint ventures with large international chemical companies. There is a good chance that future expansion can be financed out of retained profits when chemical production is established primarily for import substitution and is accorded some tariff



protection. Self-financed expansion is much harder to achieve, however, if a substantial proportion of production has to be exported.

Chapter 4 gives an account of the issues relating to the chemical industry as presented to the International Symposium on Industrial Development, the discussions held and the recommendations adopted. The discussion emphasized that the conflict between restricted domestic markets and the strong economies of scale, especially for heavy chemicals, produced a strong economic argument for regional co-operation and integration of markets. It was admitted, however, that the advantages had to be balanced among the participating countries and that this could be a complex operation. Among the specific product groups discussed were synthetic rubber, chemicals having either backward or forward linkages to the agricultural sector, and carbo chemicals.

It was emphasized that the planning and establishment of chemical industry complexes in the developing countries would require the Governments to play a positive role. There was a discussion of the type of institution through which this role should be exercised. It was stressed that joint ventures with foreign companies were an important means of creating such complexes. There was also a full discussion of the practical problems that arise in connexion with the transfer of technology and skills from developed to developing countries.

Chapter 5 deals with United Nations action and other action to promote the development of the chemical industry. It describes first the work done by UNIDO in connexion with basic chemicals, particularly those based on salt, since many developing countries possess this source of raw material, and with petrochemicals.

In the last few years UNIDO has provided technical assistance in evaluating the possibilities of developing the production of essential oils, and also pharmaceuticals. Work has been started in promoting the manufacture of industrial products by fermentation. Since the equipment is simple to design and construct, the investment required is not great and the agricultural or waste products needed as raw materials are usually available domestically, these activities are well suited to many developing countries.

Consideration is given to the use of consultant and trouble-shooting groups that can be made available for limited periods at very short notice to advise and assist in a number of urgent tasks. Measures are outlined for increasing the capacity of developing countries to undertake research, development and process engineering.

Chapter 1

WORLD SITUATION OF THE CHEMICAL INDUSTRIES

PRODUCTION AND CONSUMPTION

It is expected that the world production of chemical products, excluding China (mainland), will more than double between 1960 and 1970, increasing in value from $72 billion to $153 billion, of which the developing countries account for only about five per cent. *Per capita* the production in developing countries is only about 8.5 per cent of the average for the world as a whole.

Over this ten-year period the relative position of the developing countries has improved slightly; their share in the total production is estimated to have risen from 4.7 per cent to 5.2 per cent between 1960 and 1965, but is not expected to rise further by 1970. Since the population increase over the decade has been more rapid in the developing countries than in the rest of the world the improvement in their share of *per capita* production is smaller.

Production figures for individual developing countries, by region, compared with the world total are given in table 1 for 1960 and 1965 together with estimates for 1970. It may be seen that the world-wide expansion of the industry was less rapid in the second half than in the first half of the decade, the average annual growth rates being 6.5 and 9.2 per cent respectively. The corresponding figures for the developing countries are 6.1 and 11.2 per cent respectively. It is estimated that in the decade 1970—1980, the growth rate will be between 4 and 6 per cent per year for the world as a whole, with production in the developing countries increasing at between 5 and 7.5 per cent per year.

Consumption of chemical products in the developing countries is substantially higher than production, the balance being imported. The share of developing countries in world consumption, excluding China (mainland), was 7.2 per cent in 1960 (compared with 4.7 per cent production) and 7.6 per cent in 1965 which is also the expected share for 1970

TABLE 1: VALUE OF CHEMICAL PRODUCTION IN SELECTED YEARS: THE WORLD AND DEVELOPING COUNTRIES

	Million dollars			*Dollars per capita*		
	1960	*1965*	*1970*[a]	*1960*	*1965*	*1970*[a]
Summary						
WORLD, TOTAL	72,281	112,092	153,400	31.3	44.2	55.0
DEVELOPING COUNTRIES, TOTAL	3,423	5,810	7,902	2.6	3.8	4.7
SHARE OF DEVELOPING COUNTRIES IN TOTAL WORLD PRODUCTION (per cent)	4.7	5.2	5.2	8.3	8.6	8.7
Developing countries, by region						
Africa	330	580	788	1.3	2.0	2.4
United Arab Republic	230	420	536	8.9	14.2	15.6
Other countries	100	160	252	0.4	0.6	0.8
Asia	983	1,870	2,400	1.1	1.8	2.1
Burma	10	13	16	0.4	0.5	0.6
China (Taiwan)	73	206	370	6.9	16.6	26.4
India	573	1,050	1,225	1.3	2.2	2.3
Indonesia	45	60	68	0.5	0.6	0.6
Iran	20	37	43	0.9	1.5	1.6
Pakistan	20	70	116	0.2	0.7	1.0
Philippines	110	180	229	4.0	5.6	5.9
Republic of Korea	24	55	64	1.0	1.9	2.0
Republic of Viet-Nam	25	35	41	1.8	2.2	2.3
Thailand	14	20	25	0.5	0.6	0.7
Turkey	55	83	128	2.0	2.7	3.6
Other countries	14	61	75	0.1	0.6	0.7
Latin America	2,110	3,360	4,714	10.5	14.5	17.7
Argentina	380	520	666	18.3	23.2	27.6
Brazil	780	1,146	1,500	11.2	14.2	16.0
Chile	71	83	115	9.2	9.6	11.9
Colombia	95	140	200	6.[illegible]	7.8	9.7
Mexico	530	963	1,456	14.7	22.5	30.0
Peru	70	133	207	7.0	11.4	15.7
Uruguay	18	24	29	7.2	8.9	10.0
Venezuela	120	250	375	16.4	28.7	36.1
Other countries	46	101	166	1.4	2.8	3.4

SOURCE: Verband der Chemischen Industrie, e.V., *Chemical Industry and Developing Countries*, prepared for the United Nations, Frankfurt/Main, 1966, for years 1960 and 1965.

[a] Forecast extrapolated from annual series 1960—1967.

(compared with 5.2 per cent production). The average *per capita* consumption for all the developing countries is about 12.5 per cent of the world average (compared with 8.5 per cent production). Table 2 gives data for consumption corresponding to the production data given in table 1.

TABLE 2: VALUE OF APPARENT CHEMICAL CONSUMPTION IN SELECTED YEARS: THE WORLD AND DEVELOPING COUNTRIES

	Million dollars			*Dollars per capita*		
	1960	*1965*	*1970*[a]	*1960*	*1965*	*1970*[a]
Summary						
WORLD,[b] TOTAL	72,230	112,315	153,400	31.3	44.2	55.0
DEVELOPING COUNTRIES, TOTAL	5,186	8,554	11,610	3.9	5.6	7.0
SHARE OF DEVELOPING COUNTRIES IN TOTAL WORLD CONSUMPTION (per cent)	7.2	7.6	7.6	12.5	12.7	12.7
Developing countries, by region						
Africa	699	1,104	1,442	2.7	3.8	4.3
United Arab Republic	302	532	690	11.7	18.0	20.0
Other countries	397	572	752	1.7	2.2	2.5
Asia	1,672	2,894	3,843	1.9	3.0	3.4
Burma	30	34	39	1.4	1.4	1.4
China (Taiwan)	112	265	436	10.6	21.4	31.1
India	739	1,232	1,615	1.7	2.5	3.0
Indonesia	50	68	82	0.5	0.7	0.7
Iran	67	138	167	3.1	5.6	6.3
Pakistan	81	166	233	0.9	1.6	2.2
Philippines	166	262	310	6.1	8.1	8.1
Republic of Korea	104	168	220	4.3	5.9	6.7
Republic of Viet-Nam	55	84	92	3.9	5.2	5.1
Thailand	60	100	139	2.3	3.2	3.9
Turkey	90	142	190	3.2	4.0	5.4
Other countries	118	235	320	1.2	2.2	2.9
Latin America	2,815	4,556	6,325	13.9	19.7	23.7
Argentina	410	720	1,018	19.8	34.0	41.9
Brazil	912	1,312	1,680	13.1	16.2	17.9
Chile	68	116	165	8.8	13.4	17.0
Colombia	174	207	295	11.3	11.5	14.3
Mexico	697	1,282	1,904	19.4	30.0	39.2
Peru	113	194	275	11.3	16.6	20.7
Uruguay	22	30	37	8.6	11.0	12.6
Venezuela	225	381	495	30.9	43.8	47.6
Other countries	194	314	456	6.0	8.7	10.6

SOURCE: Verband der Chemischen Industrie, e.V., *Chemical Industry and Developing Countries* prepared for the United Nations, Frankfurt/Main, 1966, for years 1960 and 1965.

a Forecast extrapolated from annual series 1960—1967.

b World apparent consumption is assumed equal to world production

The correlation of production and import trends with *per capita* income and population

The pattern of production and imports by countries can be analysed in order to provide guidelines for development measures and to establish norms against which their effectiveness may be judged. The level of *per capita* income is a broad indicator of a country's endowment of labour skills, technological and organizational sophistication, and capital. The size of population at a given income level also exerts an influence on the size of the domestic market and hence the feasibility of local production. The statistics of production and imports for several dozen countries have been analysed with regard to these two variables in order to calculate the trends, and the results are shown graphically in figure 1. It must be appreciated that large deviations from the trend lines may occur in the case of individual countries, owing to different endowments of natural resources and differences in skill and organizational ability. Such differences are reflected in the level of industrialization and the participation in world trade of individual countries.

Chemical production *per capita*, as measured by value added, would seem to increase by 1.66 per cent for every 1 per cent increase in *per capita* income. These are compound rates of growth, so that an increase of 100 per cent in *per capita* income is associated with an increase of over 200 per cent in chemical production. *Per capita* imports, on the other hand, would appear to rise almost exactly in step with the income level, i.e. 0.96 per cent for each 1 per cent rise in *per capita* income.

The influence of population size on production and imports is not as great as that of the income level but is nevertheless substantial. The effect is illustrated graphically in figure 1 by sets of parallel lines representing populations of 1, 5, 25 and 125 million respectively.

These trends are also illustrated in dollar terms in table 3 for income levels of $100, $200, $400 and $800 *per capita*. Thus, for a country with a population of 1 million, the expected value added in the chemical industry is only $0.9 *per capita* where the income level is $200 *per capita* but rises to $2.8 *per capita* for an income level of $400 *per capita*. By comparison, where the population is 25 million, the corresponding figures for the expected value added in the chemical industry are $2.0 and $6.3 respectively. (It is estimated that gross production value in the chemical industry is 2.3 times the value added in production.)

The gross production value *per capita* in 1965 is given in table 1, the averages for the developing regions being as follows: Africa $2.0;

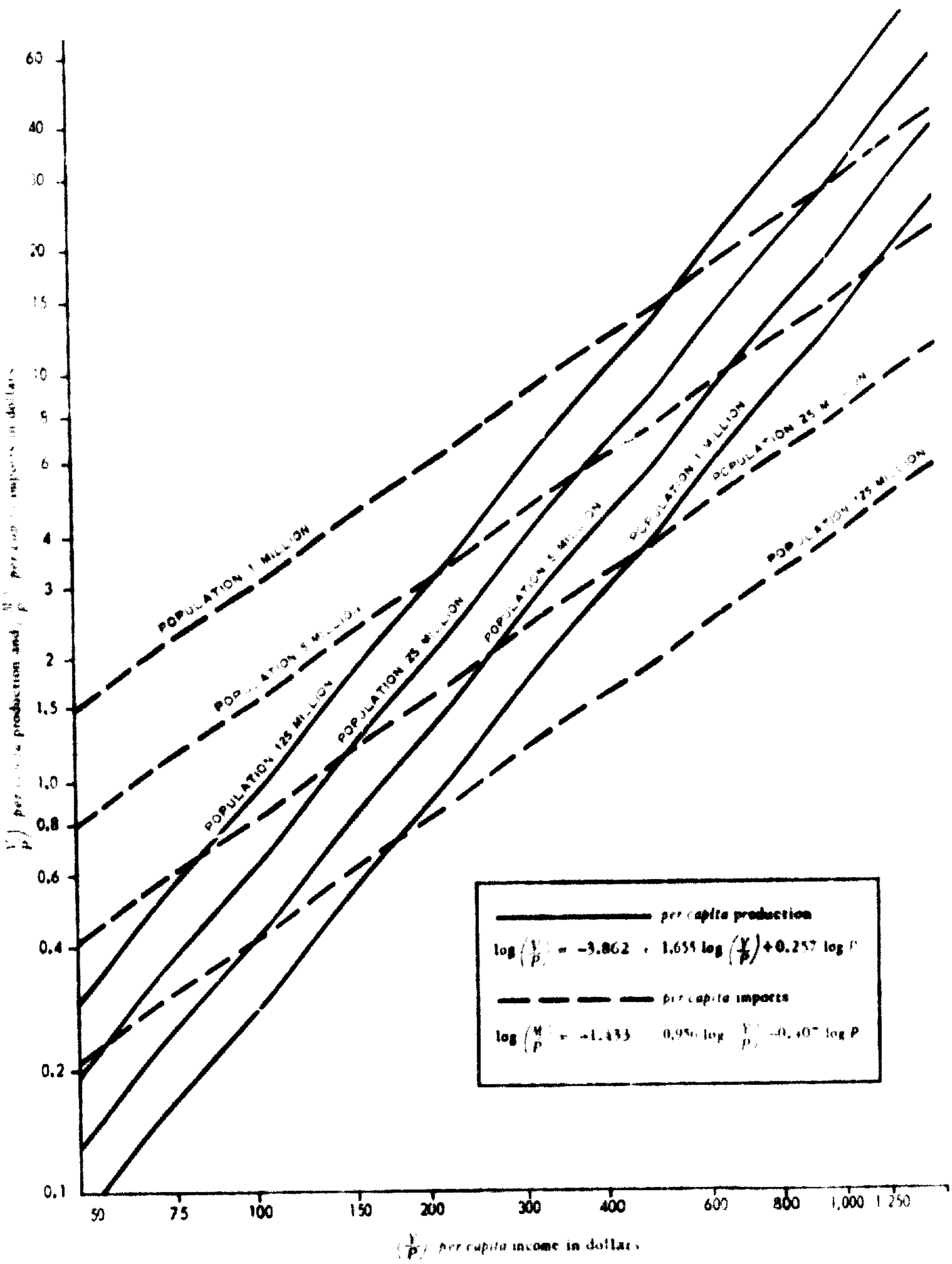


Figure 1. Per capita *chemical production and imports as functions of population and* per capita *income*

Asia \$1.8; and Latin America \$14.5. If it is assumed that population will grow at the annual rate of 2.5 per cent and *per capita* income at 3 per cent, it may be calculated that Asia or Africa would require thirty years to reach the average *per capita* level of chemical production ruling in Latin America in 1965.

TABLE 3: STATISTICAL TRENDS FOR THE CHEMICAL INDUSTRIES

	Population (millions)	Per capita *income in dollars* *100*	*200*	*400*	*800*
			Expected value in dollars		
1. Value added in chemical industries production, *per capita*	1	0.3	0.9	2.8	8.8
	5	0.4	1.3	4.2	13.3
	25	0.6	2.0	6.3	19.9
	125	1.0	3.1	9.6	30.3
2. Value added in all manufacturing production, *per capita*	1	13	33	84	217
	5	15	40	103	265
	25	19	48	125	324
	125	23	59	153	396
3. Chemical industries imports, *per capita*	1	3.0	5.8	11.3	22.0
	5	1.6	3.0	5.9	11.4
	25	0.8	1.6	3.1	5.9
	125	0.4	0.8	1.6	3.1
4. All imports, *per capita*	1	39	77	153	303
	5	25	49	100	193
	25	16	31	62	123
	125	10	20	39	78
			Expected percentages		
5. Value added in chemical industries production, per cent of national income	1	0.3	0.4	0.7	1.1
	5	0.4	0.7	1.1	1.7
	25	0.6	1.0	1.6	2.5
	125	1.0	1.5	2.4	3.8
6. Value added in all manufacturing production, per cent of national income	1	13	16	21	27
	5	15	20	26	33
	25	19	24	31	40
	125	23	29	38	49
7. Value added in chemical industries production, per cent of value added in all manufacturing	1	2.2	2.7	3.3	4.0
	5	2.8	3.3	4.1	5.0
	25	3.4	4.2	5.1	6.2
	125	4.2	5.2	6.3	7.7
8. Chemical industries imports, per cent of all imports	1	7.7	7.5	7.4	7.3
	5	6.3	6.1	5.9	5.9
	25	5.2	5.0	4.9	4.8
	125	4.2	4.1	4.0	4.0

SOURCE: United Nations, *A Study of Industrial Growth*, New York, 1963 (Sales No.: 63.II.B.2).

It has been shown that production rises with an increase in population for any given level of income. This reflects the substantial economies of scale prevalent in the chemical industry. *Per capita* consumption, however, does not appear to vary significantly with size of population for any given income level and, consequently, *per capita* imports of chemical products tend to fall as population grows. Thus, for a country with a population of 1 million and a *per capita* income level of $200, the expected value of imports is $5.8 *per capita* increasing to $11.3 *per capita* if the income level is $400 *per capita*. For a country with a population of 25 million, the *per capita* import value would be $1.6 for an income level of $200 *per capita* or $3.1 for an income level of $400 *per capita*.

Table 3 also gives data for total imports *per capita* according to the same income levels and population sizes. These data show that the total imports *per capita* also fall with increasing population size but not to the same extent as chemical imports. It follows that the ratio of chemical imports to total imports tends to fall with increases in population. The ratio of chemical imports to total imports also tends to fall slightly as the income level rises, but this movement is very slight.

As the trend lines in figure 1 indicate, chemical products are almost entirely imported at the lowest levels of *per capita* income and domestic production does not overtake imports until *per capita* income reaches some $250 to $300.

Relationship of chemical production to national income and all manufacturing

Table 3 shows chemical production on a value-added basis as a percentage of national income for the same ranges of *per capita* income and population. Whereas the expected percentage is only 0.3 for a country with a *per capita* income of $100 and a population of 1 million, it is as high as 3.8 per cent for a country with a *per capita* income of $800 and a population of 125 million.

Similar information is given in table 3 for the relationship between chemical production and all manufacturing. For the same two examples, the range is from 2.2 per cent to 7.7 per cent.

INTER-INDUSTRY LINKAGES

The chemical industry is both its own most important supplier and its own most important customer. This is because the industry is characterized by processing chains that involve many intermediate steps in the transformation of chemicals.

Table 4 shows the principal linkages between the chemical industry and other sectors of the economy for four developed countries and one

TABLE 4: INPUT AND OUTPUT COEFFICIENTS OF THE CHEMICAL INDUSTRY

Industry	*Input coefficients × 10^4*					*Output coefficients × 10^4*				
	Japan	*Italy*	*Norway*	*United States*	*India*	*Japan*	*Italy*	*Norway*	*United States*	*India*
1. Apparel	1	0	0	0		27	97	4	98	
2. Shipbuilding	0	0	0	0		23	5	28	5	
3. Leather and products	1	0	3	3		2	127	95	91	
4. Processed food	167	289	81	486	448	301	224	1,144	777	116
5. Fishing	226	0	2,102	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. Industries not counted elsewhere (NEC)	0	58	0	39		149	184	38	156	
9. Transport equipment	0	0	0	1		12	100	20	107	
10. Rubber products	45	1	0	13		216	244	37	444	102
11. Textiles	40	49	12	64		1,676	1,206	116	600	776
12. Machinery	5	0	0	7		65	69	33	334	131
13. Iron and steel	63	6	199	118		15	122	50	124	36
14. Nonmetallic mineral products	73	52	20	74		94	104	35	75	71
15. Lumber and wood	19	8	21	36		39	40	73	53	21
16. Chemicals	2,361	3,534	1,972	2,090	1,887	2,361	3,534	1,972	2,090	1,887
17. Printing and publishing	18	0	1	12		53	68	26	71	
18. Agriculture and forestry	581	235	830	901	237	1,440	967	1,094	622	633
19. Non-metallic minerals	53	182	125	144	279	5	19	14	15	
20. Petroleum products	14	135	177	157		21	50	1	126	
21. Nonferrous metals	199	152	35	128		33	67	89	53	
22. Metal mining	106	106	9	40	a	19	34	13	15	
23. Coal products	234	128	27	86		16	7	0	10	
24. Trade	268	216	296	225		0	40	1	92	
25. Paper and products	452	62	423	260	50	105	293	190	145	163

26. Electric 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. Petroleum and natural gas	0	10	0	19		0	0	0	15	
30. Interindustry total	6.123	6.193	6.682	5.737		7.306	7,781	5,565	6,839	
31. Final demand						3,128	3,162	6,421	3,649	
	Value of flows									
	10⁹ yen	*10⁹ lire*	*10⁹ kroner*	*10⁷ $*	*10⁷ rupees*					
32. Total production	5,853	6,678	1,299	1,356		10,000	10,000	10,000	10,000	
33. Imports	254	630	258	66		434	943	1,986	487	
34. Total supply	6,107	7,308	1,557	1,422		10,434	10,943	10,986	11,487	

SOURCE: *Techniques of Sectoral Economic Planning: The Chemical Industries*, United Nations, New York, 1966 (Sales No.: 66.II.B.17), table 2, p. 10.

[a] Included in total of 279 reported under non-metallic minerals.

developing country. The input coefficients show the proportions in which various industrial sectors (including the chemical sector itself) and other economic sectors provide the goods and services consumed by the enterprises that make up the chemical sector. The output coefficients show the proportions in which these enterprises sell their production to the various sectors and also to final consumers and export markets. The most important inputs are, of course, the raw materials and intermediate chemical products. Energy, transport and various other services, however, are also significant. It may be seen from the output coefficients that the principal markets of the chemical industry are agriculture and the textile, food, rubber and paper industries. It is evident that the coefficients vary considerably from country to country. The output coefficients for India are significantly smaller than those for the other four, more highly developed countries. In general, inter-industry linkages increase with the level of industrialization. In the initial stages of industrial development, the industrial sector tends to consist of a collection of fairly isolated projects, between which there are only weak linkages. It is only at later stages of development that a web of complex industrial relationships links up the scattered projects.

Branch structure of the chemical industry

The increase in value of chemical production with the income level and population is accompanied by changes in the branch structure of the sector in the course of industrialization. Basic changes in the structure of branches have also taken place in the advanced industrialized countries because of the changes in technology during the last two decades.

Despite the limitations of the statistics, it may be said that more than 80 per cent of the value of chemical production in the industrially advanced countries takes place in the following eight branches: inorganic industrial chemicals; organic industrial chemicals; fertilizers; plastics; man-made fibres; pharmaceuticals; soaps, detergents and cosmetics; and paints, varnishes, etc.

A study of the branch structure in the early 1950s and again in the early 1960s for the European Economic Community and seven other countries, whose combined production represented about 85 per cent of world chemical production [excluding China (mainland)] shows that the pattern in both periods varied greatly from one country to another. Table 5 shows not only the average for this group of countries as a whole,

TABLE 5: PRODUCTION OF CHEMICAL INDUSTRY ACCORDING TO MAIN BRANCHES
(in percentages)

	Selected developed countries[a]						*Selected Latin American countries*[b]		
	Early 1950s			*Early 1960s*			*Early 1960s*		
	Average	*Minimum*	*Maximum*	*Average*	*Minimum*	*Maximum*	*Average*	*Minimum*	*Maximum*
Inorganic industrial chemicals	14.4	7.0	42.6	16.4	9.4	26.3	6.8	4.2	10.6
Organic industrial chemicals	12.8	0.7	14.9	15.0	5.6	24.5	7.8	2.0	11.3
Fertilizers	6.3	4.1	27.5	5.5	4.3	21.8	6.9	4.1	10.0
Plastics	4.9	0.7	7.1	9.9	4.1	12.3	6.4	5.6	6.8
Man-made fibres	7.1	2.0	10.6	7.3	3.9	15.0	13.1	9.9	15.1
Varnishes, paints, inks, etc.	6.5	3.0	15.3	8.4	2.9	11.5	7.9	6.5	12.3
Pharmaceuticals	9.2	2.0	13.0	10.5	2.5	13.0	13.4	11.4	17.4
Soaps, detergents and cosmetics	12.0	2.3	20.8	10.1	2.5	12.5	15.9[c]	13.5[c]	18.7[c]
Other branches	26.8	...	...	16.9	...	...	21.8	...	...
TOTAL	100.0			100.0			100.0		

SOURCE: *Chemical Industry and Developing Countries*, pp. 213, 214.

[a] Members of European Economic Community, Great Britain, Norway, Poland, Sweden, United States and USSR.

[b] Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela.

[c] Excluding cosmetics.

Note: ... not available.

but also the minimum and maximum values found for the percentage share of total production attributable to any given branch of the industry.

In the developing countries the statistical detail is generally lacking to document accurately the branch structure of the chemical industry but some indications can be given, based on estimates.

In the developing region of Africa the United Arab Republic accounts for over 70 per cent of the value of chemical production and it is mainly the pattern in this country that is described. Compared with the industrially developed countries, there is a strong emphasis on inorganic industrial chemicals and fertilizers, but the most striking feature is the high proportion of total output contributed by soaps.

In the developing region of Asia, India accounts for over half the value of chemical production, while China (Taiwan) and the Philippines together contribute more than 20 per cent. Like Africa, the Asia region shows an emphasis on inorganic industrial chemicals and fertilizers, but the share of soaps and detergents in the Asia region, while above the average for the developed countries, is much less than in Africa. On the other hand, Asia devotes a far greater percentage of its chemical production than Africa to pharmaceuticals and man-made fibres. Both regions have a negligible activity in the field of organic industrial chemicals, as compared with the industrially advanced countries.

Rather more data are available for Latin America.[3] Seven countries, namely Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela, account for more than 95 per cent of the value of chemical production in Latin America. The estimates prepared in respect of 1965 for these countries taken together are also shown in table 5. Latin America is in general further advanced in chemical production than the other developing regions and its branch structure is rather closer to that of the developed countries. The share of organic industrial chemicals is much greater than in Africa and Asia but still below that in the developed countries. On the other hand, the inorganic basic chemicals account for only a small proportion of the total production and there is not the same strong emphasis on fertilizers as in Africa and Asia. Pharmaceuticals, soaps and detergents account for twice as high a percentage of the total as the average for industrialized countries.

---

[3] See *La industria química en América Latina;* for full reference see annex 3 under "Economic Commission for Latin America".

CHARACTERISTICS AND PROBLEMS

MARKETS AND ECONOMIES OF SCALE

The relationship between the size of the market and the minimum scale of production that is economical for various chemical products has a critical effect on the prospects for developing the chemical industry in any given country. As far as the production of basic heavy chemicals is concerned, the higher the level of general industrial development and the larger the population to be served—all the way up to markets of sub continental size—the better the prospect of profitable operation, owing to the economies of scale. In the case of chemical end-products, however, the economies of scale usually impose less rigid constraints. Examples of such end products are paints, varnishes and waxes; matches and candles; and pharmaceutical formulations. Some end-products however, are subject to as substantial economies of scale in their production as the basic heavy chemicals; synthetic rubber is a case in point. The discussion of economies of scale is therefore concerned primarily with basic heavy chemicals.

Inter-industry linkages and demand for chemicals

The demand for chemical products is not closely tied to the development of a few selected industries but depends rather on the development of the economy as a whole. The chemical industry sells to a large number of other industries producing final products, intermediate goods and capital equipment, in addition to its sales to the Government and to final consumers. Some indication of the diversity of sales outlets may be obtained from the following broad survey.

Sales to final consumers include drugs and pharmaceuticals, cosmetics and soap, household chemicals and photographic materials. Only one step removed from the final consumers are the following industries that supply goods for final consumption, with an indication of the chemical products sold to them:

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.

Other industrial sectors less closely identified with consumer goods are supplied with an extremely wide variety of chemical products, some of which are given below:

Agriculture:	Fertilizers, agricultural control chemicals (pesticides), chemicals for animal husbandry (feed additives, veterinary drugs, disinfectants);
Pulp and paper:	Chemicals for pulp making, bleaches, adhesives;
Glass and ceramics:	Soda ash and additives;
Lumber and wood products:	Wood preservatives, resins and adhesives, paint and varnish, bleaches, stains;
Metallurgy:	Pickling acid for steel; sodium hydroxide (aluminium); flotation chemicals, leaching agents, additives;
Petroleum refining:	Sulphuric acid, alkalis, solvents.

Sales to industries manufacturing capital goods and consumer durables include the following:

Construction:	Roofing materials, paints and varnishes adhesives, plastic components (as well as products sold to the lumber and glass industries as shown below), explosives;
Electrical machinery:	Plastics for insulating wires and cables, insulating bases and shapes;
Transport equipment:	Components for batteries, plastic for seals and trim, paints and varnishes;
Household appliances and furniture:	Plastic components, enamels (as well as products sold to the lumber and wood industries as shown above).

These lists convey the impression that demand for chemical products is widely diffused throughout the economy and this is fully supported by statistics. Table 4 shows that inter-industry demand, as distinct from the sale of end-products to final consumers, generally represents between one half and two thirds of total demand.[4] Furthermore, inter-industry sales are less sharply concentrated in the case of chemical industry than for most other manufacturing and extractive industries. In this respect, the chemical industry is more akin to the investment goods industries and to the service sectors of the economy. The 50 × 50 input-output table constructed for the United States economy for the year 1957 showed the following share of inter-industry demand going to the four largest industrial markets (i.e. output sectors): 49 per cent for the service industries; 58 per cent for the capital goods and consumer durables industries; 53 per cent for the chemical industry; and 78 per cent for other manufacturing and extractive industries.

Demand for an individual chemical product is based in most cases on many different end-uses. Growth in product demand usually depends, therefore, on a balanced growth in the economy as a whole rather than on expansion of one or two particular industrial sectors. Because of the network of interconnexions between the chemical processes in the chain between production of basic chemicals and production of end-products, it follows that the demand for many basic heavy chemicals depends ultimately on balanced growth of the economy as a whole though for any given basic chemical there may be a direct forward linkage to only a few other intermediate products.

One consequence of the widespread distribution of chemical demand is that planners have only limited scope to create a market by simultaneously expanding one or two other key industries, as can be done for some industrial sectors. For example, the cement industry can be launched to serve a large public works programme, comprising the construction of dams, roads, schools and hospitals; the reason for this is that cement manufacture and the construction sectors are highly interdependent and lend themselves to joint planning. For the chemical industry the only significant concentrated linkage is to the agricultural sector, particularly at the early stages of development when other interindustry linkages are not highly developed in most countries. The development of chemical products allied to agriculture, such as fertilizers and pesticides, may be linked to the growth of and the introduction of modern technology in the agricultural sector.

[4] For the comparable percentage in other industrial sectors, see UNIDO *Techniques of Sectoral Economic Planning: The Chemical Industries*, table 4, page 20 (ID/SER. E/1; ST/CID/14) (United Nations publication, Sales No.: 66.II.B.17).

The nature of economies of scale[5]

The most significant source of economies of scale is the reduction in the cost of fixed investment per unit of annual output as the annual capacity of the plant increases. While there is also a sharp reduction in unit labour requirements in these circumstances, the importance of this factor is relatively minor because labour costs represent in most cases such a small fraction of total production cost, especially with respect to the basic chemicals. Some economies may also arise from greater efficiency in the recovery of auxiliary chemicals or in the use of fuel, steam and power; but it is customary to assume that the cost of such inputs is strictly proportional to the volume of output and there are few circumstances in which this assumption produces significant errors.

The relationship between increases in the capital cost of fixed assets (fixed investment) and increases in annual production capacity can be described satisfactorily for many entire chemical processes by a simple exponential equation, which is valid over a certain range of annual outputs. A similar type of equation relates labour costs to annual scale of output. The chemical engineer is accustomed to relationships of this kind expressed in the following form:

$$\frac{C_1}{C_2} = \left(\frac{S_1}{S_2}\right)$$

where C_1 and C_2 are capital or labour costs at two scales of annual output, S_1 and S_2, while the exponent f varies between 0 and 1 according to the chemical process. For the economist, f represents the elasticity of the cost of fixed assets or labour in relation to the scale of annual production. For fixed investment the value of f lies typically in the range 0.6—0.8, and for labour cost in the range 0.2—0.4. In the case studies from which these results are derived, labour generally means direct labour engaged in production. The cost of indirect labour and supervision, together with labour-associated costs such as paid holidays and pension and social security contributions, are conventionally reckoned as a percentage of direct labour, which would imply the same economies of scale as for direct labour. There are some further indirect costs of production and general office overheads that are likewise conventionally expressed as percentages

[5] Economies of scale are more fully discussed in the UNIDO publication *Techniques of Sectoral Economic Planning: The Chemical Industries*, pages 19 to 31, 51 and 52.

of direct labour costs. There are still other cost elements that are customarily expressed as percentages of fixed capital investment, for example, maintenance and insurance of fixed assets.

As an example of the relationship of costs to scale, figure 2 illustrates the position with regard to the production of ammonia from natural gas.

By way of further illustration, table 6 shows estimates of the value of *f* for fixed investment in the production of 18 chemicals, and the range of annual production over which economies of scale occur, from a minimum feasible scale (often determined by the commercial availability of factory equipment) to an upper limit beyond which few further economies

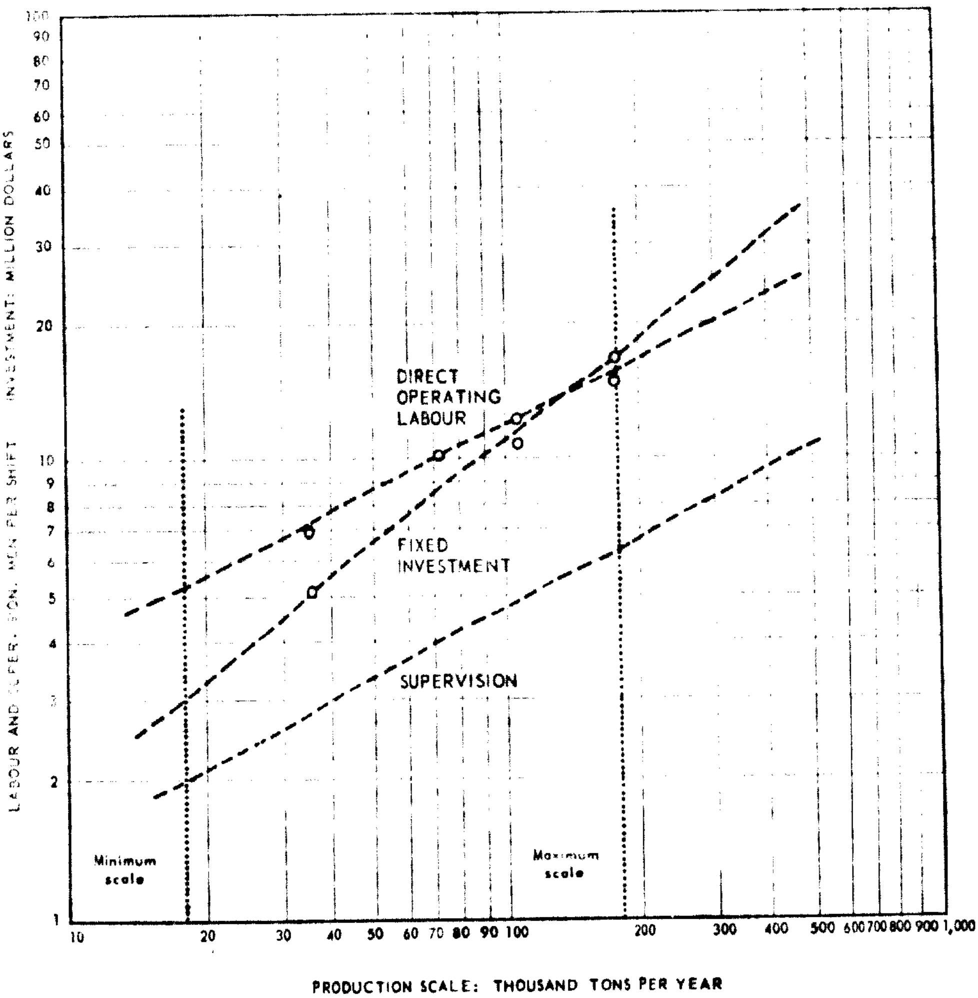


Figure 2. Ammonia: economies of scale

SOURCE: ***Industrialization and Productivity***, **Bulletin 10, 1966 (United Nations publication, Sales No.: 66.II.B.8), figure VIII, p. 16.**

of scale are achievable with known technology and available types of equipment. The table also shows for each chemical product the basic reference scale of annual output (corresponding roughly to an "economic size") and the related unit investment cost used in calculating the information presented, together with the percentage reduction in unit investment costs that can be achieved by producing at three times the reference scale of output.

TABLE 6: ECONOMIES OF SCALE IN FIXED INVESTMENT

Product	*Reference scale C_0 (tons per year)*	*Reference unit investment I_0 (dollars per ton annual capacity)*	*Exponent f*	*Index or unit investment savings*[a]	*Range subject to scale economies (tons per year)*
Isopropanol	6,000	242	0.49	43	2,000— 30,000
Calcium carbide	15,000	147	0.52	41	5,000 — 60,000
Polyvinyl chloride	6,000	285	0.56	38	2,500 — 40,000
Calcium oxide	15,000	34	0.56	38	5,000 —100,000
Butadiene	10,000	600	0.56	38	5,000 — 60,000
Acetylene carbide	4,880	71	0.59	37	2,000 — 20,000
Acetaldehyde	20,000	100	0.59	37	10,000 — 60,000
Carbon black	10,000	300	0.59	37	4,000— 30,000
Ethylene	10,000	570	0.61	35	10,000 — 60,000
Titanium dioxide	5,000	1,200	0.62	34	4,000 — 30,000
Urea	33,000	85	0.65	31	16,000 —165,000
Acetylene (from natural gas)	13,600	465	0.68	30	10,000 — 45,000
Styrene	10,000	280	0.76	23	5,000— 50,000
Polyethylene (low density)	8,130	492	0.77	22	6,000— 12,000
Methanol	10,000	444	0.77	22	5,000— 60,000
Chlorine (and sodium hydroxide)	16,500	340	0.77	22	6,000 — 35,000
Ammonia	36,000	139	0.77	22	18,000—180,000
Sulphuric acid	36,000	18	0.83	17	10,000 —100,000

SOURCE: *Industrialization and Productivity*, Bulletin 10, p. 55.

[a] Equal to $\left(\frac{I_0 - I_3}{I_0}\right) \times 100$

where: I_3 = unit investment corresponding to capacity $3 \times C_0$.

Economies of scale in relation to factor inputs

From the point of view of economic development, it is important to relate economies of scale to the primary factors of production, especially capital and labour. In most developing countries foreign exchange is of

CHEMICAL INDUSTRY

critical importance, not only as an ingredient in capital but also as a continuing requirement for material inputs. As regards capital, which includes working capital for stocks and other purposes, the amount required is generally proportional to fixed investment. It follows that the use of an excessively small scale of production raises the capital output ratio for the economy as a whole and thus slows economic growth. This risk is particularly great in the chemical industry because, as shown above, the most important source of economies of scale is precisely fixed investment. This is not the general situation in other industrial sectors; in the metal transforming industries, for example, production on a small scale or in short series has mainly the effect of increasing labour requirements rather than utilizing capital equipment less efficiently, and this causes a smaller reduction in the growth rate of the economy (assuming that there is a labour surplus).

In the chemical industry much of the production machinery and equipment has a relatively short life-span and therefore the choice of a high rate of production in order to obtain the economies of scale implies a constant flow of replacement machinery and equipment. Even if manufactured locally, such machinery and equipment may be in short supply; more generally, the supplies have to be imported and impose a severe burden on foreign exchange resources. In either case, the growth of the economy is constrained. In industries where the diseconomies of small-scale production take mainly the form of low labour productivity, the retardation of economic growth will be far less pronounced than in the chemical industry (providing that there is a labour surplus). On the other hand, under conditions of high growth rates, the manpower base is the ultimate limiting factor and all diseconomies of small-scale production will have the effect of retarding growth.

The relationship between market size and economies of scale

Studies by ECLA* have examined the relationship between *per capita* income and *per capita* consumption of various basic chemical products. From these studies, it is a simple matter to calculate the population

* E/CN/12/525, *Progress Report on the Work of Secretariat in Connexion with the Chemical Industry in Latin America*, Santiago 1959, summarizes the report of a joint working party of ECLA and the Chilean Development Corporation, by Vietorisz, T., *et al.* These studies are further developed in *La indústria química en América Latina;* for full reference see annex 3 under "Economic Commission for Latin America".

required at a given income level to provide the market necessary to absorb production at the minimum economic scale for a particular product. At the levels of income of most developing countries, it is evident that only the organization of a market on a regional or subregional scale would give the necessary volume of demand for most basic chemical products.

Two examples may help to illustrate the problem. Sodium hydroxide produced by electrolysis is a relatively encouraging case, since the minimum plant capacity is only about 20,000 tons per year. Nevertheless, if the average *per capita* income is as low as $100, it is calculated that a market of 36 million people is necessary to absorb the annual output. If the average *per capita* income is $300, however, it is calculated that a population of 12 million would suffice to absorb the output.

The production of synthetic rubber (SBR) may be taken as a second example, making the favourable assumption that all rubber tyres are made from synthetic material. The minimum size of plant is estimated at 18,000 tons per year, and at an income level of $100 it is calculated that a population of 90 million people would be required to absorb this output. At income levels of $300 to $600, the required population falls to 18 million and 7 million respectively. This, however, is not the only consideration, because there are even greater economies of scale for some of the intermediate products used to make synthetic rubber. The minimum size of plant to manufacture butadiene, which represents 80 per cent of the material input for SBR, is approximately double the minimum of 18,000 tons per year required for SBR itself. Many intermediate chemical products are jointly utilized in several subsequent processes and this helps to solve the problem of production scale; in the case of butadiene, however, there is no alternative use in significant volume and therefore economies in the scale of its production are an effective constraint on the production of synthetic rubber.

If we turn to consider the production capacity necessary to obtain the maximum economies of scale, the position is naturally worse still, having regard to the income levels and population sizes of the developing countries. Thus, for sodium hydroxide, economies of scale persist up to about 150,000 tons per year, and even for an income level of $300 it is calculated that a population of 90 million people would be required to absorb this output. In the case of synthetic rubber, the size of plant for maximum economies is estimated to be 180,000 tons per year; the absorption of this output is calculated to require a population of 180 million people if the average income is $300 *per capita* and 65 million people if the average is $600 *per capita*. In both these examples the calculated population size for income levels lower than $300 is, of course, even larger and exceeds the total for South America or Africa south of the Sahara.

Raw materials

The principal raw materials of the chemical industry are shown in table 7 below. The most important supplying sectors are agriculture, forestry and fishing which, together with processed food 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) and by the petroleum products industry. Carbon (except for petroleum coke) is supplied by the coal-mining sector. The other minerals referred to are mainly non-metallic.

The input coefficients for various industrial sectors in the developed countries presented in table 4 have been averaged in order to calculate the approximate input coefficients shown in table 7.

TABLE 7: CHEMICAL INDUSTRY: ANALYSIS OF PRINCIPAL INPUTS

	Percentage by value of all items shown
Raw materials	
Inorganic:	
Non-metallic minerals—sulphur, salt, limestone, phosphate rock, potassium salts, fluorspar, sand and pigment minerals	0.5
Metals and ores	2.0
Organic:	
Hydrocarbons—derived from petroleum, fuel oil, natural gas and liquified petroleum gas	1.3
Carbon—derived from coal, coke, petroleum coke, lignite and graphite	1.2
Cellulose, oils and fats, waxes, wood distillates, bagasse, molasses and other agricultural wastes	18.0
Intermediate commodities and other inputs	
Chemical intermediate products	25
Electric power	2
Transport and other services	7
Machinery and equipment (capital account)	20
Construction (capital account)	7
TOTAL	100

SOURCE: Shreve, R. N., *The Chemical Process Industries*, McGraw-Hill, New York, 1956, and table 4.

Table 7 also shows other intermediate inputs, including the intermediate products of the chemical industry itself which represent one quarter of the total value of inputs. Inter-industry purchases (including some minor inputs not shown) account for some 60 per cent of the total inputs, the remainder consisting of value added. Although purchases of machinery and equipment and expenditure on construction are excluded by definition from current-flow input-output tables, they are included in table 7 so that the importance of raw material inputs may be appreciated in relation to all other inputs, including those on capital account.

The miscellaneous raw materials of organic origin, which are estimated to account for 18 per cent of inputs, are used mainly by the branches of the chemical industry producing consumer products in large volume, such as soaps, cosmetics, paints and varnishes, oils, fats and waxes. The comparative importance of this group of raw materials is considerably less in the branches that manufacture basic and intermediate chemical products. Generally speaking, the supply of these raw materials poses fewer problems in the course of industrial development than does the supply of hydrocarbons, carbon-based raw materials and some of the inorganic minerals shown in table 7.

The following discussion indicates briefly the technical and economic problems relating to the use of the inorganic minerals, hydrocarbons and carbon raw materials. A fuller survey of these problems is contained in the ECLA study.[7]

Sulphur

Sulphur is used by the chemical industry mainly to make sulphuric acid, which, in turn, has been used since the 1940s in the production of fertilizers. Over the last twenty-five to thirty years supplies and prices of sulphur have varied more than those of any other mineral basic material of the chemical industry. Elemental sulphur or brimstone is derived from the following sources:

(*a*) Subterranean deposits of sulphur-bearing limestone from which the sulphur is extracted by the Frasch process;

(*b*) Recovery from refinery gas or sour natural gas, which contains a proportion of hydrogen sulphide;

[7] *La industrie química en América latina*, pp. 113—129; for full reference see annex 3 under "Economic Commission for Latin America".

(*c*) Deposits of natural sulphur; sulphides and waste gases.

Non-elemental sulphur is derived from the following:

(*a*) Pyrites—ores containing sulphur in combination with other elements;

(*b*) Effluent gases from smelters and some blast furnaces; spent oxide arising from the purification of town gas; anhydrite and gypsum.

The Frasch method has proved applicable so far only to deposits in Mexico and the United States. The recovery of sulphur from gases occurs mainly in Canada, France and the United States. For the most part, sour natural gas is used.

A developing country has therefore a number of alternative possibilities to consider when reviewing its sulphur requirements. The presence of sulphur in crude petroleum is a disadvantage in refinery operations, lowering quality and causing corrosion. If, however, recovery of sulphur is an attractive proposition because of the needs of a chemical industry, it may even pay a country to build large new refineries to working with crude petroleum of high sulphur content, despite the higher cost of corrosion protection which this necessitates.

Roughly 85 per cent of sulphur is used for the production of sulphuric acid other uses being for paper production, the manufacture of carbon disulphide, pesticides and bleaching agents. World production totals nearly 30 million tons per annum of which about 3 million tons comes from developing countries.

Further discussion of sulphur as a raw material for the production of fertilizers is to be found in Monograph 6 in this series.[8]

Salt

Sodium chloride is one of the most widely dispersed resources in nature, in solution in water or in the form of rock salt. Commercial production takes one of three forms: the mining of solid salt, solar evaporation of salt water, and evaporation of brines of subterranean origin. In the developing countries, solar evaporation is of special importance. In the developed countries, some 60 per cent of the salt production is consumed in chlor-alkali-electrolysis and 30 per cent in the production of

---

[8] Monograph No. 6: *Fertilizer Industry.*

soda ash. In the developing countries, however, the production of soda ash generally consumes more salt than does the production of caustic soda. Other uses are related to the food processing industries, pulp and paper, ceramics, plastics, oil and soap, textile dyeing, ice manufacture and water conditioning.

Gypsum, magnesium chloride and sulphate, potassium chloride and bromine are among the by products of salt production but, with the exception of gypsum, their recovery and commercial sale is unlikely to be economic unless salt production is at least 100,000 tons per year. In developing countries the important step is generally to upgrade salt recovery technically from being a handicraft to a factory operation.

The annual world production of salt exceeds 100 million tons and shows a steady growth. The share of the developing countries is about 15 per cent of the total, excluding China (mainland).

Phosphates

The third large group of mineral raw materials for the chemical industry consists of phosphates. Phosphorus is indispensable to organic life in plants and animals; the growth in consumption of mineral phosphates is very closely tied to the expansion of the fertilizer industry.[9]

Limestone

The chemical industry uses limestone in the manufacture of calcium carbide, sodium bicarbonate (Solvay process) and caustic soda. Although limestone deposits are widely distributed around the world, the chemical industry prefers to use deposits with at least 94 per cent content of calcium carbonate and a low percentage of silicate, magnesium and iron. The metallurgical and construction industries are, of course, large users of limestone.

Hydrocarbon raw materials

The most important hydrocarbon raw materials for the chemical industry are natural gas, crude oil and petroleum refinery streams (including the gases and refined products). These hydrocarbon raw materials are

---

[9] Monograph No. 6: *Fertilizer Industry*.

converted into basic petrochemicals, such as ammonia, methanol, ethylene, propylene, butylene, butadiene, acetylene, benzene, toluene, xylenes and many others. Some of the conversion processes are highly specific; for example, para-xylene (which is used to manufacture polyester fibre) is obtainable only from the light distillates of highly naphthenic crude petroleum or from reformed naphtha. At the other extreme, ammonia can be produced from any hydrocarbon ranging from natural gas to heavy fuel oil, although the production costs vary somewhat according to the raw material used. The degree of flexibility in production of other basic petrochemicals lies between the extremes.

By far the greatest part of the consumption of hydrocarbons is as fuels to provide heat for every kind of application in industry, commerce and homes, as well as steam-raising for turbines in electric power generation and marine transport and as fuel for internal combustion engines. Since the chemical industry accounts for only a small fraction (one or two per cent) of the total consumption of hydrocarbons, the cost of these raw materials is determined almost entirely by their primary use as fuels. In their application as fuels, the different hydrocarbon streams are interchangeable to a considerable extent and their prices tend to be related to their calorific value. Although this is the broad outline, the price structure is adapted in detail to their costs of production, refining and transport and to their convenience and specific use.

Thus, a fuel for automobiles is always priced substantially higher than industrial fuel oil; and natural gas may command a premium price as a household fuel in areas where it is relatively scarce. In terms of volume, the outstanding use of hydrocarbons is as an industrial fuel and the conditions of supply and demand for this market are the basis of the entire price structure. It follows that the cost of hydrocarbons per calorie at various geographical locations is a key consideration when planning the development of the chemical industries. The other main determinants of location, according to a number of studies (including the ECLA study cited above) are economies of scale and transport costs.[10]

The cost of one calorie of heat can be used to measure the effect of a number of factors that strongly influence production costs in the chemical industry. Thus, fuel is used directly in most chemical processes and for the generation of steam or power, constituting a significant part

[10] See also: Isard W. and E. W. Schooler, *Location Factors in the Petrochemical Industry*; Airov J., *The Location of the Synthetic Fibre Industry*; and Isard W., E. W. Schooler and T. Vietorisz, *Industrial Complex Analysis and Regional Development*; for full reference see annex 3 under "Other sources".

of total production costs. In addition, the refinery streams used as feed-stock for petrochemicals are priced in relation to their calorific value. It is therefore of some interest to consider the geographical structure of fuel prices.

Fuel prices are reasonably stable geographically in the long run and a simple analysis of their basis, which is useful for long-term planning, was made by Dwyer in 1958.[11] On the basis of historic data about the course of fuel prices he assumes that the delivered price of industrial fuel is the same in two key markets: the Eastern seaboard of the United States (for which New York may be taken as representative) and the industrial zone of northwest Europe (for which Rotterdam may be taken as representative). The world fuel price structure can then be mapped out by a series of calculations. The first step is to consider the surpluses available from secondary supply areas after meeting the requirements of their local markets and the price of fuel for the world market at these supply points. The second step is to calculate the pattern of distribution from each supply point to all consumer zones (other than "tied" local markets) which will bring about the lowest delivered prices of fuel. New supply areas such as the Sahara oil fields can be fitted readily into this general framework.

In this scheme transport costs play a basic role and the projections have to assume a suitable basis for the geographical structure of long-term shipping costs, making allowance for the trend towards cost reduction on certain routes through the use of exceptionally large tankers. Likewise, the cost of transporting natural gas by pipeline has to be used in order to relate fuel costs near gas fields to the world fuel price structure, whenever a sufficient quantity is available for it to enter general industrial use as well as the consumer market in which it commands a premium price.[12]

---

[11] Dwyer, C. J., *Nuclear Energy and World Fuel Prices*, Washington, D.C., National Planning Association, 1958. The most complete and up-to-date economic analysis of the world fuel market and the oil and natural gas industries may be found in Adelman, M., *The Supply and Price of Natural Gas*, Blackwell, Oxford, 1962, and Adelman, M., "*The World Oil Outlook*", (M. Clawson, ed.) *Natural Resources and International Development*, published for Resources for the Future, John Hopkins Press, Baltimore, 1964, p. 77–125. See also: Chazeau, M. G. D. and A. E. Kahn, *Integration and Competition in the Petroleum Industry*, Yale University Press, New Haven, Conn., 1959. (American Petroleum Institute. Petroleum monograph series, Vol. 3.)

[12] See Cookenboo, L., 1954, *Costs of Operating Crude-oil Pipelines*, Rice Institute, Houston, Texas, and *Crude-oil Pipelines and Competition in the Oil Industry*, Harvard University Press, Cambridge, Mass., 1955; Isard, W. and E. W. Schooler, *op. cit.*

When refinery products other than fuel oil are used (as raw materials for the petrochemical industry) their price is determined by the major alternative uses of these products. For example, naphtha used for reforming in the production of aromatics is priced according to conditions in the market for motor fuel. Similarly, a C_4-stream[13] used for the manufacture of butadiene is priced according to the marginal alternative use, which may be as liquified petroleum gas, or as additive to motor fuel or as an industrial fuel.

Raw materials derived from carbon

Until recently raw materials derived from carbon played a fundamental role in the manufacture of organic chemical products. Plants for the production of these products were located at large centres of iron and steel manufacture and to a lesser extent near city gas plants, making use of the liquid and gaseous by-products of the coking process. Demand for organic chemicals, however, and particularly for aromatics, rapidly outpaced the supplies obtainable in this way. Alternative processes based on hydrocarbon raw materials were then developed, in the United States initially, and have steadily gained ground until today chemicals derived from carbon play a minor role in world production.

The principal raw materials based on carbon are gas, coal tar, light oils and aqueous ammonia (a by-product of coke manufacture). Coke-oven gas yields ammonia, methanol and some ethylene. The light oils are the raw materials for the manufacture of aromatics: benzene, toluene and xylenes; coal tar on the other hand yields heavier aromatics such as naphthalene and anthracene, the phenols and cresols etc. All these products are also obtainable from petrochemical sources and their manufacture from coal was tied historically to the demand for coke.

Coke is used as an industrial fuel and as a metallurgical raw material. For the latter purpose, it has to be of high quality and many coal deposits in developing countries do not yield coke of metallurgical grade. In these cases or where there is no demand for the metallurgical quality, a considerable saving in the investment and production costs of coke making can be achieved by adopting the dry distillation of coal at a relatively low temperature. Low-grade coals and lignite (brown coal) are suitable

[13] Butanes and/or butylenes.

for this purpose. In the past, before appreciable local resources of petroleum were discovered in Europe, an extensive study was made of the use of dry distillation of lignite. The by-products of this low-temperature process can be converted into liquid fuels and lubricants. Certain technical difficulties, however, mainly associated with the heating and mechanical handling of coal and tar in the distillation ovens, have not been entirely overcome and in any case the process requires several stages. The synthetic production of hydrocarbons from carbo-chemical sources has in consequence been unable to compete in the past with natural petroleum derivatives. Nevertheless some developing countries, especially those that possess coal resources but are poorly endowed in petroleum or natural gas, have shown a clear interest in the production of organic chemicals from raw materials derived from carbon.

Process equipment: linkages to the engineering sector

The general order of magnitude involved in the linkage between the chemical and engineering sectors has been indicated in table 7, in which input coefficients are shown for machinery and equipment as well as for raw materials and intermediate products. Unlike the material inputs however, the machinery and equipment inputs depend on the rate of growth of the chemical sector. If the economy as a whole is growing at 6 per cent per year, it may be expected that the inputs of machinery and equipment in the chemical sector will represent about 18 per cent of the value of total current-flow inputs; this is only slightly less than the value of all raw material inputs or all inputs of intermediate chemical products. Development prospects and planning of the chemical industry are therefore affected by the situation in the metalworking sector.

The percentage cited above should be taken as a rough guide only because in each country it must depend heavily on the particular structure of the economy. The rate of growth of the chemical sector influences the need for new investment, while the amount and the age of the plant and equipment already in use determine the investment in replacement inputs. In many developing countries the existing chemical plants are of relatively recent origin and therefore replacement inputs are currently insignificant: it often happens that one or two plants account for a large fraction of the total capacity and replacement, when it occurs, causes a sharp increase in the machinery and equipment inputs.

The economically useful lifetime of plant and equipment used to manufacture basic chemical products is generally between 10 and

18 years, according to recent estimates of depreciation made for 90 manufacturing processes employed in this branch of the industry. Technical progress and the consequent economic obsolescence sometimes causes equipment to be replaced before it is worn out. Where replacement is not enforced by technical progress the decision to replace is determined by balancing the steadily growing cost of maintenance, repair and technical inefficiency of the machinery and equipment against the cost of tying up capital in the purchase of new machinery and equipment. When there has been technical progress, it introduces a further element to be considered, namely the reduction in production costs which is foregone if the old equipment continues in use instead of being replaced by new and more efficient equipment.

While the date of replacement can be advanced or retarded to some extent according to individual judgement of where the balance lies, a lengthy extension of service beyond the economic optimum can lead to serious inefficiency and rising costs. It should also be noted that while the average service life mentioned above relates to the key components of a process plant, individual components and ancillary equipment may have a service life of a different length from the plant as a whole. Generally speaking, individual components can be replaced. Often a key component nearing the end of its economic life can be replaced by a technically improved model; this can lead in turn to the installation of new ancillary equipment. It is also common as a result of technical progress that a replacement item makes possible an increase in output, so that replacement and expansion become a single operation.

Thus the division between investment for expansion and investment for replacement is not always as sharp as the two terms might imply. Another reason why the distinction tends to be blurred in practice is that different components or items of equipment often have capacities that do not perfectly match the scale of total output; standard sizes of equipment (e.g. pumps, heat exchangers) are often used that have different effective capacities in relation to a given chemical process. The capacity of one of these items therefore will limit effectively the maximum capacity for the process as a whole. If this particular bottle-neck is removed it will be possible for capacity to expand until the next bottle-neck becomes effective. In this way it is often possible for "unbalanced" expansion to take place and where this is feasible it requires fewer resources than a balanced expansion.

Linkages with the engineering sector appear in input/output analysis of industry as capital coefficients rather than current-flow coefficients.

(This applies to all industrial sectors, not merely to the chemical industry.) The capital coefficients obtained from some research studies, however, apply simply to total investment in fixed capital by a given industrial sector; in other words, they do not indicate the proportion of the investment devoted to various types of production equipment and to land and buildings nor the various industrial sectors from which the purchases are made.[14] Other sources containing greater detail tend to have the disadvantage of being out of date.[15] One compilation of capital coefficients which is both detailed and comparatively recent should be mentioned since it contains data for the separate branches of the chemical industry according to the four-digit code employed in the United States industrial classification.[16]

For the chemical industry as a whole the most probable estimate of the aggregate of purchases on capital account from the engineering sector is one dollar per dollar of inter-industry sales (including such sales within the chemical industry itself).[17] This ratio is used in table 8 to relate growth in sales by the chemical industry to expenditure on machinery and equipment to secure this expansion. In addition, it is assumed that machinery and equipment used by the chemical industry has an average lifetime of 12.5 years so that 8 per cent of capital spending is allowed for replacements. The effective linkage to the engineering sector is then the sum of the requirements for expansion (at any given growth rate) and replacement. The table also shows the expected growth rate of the economy as a whole associated with a given rate of growth by the chemical industry. This is based on the assumption that the income elasticity of production is 1.66 for the chemical industry (see chapter I).

---

[14] See for example "Programming Data Summary for the Chemical Industry" in *Industrialization and Productivity* Bulletin 10, and *Studies in Petrochemicals*; for full reference see annex 3 under "United Nations Industrial Development Organization".

[15] Cristin, H. R., C. S. Cameron and A. P. Carter. "Where Do Construction Dollars Go?" *Chemical Engineering*, 60, New York, November 1953, based on data compiled by the Harvard Economics Research Project; and Grosse, R. N., *Capital Requirements for the Expansion of Industrial Capacity*, Washington, D.C., Government Printing Office, 1953. Reprinted by the Research Analysis Corporation, August 1964.

[16] Waddell, R. M., P. M. Ritz, N. J. Dew and M. K. Wood, *Capacity Expansion Planning Factors—Manufacturing Industries*; for full reference see annex 3 under "Other sources".

[17] For details of this estimate see *Techniques of Sectoral Economic Planning: The Chemical Industries*, pp. 30–40; for full reference see annex 3 under "United Nations Industrial Development Organization".

TABLE 8: GROWTH OF CHEMICAL INDUSTRY AND PURCHASES FROM ENGINEERING SECTOR

Growth rate of national economy (per cent per year)	2.0	4.0	6.0	8.0
Related growth rate of chemical industry (per cent per year)	3.3	6.6	10.0	13.3
Purchases of chemical industry on capital account from engineering sector (per cent of value of sales):				
for expansion	3.3	6.6	10.0	13.3
for replacement	8.0	8.0	8.0	8.0
	11.3	14.6	18.0	21.3

To the extent that there is no domestic production of engineering goods, the flows indicated in table 8 will have to be imported and this will be a substantial offset to the foreign exchange savings achieved by replacing chemical imports by domestic production. If anything, table 8 understates the capital expenditure required because the coefficients are based on experience in the United States and in a developing country where the scale of operation is substantially smaller the capital requirement per dollar of sales will tend to be higher.

If shortage of foreign exchange leads a country to postpone replacement expenditure, efficiency and operating costs in the chemical industry will suffer and eventually the requirement of foreign exchange for repair and maintenance will be even greater and impossible to postpone without disastrous effects on production. If, however, the beginnings of an engineering industry have been set up in the country the picture is more favourable. Some repair and replacement of relatively simple components of process equipment (tanks, vessels, towers, piping) will now become practicable; as the metalworking sector is diversified and expands its capacity, the proportion of the flows in this linkage that can be domestically supplied will increase.

Chemical processes differ substantially in the degree to which their production equipment uses simple rather than complex fabricated components. Furthermore, developing countries vary greatly in the extent to which they have developed the metal-transforming and machinery branches of the engineering sector. Countries with a small population and *per capita* income in the range of $100 to $300 appear unlikely to be able to meet more than one third of the requirements of machinery and equipment for the chemical industry from domestic sources and will generally be able to meet a great deal less. On the other hand, an ECLA study[18] found that domestic sources could provide 64 per cent of the equipment needed for an expansion programme of the petroleum refining and petrochemical industries in Brazil. Few developing countries, however, have such a large domestic market and so highly developed a metal-transforming and machinery industry as Brazil.

Domestic production of the more sophisticated components in chemical machinery and equipment generally prove uneconomic for developing countries. The manufacture of these components often requires specialized or outsize metalworking equipment which would have a very low utilization in meeting the demand generated by the chemical industry or even by the entire manufacturing sector. A second difficulty arises from the rapid technological progress of a modern chemical industry. New processes involve the development of new types of machinery and equipment. Many developing countries do not possess the accumulated skills and know-how needed to keep abreast of these developments and are unable to maintain the large technical engineering facilities which are required.

While, therefore, there are generally practical limits to import substitution in regard to machinery and equipment for the chemical industry, the situation is far simpler in regard to factory construction and the installation of machinery and equipment, which accounts for a considerable part of the gross capital expenditure (see table 7). The opportunities for import substitution in this area should be pursued vigorously in all cases.

Employment

The chemical industries provide very few jobs, especially for unskilled labour, and therefore contribute little to solving the often very serious problem of under-employment in developing countries. Few industrial sectors have lower labour costs in relation to sales than the chemical industries.

The point is well illustrated by the estimates of manpower requirements for an ambitious import substitution programme in Latin America derived from an ECLA study of the chemical industry.[19]

[18] *The Manufacture of Industrial Machinery and Equipment in Latin America. I. Basic Equipment in Brazil*, 1963 (United Nations publication, Sales No.: 63.II.G.2).

[19] Summarized in *Techniques of Sectoral Economic Planning: The Chemical Industries*, pp. 42 and 43; for full reference see annex 3 under "United Nations Industrial Development Organization".

TABLE 9. HYPOTHETICAL MANPOWER REQUIREMENTS FOR SELECTED CHEMICAL PLANTS IN LATIN AMERICA[a]
(thousands of man-hours per year)

Product group	*In absence of regional integration*					*Total for integrated region*
	Chile	*Argentina*	*Brazil*	*Venezuela*	*Mexico*	
Sodium carbonate	1,277	1,782	1,693	1,122	1,877	1,380
Sodium-dicalcium phosphate complex	560	847	1,091	605	801	3,124
Superphosphate-tripolyphosphate complex	251	562	839	458	337	1,926
Silicon carbide	87	124	132	102	123	167
Nitrogen complex	210	502	710	343	392	2,164
Urea and phenolformaldehyde complex	420	b	528	480	502	662
Cellulose acetate-PVA-PVC complex	4,219	5,424	6,012	4,179	5,004	8,630
Polyethylene-polystyrene-butadiene complex	477	733	880	639	781	1,492
Carbon black	45	56	67	51	58	137
Dodecyl benzene-propylene tetramer complex	111	180	204	116	172	252
Acetone-isopropylene alcohol	152	203	240	166	211	320
TOTAL	7,809	10,413	12,396	8,261	10,258	20,254
	Number of jobs created, estimated at 2,000 man-hours per year per job					
ALL PRODUCT GROUPS	3,900	5,200	6,200	4,100	5,100	10,100

SOURCE: UNIDO, *Techniques of Sectoral Economic Planning: The Chemical Industries*, table 13, p. 43.

[a] Direct operating labour, increased by 75 per cent to allow for indirect labour.

[b] Not estimated.

These estimates, summarized in table 9, relate to eleven product groups covering 46 basic products whose output accounts for about 25 per cent of total output by the chemical industry, as projected for 1965 some years previously. On the assumption that production would be concentrated in integrated plants serving the entire regional market of 20 republics, it was estimated that manpower requirements would be 20.3 million man-hours per year, thus providing jobs for about 10,100 people. On the other hand, in the absence of regional integration, the five largest producing countries of the region would require some 49.1 million man-hours per year for their output of the selected chemical products and this would generate jobs for about 24,600 workers. When it is added that the labour force in Latin America was expected to increase by roughly 2 million people per annum in the mid 1960s, it may be seen that the projected programme was capable of employing between a half and one and a half per cent of the *increase* in the labour force of the region which occurs in any single year.

Skilled and technical manpower

Compared to other industrial sectors the chemical industry is a relatively small employer of skilled labour but a relatively high employer of technical and professional manpower.

An ECLA study[20] found that in Peru skilled labour represented about 15 per cent of total labour in the chemical industry, compared with about 80 per cent for the apparel industry, 50 per cent for furniture, 30 to 40 per cent for textiles and about 25 per cent for metal manufactures and machinery. A similar picture emerges from a companion ECLA study dealing with Argentina,[21] where the chemical industry employs a smaller percentage (12–15) of skilled labour than the seven other industrial sectors analysed.

In regard to technical and professional manpower, the chemical industry appears at or near the top of the list of industrial sectors in the ECLA studies of Peru and Argentina cited above, together with machinery and transport equipment and, in the case of Argentina, petroleum. As a proportion of total employees the technical and professional group represents 4 to 6 per cent for Peru and 6 to 8 per cent for Argentina.

The role of labour input in development planning

Whether the need to train manpower for the chemical industry becomes a significant element in development planning will depend on the size of the chemical sector in relation to other industrial sectors in any given development programme.

---

[20] *The Industrial Development of Peru*, 1959 (Analysis and Projections of Economic Development Series, No. 6) (United Nations publication, Sales No.: 59.II.G.2).

[21] *The Economic Development of Argentina*, 3 vols., 1959 (Analysis and Projections of Economic Development Series, No. 5) (United Nations publication, Sales No.: 59.II.G.3).

Labour inputs in the chemical industry are subject to economies of scale even more strongly than fixed capital inputs. The correlation of labour inputs with the scale of output indicates an elasticity of the order of 0.2; thus even large increases in scale will produce only small additional labour requirements or even no increase at all since the number of workers per shift must be an integer and in many processes only a handful of operators is required.

The possibilities of capital-labour substitution in the chemical industry are limited for two reasons: first, because the modern chemical processes were developed in the industrialized countries to some extent because they were advantageous in the context of high wage rates; and secondly, because the chemical industry appears to offer fewer choices of alternative processes than other industries, where manufacture usually involves mechanical transformation. Some ancillary operations such as materials handling are, however, exceptions to this general observation but the amount of capital that can be saved by substituting labour in this way is probably about 5—10 per cent.

Chapter 3

ISSUES OF POLICY

PLANNING AT DIFFERENT STAGES OF DEVELOPMENT

Some branches of the chemical industry stand in greater need of centralized decision making than others where the stimulus of market demand is more likely to bring forth the desirable economic and social response. Certain branches of the industry tend to be set up before others in the course of the industrial development of a given country. It is therefore convenient for purposes of policy making to define four stages in the development of the chemical industry that are characterized by qualitative as well as quantitative changes. These stages tend to be related to population as well as level of income in a given country because, as shown in chapter 1, both these factors influence the size of the market and the feasibility of domestic production.

Stage 1 covers the beginnings of the chemical industry. If production takes place at all it is restricted to simple chemicals and products derived from them which are classified in the chemical industry. This stage is characterized by the following features:

The products manufactured may include: oils and fats; paints and varnishes and lacquers; cosmetics and soaps; polishes, inks, candles, matches; and pharmaceutical formulations;

The processing technology is unsophisticated, skill requirements are low and the equipment used is simple;

Research and development, design and chemical engineering all depend on sources outside the country;

The domestic engineering industry can at most undertake maintenance and repair of equipment.

In stage 2 the manufacture of a wide range of chemical end-products is introduced. Backward integration, if it occurs at all, is sporadic and depends either on specific favourable circumstances or high protective tariffs. The following are the characteristics of this stage:

The products manufactured include fertilizers, often integrated with basic ammonia; chemicals for agriculture such as pesticides; plastics and man-made fibres; and detergents, dyes and explosives.

Backward integration may include, in addition to ammonia manufacture, the production of sulphuric and nitric acid used as fertilizer intermediates; other basic inorganic chemicals, such as chlorine and caustic soda, may not be produced because of inadequate market size;

Some capability for research and development usually exists at this stage, primarily in university faculties, together with the chemical engineering skills to design simple process equipment;

The domestic engineering industries are generally capable of providing the structural steel works and piping required when installing process equipment, as well as simple items of equipment, such as tanks, packed columns, ducts and bins.

When a country has reached stage 3 it already possesses a well integrated diversified industrial base in the field of heavy inorganic and organic chemicals, and it manufactures sophisticated end-products. The essential characteristics of this stage are the following:

Production of basic heavy inorganic chemicals now includes acids, alkalis, salts, chlorine and other industrial gases; petrochemicals are produced from domestic or imported feedstocks (fuel oil, naphtha) as well as synthetic rubber; there is a broad range of organic intermediate products; complex dyes and pharmaceuticals are domestically synthesized; and metallurgical reagents and additives are manufactured;

There is substantial domestic capacity for research and development and chemical engineering, although imported technology is still used to a considerable extent;

The domestic engineering industry may be capable of providing from one half to three quarters of all process equipment required, including blowers, compressors, pumps, mixers, pressure vessels and corrosion-resistant units;

The products of chemical technology are now increasingly used in other industrial sectors as well as in agriculture. Plastics, man-made fibres and synthetic rubber are adopted as structural components of industrial products, while chemical processes transform technology in primary metallurgy, food manufacture, metalworking and many other industries.

The technologically independent chemical industries of the industrially advanced countries are to be found in stage 4. Their essential features are as follows:

Important new products and processes spring from domestic research and development activity, which usually specializes in particular lines and is supplemented by an international exchange of advanced technology;

The know-how of domestic chemical engineering groups is now capable of translating laboratory innovations into efficient industrial production by devising new manufacturing processes and designing sophisticated equipment;

The domestic engineering industry can now supply heavy specialized and sophisticated process equipment for the chemical industry, while not neglecting the advantages of international specialization and exchange.

Let us now consider what the role of planning should be in these four stages. Comment can only be given in rather general terms since the circumstances of each particular developing country call for special consideration.

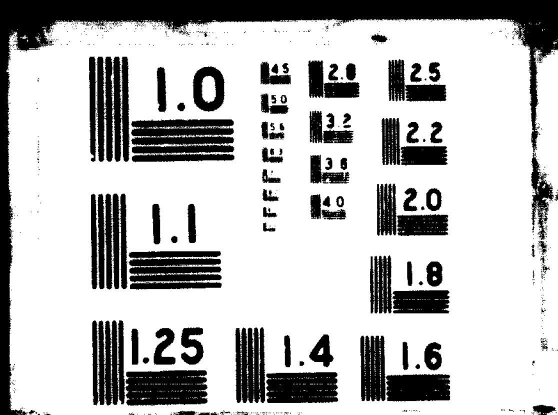
In the first stage, the interrelations between individual projects or between chemical projects and those in other industries are slight. Planning may therefore be restricted to a general promotional role, taking the form of legislation favourable to new initiatives and a tariff policy that enables infant industries to procure their raw materials at relatively low prices while giving them some protection for their products in the home market.

In the second stage there is more scope for planning activities. As the range of chemical end-products manufactured in the country widens, the question is raised repeatedly whether to rely on importing intermediate chemical products or to integrate backwards to heavy chemicals. At this stage it would not be possible to establish a diversified heavy chemical base and if there is any backward integration it must be highly selective. Every project that relies on imported intermediate chemical products, on the other hand, undoubtedly adds to the list of foreign exchange commitments that are difficult to prune during a period when the balance of trade is unfavourable. Only if investment in new chemical projects is centrally co-ordinated can these conflicting considerations be properly balanced from the point of view of the national interest. Individual enterprises cannot be expected, if left to take these decisions in isolation,

74. 10. 7

2 OF 2

01411



to have regard to those considerations of national policy that involve several basic resources—investment capital foreign exchange, skills and technological capabilities—and ought to be judged against a time-scale of several years.

When the third stage is reached the scope for planning is much greater still, especially in countries whose small population and modest level of income make it difficult to build up a diversified heavy chemical base, in view of the diseconomies of small-scale production. In this situation regional or international economic integration, if it can be achieved, simplifies the problems. Even in the absence of integration, however, some progress can be achieved gradually if there is a willingness to support the necessary measures and to sustain them over a period of time. The social and political difficulties of doing so, should not be under-rated. At the cost of holding down consumption, the savings rate can be raised to levels that permit investment in expanding heavy chemicals production in spite of the less favourable capital-output ratios. Except in the largest developing countries such as India, where it may be economic to set up more than one plant per product line,[22] basic chemical processes have to be operated on the largest possible scale by co-ordinating the end-uses and also, if possible, by serving several markets in a region or sub-region following on international arrangements for co-operation. Research and development activities also need co-ordination at the national level, and if possible regionally, in order to give proper technological support. Unless sufficient attention is given to planning the chemical sector at this stage of development it is likely that small-scale, high cost production facilities will be set up haphazardly or that the rate of growth will decline.

A country that has reached the fourth stage should no longer be defined as a developing country and only the briefest comment is called for here about the role of planning in this stage. Some of these countries find it advantageous to pursue active policies of co-ordination if not actual programming of sectoral development. In those with relatively small populations, the economies of scale in manufacture remain a controlling factor even at this stage. Almost regardless of size, countries are concerned with such economies in research development, as demonstrated

[22] For a case study of chemical process plants in India see Manne, A. S., *Investments for Capacity Expansion—Size, Location and Time Phasing*. A cyclical building pattern involving multiple locations was found to be optimal for balancing economies of scale in plant building against long transport hauls and large excess capacities (when building too far ahead of demand). For full reference see annex 3 under "Other sources".

by the United States and the USSR. Some countries set themselves planning goals in terms of time limits in which to attain internationally competitive standards of quality or productivity, branch by branch or product by product.

Regional integration

The discussion of the characteristics and problems of the chemical industry has clearly demonstrated the disadvantage of serving restricted markets and pointed out that, particularly for the production of basic chemicals, the industry tends to require sub-continental markets for efficient operation and these are generally unobtainable without integration on a regional or subregional scale. If production is set up on too small a scale this means, above all, a lower productivity of capital embodied in machinery and equipment. The capital-output ratio of the economy deteriorates and so does its potential for growth. As an alternative to national development in restricted markets it is evidently preferable to *plan* the expansion of the chemical industries jointly in common market areas of sub-continental dimensions.

There are, however, few successful precedents for supra-national co-operation of this kind and the difficulties are many. Industrialists in some countries will tend to oppose such an arrangement for fear that their enterprises may not be viable if exposed to the competition of a common market. When development policies are subject to international consultation there is greater uncertainty about the outcome and it will take longer to reach decisions. The supra-national planning effort requires the maintenance indefinitely of a favourable political atmosphere in all the countries concerned and some of those engaged in the negotiations may be doubtful whether this is possible. National political groups may fear a loss of power and prestige in the event of far-reaching economic integration; and in some cases there may be ideological arguments about a diminution of national sovereignty. Furthermore, every country participating in such supra-national planning will strive to obtain what it regards as its proper share of the benefits of economic integration.

Since the optimum geographical location for the production of basic chemicals is largely determined by the cost of a calorie, those areas within a common market where fuel prices are low have a great advantage over other areas. If fuel prices are low in several areas, this makes it possible to distribute the major chemical complexes among them, but this will still leave the Governments of other areas dissatisfied, since they tend to equate benefits from integration with the location in national territory of some large-scale integrated basic plants.

The problem is further complicated if the larger countries of the proposed common market are also those with the higher fuel prices; the latter are often in a position to go forward without the creation of a common market, because they can offset their high fuel prices against the economies of scale made possible by the size of their national markets. In Latin America this is the position of Brazil, where the areas of low fuel prices are to the north in the Caribbean basin and at the southern extreme of the continent.

The attempt to spread the various branches of the chemical industry over all the participating countries, in order to reach a solution acceptable to all parties, is unlikely to produce the best answer to these problems, since some of the benefits of large-scale production may still be lost. If, however, joint planning is extended to cover the entire industrial base of the region or sub-region, it will always be possible to allocate large-scale production units in one sector or another to every participating country. Many important industries can be set up almost anywhere in the common market area and still benefit from the economies of large-scale operations. After the industries subject to locational factors have been assigned to the geographical areas most suitable for them, the allocation of these other industries can be carried out in such a way that the process of joint development will leave no individual country behind the rest. The engineering sector is particularly suitable for bringing about this international compensation within the joint industrial plan. In principle, therefore, a mechanism is available for solving the technical problems of economic integration and joint supra-national industrial development planning. The institutional and political problems mentioned above will, however, still need to be overcome.

Balanced versus unbalanced growth

There are two aspects to the issue of balanced growth. The first is whether the chemical industry can be developed preferentially, somewhat ahead of the over-all development of the economy. The second aspect concerns the geographical distribution of the industry: whether it should be concentrated in certain areas or dispersed throughout the country.

The demand for basic chemicals tends to be spread over a wide range of applications, as already explained. This is an argument in favour of developing the production of basic chemicals in step with the rest of the economy. This issue arises only at a fairly advanced stage of industrial development; at earlier stages it is simpler products, such as soap and pharmaceuticals (made up from imported raw materials), that predominate (see chapter 1), and, since they serve final rather than intermediate uses, the demand for these products depends directly on the level of *per capita* income. A developing country can hope to achieve self sufficiency in these products at a relatively early stage and the question of industrial balance hardly applies to these branches of the chemical industry.

Fertilizers, pesticides and other chemical products used by agriculture are the major exception to the general proposition that the branches dealing with basic chemical products can best develop in step with the economy as a whole. This group, to which may be added some related basic chemicals, such as ammonia, sulphuric acid, nitric acid, urea, phosphoric acid, and organic intermediates for the pesticide formulations, is closely linked to the agricultural sector even though some of the intermediate products mentioned are also used for other end-products destined for many different markets. If the decision is taken to develop intensively the agricultural sector, so that demand for chemical products used by this sector expands greatly, it follows that the production of these products may be planned to grow at a faster rate than the economy as a whole. Theoretically there is a range of possible measures to stimulate agricultural development, some of which do not increase the demand for chemical products, but in practice the various measures are employed in combination.

Individual developing countries may differ in the extent to which they can achieve backward integration from the end-products (mixed fertilizers, specific insecticide and pesticide formulations, other auxiliary chemicals) to the heavy inorganic and organic intermediates. Where the market is small, it may be advantageous to import the heavy intermediate products rather than produce them domestically, even when the market has been stimulated by an accelerated programme of agricultural development. In this case, moreover, the emphasis of the programme can be shifted away from the use of fertilizers and auxiliary chemicals to other measures of agricultural development, within the limits imposed by technical requirements.

When examining the relative merits of geographical concentration and dispersion of production, a distinction should be made between the heavy basic chemicals and light products. Production of the latter can be dispersed with advantage: oils and fats, paints, varnishes and lacquers, cosmetics, soaps, polishes, inks, candles, matches and pharmaceutical formulations give rise to relatively slight economies of scale in their manufacture; also their production in close proximity to each other or to the basic chemicals does not significantly reduce costs. On the other hand many of these products gain from manufacture close to their markets because distribution costs are often a high fraction of their total costs.

In the case of heavy basic inorganic and organic chemicals, the situation is reversed; economies of scale are powerful and production costs are greatly reduced if several of these products are manufactured in an industrial complex rather than in isolated plants. Except in very large developing countries such as India, the economies of scale of individual processes are such that only one such complex is likely to be set up. When production is concentrated in an industrial complex, efficiency may be increased for the following reasons:

Common use of output. There are several cases in which an intermediate chemical product is subsequently used in the manufacture of several chemicals. When all the processes are linked together the intermediate product can be manufactured on a much larger scale.

Common exploitation of raw materials or utility inputs. Instead of an intermediate commodity, it may be a raw material or utility input whose use on a larger scale, made possible in an industrial complex, enables its unit cost to fall. Typical raw materials of the chemical industry that fall into this category are: sodium chloride (salt) and several other non-metallic minerals. Petroleum refinery streams should also be mentioned since they are generally thought of as raw materials rather than intermediate products. Among the utilities, electric power is of the greatest importance for many chemical processes, and power generation on a scale sufficient to obtain really low unit costs (3–4 mills per kWh) can be absorbed only if all electrochemical and electrometallurgical processes are grouped into a single complex, and sometimes not even then.

Concentration of sources of petrochemical feedstocks. Petrochemical processes cannot be operated efficiently unless the feedstocks are available in sufficient quantity. Many of the latter are narrow cuts obtained as a by-product of refinery operations, that is to say, the quantity obtainable is closely determined by the constitution of the crude oil used at the refinery and the pattern of demand for the products that are refined. It has to be recognized, however, that requirements of the chemical industry are not the only factor to be taken into consideration when planning the location of petrol refineries.

Across the fence exchange of intermediate products. Units located next to each other can exchange intermediate products by interconnecting pipes (or conveyors): in this way a whole range of transport costs can be eliminated. Even a distance of 10 to 20 kilometres between two plants involves more sophisticated and expensive means of transfer. For relatively small throughputs, the latter may prove uneconomical but for very large volumes interconnexion over even greater distances may be justified.

Common ancillary processes. The operation of ancillary processes represents a considerable fraction of total production costs and these processes are themselves subject to economies of scale. Where, therefore, several core processes are served by the same ancillary process, these economies of scale can be captured by locating all the core processes and the ancillary process in the same complex. The core processes may not all necessarily be within the chemical industry. Thus, the generation of steam may be shared with a paper mill or a sugar mill; the loading and unloading facilities of a transport terminal may be shared with a wide class of industrial processes; repair, maintenance and replacement facilities may be shared with any other chemical process plant that employs similar operations and has similar kinds of process equipment.

Sharing of social overheads. Although less closely tied to an individual process than the ancillary operations previously mentioned, social overheads include services that also yield economies of scale. Examples are the organization of training in specialized operational skills, administration and management within a whole geographical area, the development of transport and communications generally within the area, and the provision of housing and other community facilities.

Many of the cost savings mentioned above are described in the literature of economics under the heading of "external economies". It is an observable fact that the establishment of a given project or process often reduces the cost of production for other manufacturing activities. While many examples may be drawn from the unplanned workings in the past of private enterprise economic systems, there is no reason why planners should not seek to achieve similar results in a less haphazard way in the developing countries.

The ECLA study of the Latin American chemical industry[23] presents some detailed examples of such complexes, analysing the interrelationships that they make use of. The following are the major complexes proposed:

A complex based on acetylene, producing polyvinyl chloride (PVC), acetate and cellulose acetate;

A complex based on caustic soda and chlorine, where the surplus chlorine is used for hydrochloric acid, used in turn to treat phosphate rock in order to produce phosphate fertilizer;

A phosphoric acid complex, including triple superphosphate fertilizers and the detergent sodium tripolyphosphate;

A synthesis gas complex, including ammonia and methanol, leading to the production of ammonium sulphate, nitrate and urea fertilizers and the plastics urea-formaldehyde and phenol-formaldehyde;

An ethylene complex, including ethyl benzene and styrene, leading to the manufacture of polyethylene, polystyrene and SBR synthetic rubber;

A benzene complex, including phenol and ethyl benzene leading to the manufacture of styrene, polystyrene, SBR rubber, dodecyl benzene (detergent) and phenol-formaldehyde;

A propane-butane complex, including butadiene, leading to the manufacture of acetone and synthetic rubber.

INTEGRATING THE INTERMEDIATE AND BASIC PRODUCTS

When and to what extent backward integration should be undertaken in the chemical industry of a developing country are questions of great complexity. The two main causes of difficulty are that the intermediate and basic products are generally subject to strong economies of scale and that any given intermediate or basic chemical product is

[23] *La industria química en América Latina;* for full reference see annex 3 under "Economic Commission for Latin America". The complexes presented by ECLA are also reproduced in "Programming Data Summary for the Chemical Industry", *Industrialization and Productivity* Bulletin No. 10; for full reference see annex 3 under "United Nations Industrial Development Organization". See also Isard, W., E. W. Schooler and T. Vietorisz, *Industrial Complex Analysis and Regional Development*, New York, 1959 in which several fertilizer-petrochemical-synthetic fibre industrial complexes have been worked out for Puerto Rico. For full reference see annex 3 under "Other sources".

generally required for a large variety of end-products. It is therefore not possible for planners to increase substantially the consumption of an intermediate or basic product by selectively accentuating the growth in demand for a few end-products.

With a given structure of industrial production, therefore, the demand for various chemicals is largely fixed and, under a normal pattern of development, an increase in demand will depend on growth in the economy as a whole rather than in particular sectors. The only way to create additional demand is to favour end-uses of chemical products that are connected with consumption. Such planning action would, however, set up two biases: one favouring consumption rather than investment, and the other favouring the luxury consumption which makes intensive use of chemicals (synthetic fibres, plastic goods, rubber tires, detergents) compared with consumption of necessities by the general population. If these biases are held to be undesirable, the implications for developing the production of heavy chemicals must be faced.

A way out of this dilemma may be to import the intermediate chemical products required to set up manufacture of sophisticated end-products, such as synthetic fibres, plastics, rubbers, detergents and dyes. It is true that some of these products, particularly synthetic rubber, are as much subject to economies of scale as are the basic industrial chemicals. Others, however, are far less affected and yet their production is characterized by the use of advanced technology and complex organization, mastery of which are essential steps in making industrial progress. If these branches of the industry can be established with levels of production that are consistent with the general level of development of the country (i.e., without undesirably encouraging luxury consumption for the sole purpose of raising the production level in the processing chain), some important benefits of industrialization may be obtained without incurring the disadvantages mentioned above.

Such a strategy, however, creates some new risks in most developing countries, where foreign exchange earnings are liable to fluctuate from year to year. By setting up end-processes which require imported intermediate chemical products, a rigid demand for foreign exchange is created. If imports have to be cut, the level of activity of these new plants must be reduced, unemployment is created, the scarce capital resources committed to this branch are underutilized, and the processing industries further along the chain, such as dyes, plastics, adhesives, are starved of their input needs. When this happens, the situation for the developing country is worse than if manufacture of these chemical end-products had not been attempted: those kinds of consumption with a relatively low social priority could have been reduced without creating unemployment or underutilization of capital while producers of consumer goods would have found ways of reducing their dependence on imports, e.g. by using wooden instead of plastic components or natural glues instead of adhesives.

In this case, as in others, a balance has to be struck between the risk of serious difficulties if the balance of payments deteriorates sufficiently and the loss of the benefits of greater industrialization if manufacture in these branches of the chemical industry is not undertaken in order to maintain greater flexibility in the management of foreign exchange expenditure.

Domestic availability of raw materials

While the availability of key raw materials within the country is a stimulus to the development of the chemical industry, its significance can easily be overestimated. An adequate supply of raw materials which involves no foreign exchange expenditure is clearly helpful, but the size of the market is generally a more critical factor. In addition, project assessments based on the existence of local deposits of certain raw materials often turn out to be unduly optimistic, failing to take into account quality, accessibility and true social cost. In some cases the correct basis for valuation of a raw material is the cost of its exploitation while in others it is the opportunity cost which is appropriate.

Cost of exploitation

The cost of exploitation should be the basis of valuation when there is no important alternative use. An example is the exploitation of salt (sodium chloride) from solar evaporation of sea water in hot arid climates. There are sources of salt in practically every country so that possibilities of export are generally poor. Furthermore, household use is a minor element in total consumption. Limestone is another example of this kind.

Natural gas is sometimes a by-product of the production of crude oil. At the southern extreme of South America very little gas can be absorbed near the oil fields as household or industrial fuel and the volume of gas is not sufficiently great to justify export either by building a pipeline overland or by transporting it in liquified form by sea. In this case the social value of the gas is only the marginal cost of its exploitation. In other words the value is the extra cost incurred in collecting this gas instead of flaring it.

Opportunity costs

When a raw material which it is proposed to use for the chemical industry has other uses, either within the country or as an export, valuation should be on the basis of opportunity costs. If part of the domestic production of a raw material is withdrawn from its existing use in order to supply a new outlet in the chemical industry, the latter would generally pay the ruling price for industrial supplies. Let it be supposed, however, that although the major portion of the supplies are of domestic origin the balance has to be imported at c.i.f. prices well above domestic production costs. In this case, the introduction of new outlets in the chemical industry will entail increased imports and the opportunity cost is the c.i.f. import price not the local cost of exploitation.

As another example, the case may be taken of a raw material derived from several alternative domestic sources with markedly different production costs, all of which supply only the domestic market. If a new outlet in the chemical industry is now set up, the opportunity cost will not be the production cost of the supply source that happens to deliver to the chemical plant, but rather the price determined by the marginal source for the market as a whole (which may be one of the domestic producers or imports).

Once again we are dealing with a concept from the literature of economics that has been derived from observing the working of market enterprise economies. It is equally applicable, however, to allocation decisions whenever planning is undertaken, whether in a mixed economy or a centrally planned economy, except in certain theoretical circumstances which are not often met in practice.[24]

[24] Chenery, H. B., "The Interdependence of Investment Decisions" in M. Abramovitz *et al.*, *Allocation of Economic Resources*, Stanford University Press, Stanford, Calif., 1959; and T. Vietorisz, *Industrial Development Planning Models with Economies of Scale and Indivisibilities*, 1964.

Quality and accessibility of raw materials

Raw materials may be of low quality owing to insufficient concentration or the presence of excessive amounts of impurities. It may be possible, however, to use such raw materials by modifying suitably the existing technology. The requisite engineering know-how is, however, not available in many developing countries. In contrast, the raw materials of submarginal grade in the industrialized countries are under constant study with the object of finding processes that will make their use economically attractive. Advances in raw materials technology therefore tend to deal with geological conditions found in industrialized rather than developing countries.

While the cost of utilization may be high when low quality raw materials are used, it is the costs of exploitation that are high when raw materials are difficult of access. This may result from the geological nature of the deposits (e.g. in the case of coal, narrow or broken seams or deposits at greater depth: and in the case of crude oil small scattered fields or inadequate porosity or very deep wells). It may also occur because the sources of raw materials are located far from existing transport routes. Sometimes when raw material sources are discovered an entire frontier region must be opened up and this involves much more than simply creating new roads. (An example is the Guayana region of Venezuela.) In such cases the expenditure on infrastructure helps to generate autonomous growth in the region as a whole and should not be charged entirely to the cost of exploiting the raw material.

In formulating an industrial development plan, it will usually be sensible to adopt a policy that carries the utilization of high cost and low grade domestic resources of raw materials a little beyond the point indicated by estimates of cost under static conditions. Such a policy makes it possible to expand the exploitation of these resources substantially within a short time at reasonable additional cost. Raw materials of submarginal quality also play a part in contingency planning. In the event of an unforeseen crisis in the balance of payments, the ability to draw on additional supplies of domestic raw materials is invaluable, even if their costs are somewhat above import price levels.

INDIGENOUS VERSUS FOREIGN TECHNOLOGY

The inability to generate technology adapted to local conditions is one of the characteristics that defines underdevelopment. In the chemical industry in particular, the establishment of domestic production units offers no guarantee of genuine economic development: they are often built under a turn-key contract, by foreigners using foreign designs and technology. The operation of such units does not generally foster an indigenous learning process that will eventually enable the country to dispense with external technical assistance. For this, a systematic long-term effort in research and development is required and the technical level of process engineering design and manufacture must be improved.

The establishment of local research and development facilities brings many advantages. It is easier to adapt manufacturing processes to the specifications of local raw materials and to the local ratio of capital to labour costs; foreign exchange is saved that would otherwise have to be spent on research and development carried out under contract in foreign countries; and, perhaps most importantly, it makes it possible to keep the local industry competitive as chemical technology progresses in other parts of the world. The basic chemical plants that can be purchased and erected under contract through internationally known engineering firms may soon become inefficient and eventually obsolete unless serviced and brought up to date. This requires a substantial continuing effort in research and development which it is just as important to plan as the physical investment in machinery and equipment. Indeed, unlike the process plant, the research and development service cannot be readily purchased in the world market.

The scope for adapting technology to the specifications of local raw materials is greater in the chemical industry than in most other industrial sectors. The imported technology devised for conditions in the highly industrialized countries is seldom modified when transferred to the developing countries, where it may not be the most appropriate. In chemical technology the most important substitutions occur between operating costs and fixed costs: on the one hand, high rates of recovery of raw material, low costs of steam and power, low specific fuel requirements and high chemical conversion ratios can be achieved; on the other hand, large heat exchanger surfaces, large diameter piping, high distilling towers, catalyst beds of greater capacity have to be used to get these results. Relatively speaking, the price of equipment is lower in highly industrialized than in developing countries. Thus chemical process plants imported from industrialized countries tend to be more capital intensive than is desirable for use in the developing countries.

It is true that the scope for capital-labour substitution is narrower in the chemical industry than, for example, in engineering. The core processes are often entirely rigid, but there is generally room for flexibility in regard to ancillaries.

If technology is imported, the selection of intermediate chemical inputs also tends to be that which is used in the industrialized countries. Where there are alternative routes to the production of an organic end-product, the route adopted in the industrialized countries is generally determined only by the resulting cost of the end-product. It can usually be taken for granted in these countries that the intermediate products in the intervening chain of processes will be manufactured on a scale that is economical. This contrasts sharply with the position in nearly all developing countries, where the most important consideration is often how to achieve an adequate scale of production for every link in the processing chain. An essential function of an indigenous research and development establishment is to explore the technological possibilities and in the course of time raise the technical efficiency of the processing route, subject to the constraints imposed by problems of scale at every step. A technological route that has become standard practice in highly industrialized countries and gives the lowest cost for high-volume production will often be far more costly than another processing route when used at the scale required in a developing country. Yet the non-standard route may not be devised and proposed unless a local research and development establishment exists which has the professional competence to complete the necessary studies.

It does not require a very advanced degree of technical knowledge to put forward hypothetical processing routes and get them to work in a chemical laboratory. The lengthy and expensive development process is to translate such routes from a bench scale to a commercial scale of operation. The conversion ratio in chemical reactions has to be maximized by painstaking experiments in regard to pressure, temperature and the concentration of auxiliary chemicals. At the same time, the cost of specialized process equipment must be kept as low as possible. The research and development effort in the industrial countries cannot be geared to the needs of marginal customers in the developing countries if these differ significantly from those of the principal customers who, inevitably, are operating in industrialized countries. The specialized needs of developing countries, as regards the intrinsic nature of the transformation processes used, may thus fail to be taken into account in the custom-designed process plants prepared by engineering firms in the industrialized countries. The custom design may extend only to the proper dimensioning and interconnexion of the process equipment for the scale of production envisaged.

Although there are great advantages to be derived from the work of an indigenous research and development establishment, it has to be recognized that there are formidable difficulties in setting up such an organization. The chemical industry occupies third place in the United States after the aerospace and electronics industries in the proportion of sales revenue allocated to research and development expenditure (4 per cent); 3.3 per cent of all employees in the industry are professionally qualified people engaged in research and development, and the proportion is doubled if auxiliary personnel are added.[25] These statistics give a rough idea of the level of operations that a developing country would need to mount. On the one hand, it would not embark on research in some areas that absorb large expenditures in the United States; on the other hand, the revenue from which research and development must be financed expands in the United States largely through sales of the new products created, whereas the potential for such expansion may be more limited in a developing country. International co-operation between developing countries for the purpose of sharing the very heavy burden of research and development work in chemical technology and chemical engineering would be highly advantageous. The possibilities are worth pursuing even when the prospects of integrating manufacture for a common market are not encouraging.

In practice, of course, the choice is not limited to the two extremes of a fully imported or fully indigenous chemical technology. The various compromise measures include the purchase of patents and licensing of individual processes, the custom design of manufacturing plants by foreign engineering firms, joint ventures between foreign and domestic manufacturing enterprises, and direct foreign investments. Each of these means of importing technology can be combined with a certain element of domestically generated technology. Thus, licensing may be restricted to certain critical processing links. Foreign engineering design may be used to complement the work of indigenous engineering firms only in the case of a few processing units with particularly sophisticated technology. The participation of foreign firms in joint ventures or the licensing of direct foreign investments, may readily be made conditional on the kind and intensity of local research and development effort that will be mounted in connexion with the ventures. Some resistance to a provision of this kind is doubtless to be expected, since foreign firms generally

[25] Based on Terleckyu, N. E. and H. J. Halper, *Research and Development, its Growth and Composition*, New York, National Industrial Conference Board, 1963. (Studies in Business Economics Series, No. 82.)

prefer their affiliates in developing countries to make a contribution to centralized research and development work in the home country, rather than engage on the spot in research and development work to improve the efficiency of local operations. The affiliate may be operating in a restricted market protected by high tariffs, in which a lower level of efficiency places it at no disadvantage; the developing country suffers damage, however, to its growth prospects.

FINANCIAL AND PRICING POLICIES

In deciding its financial and pricing policies, a developing country must have regard to the structure of the world market, the extent to which new chemical enterprises can be set up as joint ventures, and the degree to which production is to be oriented towards export.

Structure of the world market

In private enterprise economies a more or less formal network of inter-company relationships tends to be set up between the various chemical enterprises in order to introduce some measure of co-ordination in pricing and investment decisions. The form these relationships take depends on the national legislation that regulates consultation and joint action among competing enterprises. The pressures which bring about this situation are not hard to discover. Because of the strong economies of scale, each investment decision is likely to involve several million dollars—for the production of basic chemicals, 20 to 30 million dollars may well be involved. Moreover, such plants meet a large fraction of the total demand for a given product even in industrialized countries and therefore only a few companies manufacture any given product. This leads to a high degree of concentration in which three or four companies at most may account for over 80 per cent of total sales of a given chemical. Because of the important role of intermediate chemical products, it also follows that a limited number of companies make extensive sales to each other, under conditions requiring assured supplies in large volume and subject to close delivery schedules. This leads to a *de facto* co-ordination of access to markets. Since each new production unit tends to cause a large percentage addition to total existing capacity to manufacture that product, unco-ordinated investment decisions can easily lead to a situation in which there is considerable surplus capacity.

which forces the companies into a price war and may reduce profits to such an extent that it may prove difficult to finance future expansion. This is a prospect that all market participants are anxious to avoid.

A distinction must be made between price reductions arising from the existence of surplus capacity and those that result from "life-cycle pricing" of individual products. This practice, which is common in industries where technological change is rapid, consists of charging relatively high prices initially for newly developed products, in order to write off the research and development expenditure that has been incurred within a relatively short period; as the novelty wears off and know-how for manufacturing these products spreads, prices are gradually reduced. Examples of this phenomenon in the field of plastics, synthetic fibres and the intermediate products from which they are made are widely known, but a similar trend is also to be seen in basic industrial chemicals such as nitric acid, methanol, phenol and acetone.

Where such cartel activities as fixing prices and allocating markets are prevented by law, the tendency is for companies in the chemical industry to engage in forms of competition other than price competition, in particular, by developing improved processes and new products. Chemical technology readily lends itself to such competition, but large and expensive research and development establishments are necessary, which serve further to discourage potential new entrants to the industry. The concentration of chemical production in large powerful enterprises enables this sector to press its views very effectively on the Government concerning such matters as import tariffs or quotas. Finally, it should be pointed out that the consequences of the oligopolistic structure of national chemical industries are felt in international markets where, in the past, allocation agreements have been worked out.

The structure described above gives every appearance of stability but is not completely invulnerable. A successful attack requires both a special situation and enterprises to exploit it whose economic strength is comparable to that of the leading enterprises in the chemical industry. The development of petrochemicals in recent years provided just such a situation and the oil companies were able to make the challenge. They held control of the raw materials, possessed large marketing organizations and well established research and development units in a closely related field of science and engineering. They did not lack financial resources. The result has been a sharp struggle for petrochemical markets, the creation of considerable surplus capacity at certain times, and a fall in the price of several major products.

In the United States, several other non-chemical companies have entered some branches of chemical manufacture. These moves have been part of the recent trend towards diversification and mergers of companies. In spite of this inter-industry competition, chemical markets tend to stabilize rapidly following a period of price competition for a particular product, with a recognition that the newcomer will remain in business as a supplier, and a consequential readjustment of market shares.

A relatively small producer in a developing country is extremely unlikely to be able to penetrate a world market that is articulated in the way just described. The domestic market may of course be protected by tariffs or other means but the possibilities of export are remote, except on the basis of common market arrangements, trade agreements or joint ventures with large international chemical companies.

Joint ventures

The arguments generally put forward in favour of joint ventures in which domestic and foreign interests participate are the following: they enable domestic capital to be invested in developing sectors that it would otherwise be unwilling to enter; they generate a faster transmission of technical and organizational know-how; and they reduce the risk of foreign economic dominance in key industrial sectors.

It can be argued that the total inflow of foreign capital will be greater if there is no insistence on joint ventures, the domestic capital finding other outlets for investment and the economy developing more rapidly. Even where this is true, however, the great economic importance of a faster transmission of know-how in the case of joint ventures is likely to be a more important consideration, especially in the case of the chemical industry. The seriousness of the risk of foreign economic dominance cannot be judged in isolation from the political and social conditions in a given country.

For their part, private enterprises in the developed market economies seem increasingly disposed to adopt joint ventures in the developing countries rather than wholly owned subsidiaries. Relations with the government, employees and the general public are likely to be better in the case of joint ventures. Locally recruited managers bring a deeper knowledge of local conditions especially as regards sales and marketing. In some developing countries some joint ventures will also obtain more favourable fiscal treatment than foreign-owned subsidiaries.

Degree of export orientation

Chemical production may be established primarily for import substitution or with a more ambitious goal that includes export promotion and the basic government policies are likely to vary accordingly. In the first case the new enterprise is likely to be protected by tariffs that raise internal prices above world market prices, thus making it more likely that future expansion can be financed out of retained profits. In the second case, the implication is that domestic prices will be kept at the level of world market prices (except when export subsidies are employed or exports are negotiated in bilateral trade agreements). Self-financed expansion is then much harder to achieve. There have been many instances in the past of this conflict between self-financing and export promotion, particularly in the case of enterprises operated or controlled by the state.

In the case of joint ventures, the issue of export orientation is often adversely decided in advance. The foreign partner may make it a condition that the joint venture shall not export to third countries served by its home operations or by its associated companies set up in those countries.

Chapter 4

THE INTERNATIONAL SYMPOSIUM ON INDUSTRIAL DEVELOPMENT: ISSUES, DISCUSSION AND RECOMMENDATIONS

The issues, the discussion and the recommendations approved by the Symposium are presented in this chapter.

THE ISSUES[26]

The chemical industry has been one of the most dynamic sectors in the industrial structure of developing countries. In many countries, investment in this industry is now higher than in any of the other industrial sectors. In view of the strategic importance of the chemical industry in both industrial and agricultural development, the United Nations, together with the regional economic commissions, has recently held a number of international and regional meetings at which the development prospects and investment needs of the chemical industry in the developing countries were discussed.

In most developing countries, the chemical industry is still in the early stages of development. The *per capita* production for most developing countries is less than $10 per year (compared with nearly $200 for North America and over $100 for West European countries). It is essential to find ways and means of promoting an accelerated development of this industry and improving the operational efficiency of existing enterprises.

In view of the wide range of products covered by the chemical industry, the Symposium focused attention on certain selected issues for discussion.

Economies of scale and the need for economic co-operation

Since modern chemical industries are usually capital-intensive and subject to economies of scale, the main problem is how to overcome the restricted size of the current market, especially in the smaller countries.

[26] From Issues for Discussion; Chemical Industry, 1967 (ID/CONF. 1/A. 7) (mimeo.).

The solution may well lie in market-sharing arrangements, whereby the countries of a group would develop complementary ranges of chemical products for sale throughout the whole area. In this way the output of a whole group could form an integrated pattern of a kind that otherwise can be achieved only by large countries.

Chemical complexes

The need to encourage the establishment of chemical complexes has been stressed at several United Nations meetings. Thus, the manufacture of caustic soda by electrolysis is sometimes uneconomic because of the small demand for the by-products, hydrogen and chlorine. If these products can be used by some other chemical enterprise (e.g. in the production of ammonia, insecticides or plastics) the manufacture of caustic soda may become profitable. There are many other instances in the petrochemical field. The authorities in developing countries and chemical companies that operate internationally should pay particular attention to the possibility of establishing chemical complexes rather than a number of scattered small units.

Utilization of unconventional and synthetic materials

Another issue for consideration is the utilization of unconventional and synthetic materials. Even when raw materials are physically available there may be economic and processing difficulties in their utilization, e.g. the necessary machinery and personnel may not be available locally. It has therefore become increasingly urgent to explore alternative sources of supply. Thus, owing to the shortage of sulphur and pyrites, considerable progress has been made in some countries in the production of sulphuric acid from gypsum and anhydrite.

Another example, as recommended by the United Nations Inter-regional Conference on the Development of Petrochemical Industries in Developing Countries (ST/TAO/SER. C/83, p. 6) is the utilization of synthetic materials. The natural products, which these materials can replace, are in short supply in some developing countries, and are sometimes more costly or give an inferior performance in some applications (e.g., synthetic instead of natural rubber or nylon, rayon and other man-made fibres instead of silk, wool and cotton). Plastics are making inroads into the markets for wood, glass, metals and other construction materials. It becomes increasingly important for the developing countries to seek alternative sources for raw materials, to study the production and applications of synthetic substitutes and ways of manufacturing chemical products via unconventional process routes.

Basic inorganic chemicals

The basic inorganic chemicals, such as the acids and alkalis, calcium carbide and chlorine are produced in the developed countries in large quantities at very low cost, owing to the economies of scale. The scope for manufacturing them in the developing countries may therefore appear at first sight to be relatively limited. Developing countries do, however, possess certain advantages. The cost of transport from the present sources of supply in developed countries and the time required for delivery automatically provide an element of protection to a local industry; raw materials are often available locally at low cost; and the availability of cheap labour is also, to some extent, a favourable factor to be taken into account.

The regional symposia on industrial development devoted much attention to the problem of developing the basic chemical industries in these regions. The African Symposium[27] emphasized the need for studies on the availability and possible utilization of raw materials such as pyrites and natural soda ash.

The Asia Conference[28] noted that large resources of rock salt were available in some countries of the region and mentioned the possible utilization of by-products of salt manufacture, such as magnesium salts, potassium chloride and bromine.

The Latin American Symposium[29] referred to studies which had indicated that the market in that region for alkali products of sodium was expanding rapidly and that by 1975 1,060,000 tons of sodium carbonate and 1,050,000 tons of caustic soda would be required. According to these studies reserves of the necessary raw materials at three or four locations in the region were sufficiently large to warrant large-scale production of sodium ash and caustic soda.

Based on actual production in 1964 and known projects for expansion, the total production capacity of basic chemicals in all developing countries is expected to double or even treble by the early 1970's. Estimated production of certain products as a percentage of the 1964 level would be as follows: sulphuric acid 280, ammonia 330, caustic soda 250, chlorine 220, and soda ash 180.

The first step to be taken in order to achieve this expansion is to prepare a full inventory of relevant resources at the national and regional levels. Prospecting for the mineral materials required should also be actively pursued. Technical assistance by the United Nations could play an important part in this effort.

---

[27] Report of the Symposium on Industrial Development in Africa (ID/CONF. 1/R.R. 1) (mimeo.).

[28] Report of the Asian Conference on Industrialization (ID/CONF. 1/R.R. 2) (mimeo.).

[29] Report of the Symposium on Industrial Development in Latin America (ID/CONF. 1/R.R. 3) (mimeo.).

The resurgence of coal as a raw material for chemical production

Processing methods recently developed in some industrialized countries have indicated the possibility of using coal for the production at economic cost of a large number of basic chemicals that are now generally produced from petroleum and natural gas. It is important, therefore, to bring this possibility to the attention of developing countries, especially those with large coal reserves, and to discuss the possibility of technical assistance in this area.

Problems in transfer of technology

Existing technology has been developed almost exclusively in the industrialized countries and is generally transferred by such means as patent and licensing agreements, the sale of appropriate equipment, and training technical personnel. The problems arising in this connexion, particularly in the chemical industry, need to be examined.

Plastics

Plastic materials have already found numerous end-uses in developing countries, particularly in consumer goods, and as components of other goods, construction materials and packaging. Plastics are replacing traditional materials that are more expensive or in short supply, such as wood, glass, natural rubber and many metals. However, insufficient knowledge of the properties and behaviour of plastics has resulted in indiscriminate use and some of the applications have been unsuitable. The chemical industries of the developing countries should study thoroughly the potential uses and also the limitations of plastics with a clear understanding of their properties; they should also strengthen their facilities for testing and quality control and progressively raise the standards of their plastic products.

End-use surveys should be carried out and the possibility examined of collaboration with foreign manufacturers. As recommended by the Symposium on Industrial Development in Africa, UNIDO should assist Governments by organizing surveys and techno-economic studies of the plastics branch of the chemical industry.

In many developing countries the plastics branch is currently integrating backward into the manufacture of polymers, intermediates and monomers from indigenous raw materials. In this connexion, the techno-economic aspects of using materials other than petrochemicals for plastics manufacture should be investigated by countries with large resources of coal and vegetable products.

The major thermoplastics such as polyethylene, PVC and polystyrene, can be produced economically only on a relatively large scale. This implies a correspondingly large market, either at home or abroad. It is improbable that most developing countries will have a sufficiently large domestic demand, at least for some years to come, and the export of a large part of the output would therefore have to be contemplated, despite the highly competitive conditions ruling in the international market. Under these circumstances and unless a particularly favourable raw material position existed, it would be preferable to import the polymers for use by enterprises manufacturing thermoplastic products.

A very different situation exists with regard to thermosetting plastics. The production of the principal thermosetting resins (phenolics, ureas, melamines and polyesters) is usually carried out in batch processes, the unit of production being comparatively small. It is advantageous to prepare these resins close to their point of use, since they tend to harden or cure, once they have been prepared, particularly in hot climates. Thus, it might be economic for a company making resin-bonded chipboard or plywood to set up manufacture of the resin as an adjunct to its main activity, preferably locating the two plants on the same site or nearby. The capital investment in resin manufacture is relatively small, the manufacturing process is relatively simple, and the "know-how" is readily obtainable from foreign manufacturers.

Pharmaceutical products

The present low levels of production and consumption of pharmaceuticals in the developing countries suggest that this branch of the chemical industry has a very considerable potential for development. Once modern medical facilities are introduced, the demand for drugs rises steeply and pharmaceuticals account for a growing share in the total chemical production of the developing countries; from 1960 to 1965 this share rose from 15.8 per cent to 19.6 per cent. Pharmaceutical industries are for the time being limited mainly to formulating active materials imported in bulk. In a number of countries, however, backward integration has begun into the manufacture of active materials from imported intermediates or even into the manufacture of the intermediates themselves.

The African and Asian Symposia dealt extensively with this branch of the chemical industry and the recommendations adopted at the Asian Conference in particular may serve as guidance for specific action. The developing countries are urged to undertake extensive health programmes, surveying the various prevalent diseases and establishing priorities for their treatment and eradication, and to plan the manufacture of pharmaceuticals in relation to these programmes. They are also recommended to survey the raw materials required for pharmaceutical production.

As to the infrastructure, steps should be taken to train the necessary technical personnel such as chemists, pharmacists, pharmacologists and microbiologists. Appropriate laws should be passed and regulations made dealing with the production, imports, distribution and retail sale of drugs. Imports of the necessary capital equipment, instruments, raw materials, and packing materials should be liberalized.

It has also been recommended that in areas where modern medical facilities have not yet been introduced and traditional medicines are widely used, production of medicines should be organized on modern lines, adopting proper methods of standardization. A thorough screening of the traditional medicines might bring to light preparations that could usefully be adopted in modern medicine and permit the ineffective products to be eliminated.

THE DISCUSSION[30]

Economies of scale and regional integration[31]

The problems created by restricted nature of domestic markets and the consequent need to raise the scale of production through international economic integration were particularly emphasized by countries that are attempting to broaden their existing markets for petrochemical and other basic chemical products or contemplate ventures in this field. The countries that would be the buyers of these products under a scheme of economic integration, however, expressed no sense of urgency. It was implicit in the discussion that there could be no important progress in integration until the potential benefits were offered to consuming as well as producing countries.

In this context the existence was cited of bilateral bargains whereby a plant for one product would be located in country A in exchange for agreement to locate a plant for another product in country B. Other countries in the region, however, with abundant hydrocarbon resources seemed to be planning the expansion of their petrochemical industries more with a view to exports in general than regional integration. It needs to be recognized however, that a reasonable bargain about the location of production units may result in opening up export markets for petrochemicals within a region that could not otherwise be entered. If the comparative advantage of the chemical industry in a given country is so

[30] From *Report of the International Symposium on Industrial Development, Athens 1967* (ID/11) (United Nations publication, Sales No.: 69.II.B.7).

[31] Monograph No. 18 in this series deals with regional co-operation in industry.

great that a bilateral bargain with another country would obviously be inefficient, this would indicate that regional integration could not take place on the basis of the chemical industries in isolation and that other industrial sectors must be brought into the planning in order to balance the advantages among the participating countries.

As an example of the benefits that could accrue from regional development of natural resources, methane in Lake Kivu was mentioned. Burundi, the Democratic Republic of the Congo, Rwanda and Uganda could benefit from UNIDO assistance in planning and developing the resources of this region to generate power and manufacture fertilizers and various chemicals. They also needed assistance in exploiting other resources (e.g. haematite ore in Uganda) through the application of new processing techniques.

A review in depth was particularly necessary for potential projects in the developing regions that might be sponsored by more than one country, projects that would benefit from economies of scale and could command a regional market. It was stated that six countries of South America had negotiated a scheme for the integration of their market for petrochemicals. Plants for the production of 22 petrochemicals would be established in various countries under multi-national ownership with access guaranteed to the combined market. In this connexion, it was pointed out that forward integration from petrochemicals to plastics (polyethylene, PVC and polystyrene) would yield similar benefits from regional co-operation and the integration of markets. Another specific instance where regional arrangements might be encouraged with the assistance of UNIDO was in the utilization of by-products, for example in finding markets for surplus quantities of chlorine arising from the production of caustic soda.

The suggestion was also made that careful study was needed to determine the optimum size of plant to install in a given country, since this was affected by the future growth rate as well as the initial size of the market. Two small units installed at an interval of three or four years could be more profitable than one large unit installed at the outset. Apart from requiring a smaller initial investment, this alternative gave a better average utilization of production capacity, a smaller loss of output due to plant shutdowns, and the possibility of taking advantage of any technical breakthrough that occurred before the second small unit needed to be ordered.

Comment on specific products

The use of coal as a source of synthetic organic chemicals, particularly by developing countries, where coal was abundant and petroleum or natural gas would have to be imported, aroused considerable interest. Detailed economic and technical studies should be undertaken, drawing on the wide practical experience of the industrialized countries. UNIDO should help to organize technical assistance in preparing the necessary studies and in evaluating the possibilities of developing these carbochemicals in individual countries.

Problems connected with rubber production interested many developing countries either as producers of the natural product or would-be producers of the synthetic products. The former group was particularly concerned with the social and economic importance of this activity in their economies and appealed to major consumers to take this factor into account when deciding their purchases of natural and synthetic products. They suggested that the problem might be carefully studied in consultation with the International Rubber Study Group. It was pointed out that UNIDO could also assist such countries to develop techniques of transforming natural rubber into other chemical products.

On the other hand the developing countries that do not produce natural rubber are in many cases anxious to establish the production of synthetic rubber, particularly as part of a petrochemical complex. These countries may benefit from UNIDO's assistance in supplying all available information about the most up-to-date processes.

More generally, it was thought that priority should be given to promoting the development of specific branches of the chemical industries in which the majority of the products manufactured have either backward or forward linkages to the agricultural sector of the economy. It was pointed out that this action would benefit not only agriculture but also certain branches of other industrial sectors, such as the metallurgical industry, where development was dependent on the availability of some basic chemical products.

Another aspect stressed was the linkages to some branches of consumer industries already established in developing countries, such as edible oils, soap and detergents, and textiles. There was also comment regarding the problems posed by the shortage of sulphur that was being experienced at the time of the Symposium.

The role of governments

It was emphasized that experience showed the necessity for Governments to play a positive role in planning and establishing chemical industry complexes in the developing countries.

A supervisory company or board was suggested, consisting of representatives from both government and private enterprise, as an institutional device to deal with the complicated mechanics of setting up this industry. Such a company or board would not own any of the capital employed in the industry, but would co-ordinate investment policy at the national level, setting priorities and making other policy recommendations to the Government. Emphasis was also laid on the creation of an appropriate legislative framework to encourage and protect investment by foreign enterprises and to offer incentives for the location of manufacture in regions other than the metropolitan area, which so often attracted an undue proportion of industrial projects. It was suggested that the Government should be involved mainly in setting objectives rather than in detailed responsibility for design, implementation and operation.

Joint ventures with foreign companies were an important means of financing big chemical and petrochemical projects in developing countries, where the shortage of investment capital and the lack of know how were sometimes acute. It was hoped, therefore, that the developed countries would urge their large chemical and petrochemical companies to expand this type of venture. In regard to such matters as licence and royalty fees, engineering fees and employment conditions for foreign personnel, the terms proposed would have to take account of conditions in the developing countries. It was also suggested that UNIDO should assist the developing countries in their search for foreign partners for such ventures.

The key role of the Government was not regarded as open to doubt and the discussion centred on the types of institution through which this role should be exercised. Apart from those already mentioned, strong emphasis was placed on institutions concerned with technological progress and training.

Technological progress and transfer of technology and skills

Case histories based on European experience were presented in order to show how a country capable of generating its own technology can adapt to the changing availability of various raw materials.

The key role of technology and training in the viability of a chemical industry was repeatedly emphasized. The rapid change brought about by constant improvement of processes under the pressure of market requirements and the activities of competitors brought about changes in the machinery and equipment used and caused their rapid obsolescence. It was considered advisable to organize research and development facilities as well as the training of engineers while chemical plants were under construction.

The problem of training skilled manpower varied considerably from one developing country to another. In some countries that had only recently gained their independence, it proved difficult to get the needed management skills without competing with the local civil service; in those cases, it was suggested that the solution would be to select appropriate candidates and send them to a university course in a developed country, to be followed by on-the-job training in that country. Even where initial operations were limited to the distribution of imported chemical products, it was felt that an adequate number of people should be highly trained in market development and technical services; only close contact with the technical problems of customers and potential customers would ensure that the market developed on sound lines.

It was regarded as being of the highest importance that local cadres should participate at all stages of developing this industrial sector, from the initial planning and detailed preparation of individual projects to operating the manufacturing units and progressively raising their productive efficiency. Mixed working groups were the best means of transmitting practical experience. In negotiating the terms on which a joint venture should be set up, a developing country should always bear in mind that such transfer of skills and technology was probably the most important long-term benefit to be gained.

The Symposium emphasized the need to improve the collection, dissemination and use of statistics relating to the chemical industries of the developing countries in order to facilitate the studies and establish development programmes. UNIDO had an important role to play in this respect, in close co-operation with other organizations concerned with these matters, especially the OECD and the United Nations regional economic commissions.

Recognizing that technical documentation was an essential element of technological know-how, the Symposium laid stress on the value of organizing its dissemination in the developing countries, while accepting that inventions must be adequately protected by suitable legislation.

RECOMMENDATIONS APPROVED[32]

UNIDO and UNDP should render assistance to the developing countries in establishing, where appropriate, demonstration plants utilizing improved or alternative methods of production of basic chemicals and petrochemicals.

UNIDO should examine and make available to developing countries the studies on carbo-chemistry and, if appropriate in the light of this examination, convene a group of experts to examine cases where carbochemicals based on coal could well be valuable.

UNIDO, in consultation with the International Rubber Study Group, should study the problems of the natural rubber and synthetic rubber industries and develop appropriate recommendations for technical assistance to both natural rubber producing countries and developing countries possessing petroleum and/or natural gas resources and desirous of developing a synthetic rubber industry.

UNIDO should assist the developing countries, on request, in encouraging the participation of foreign companies in their petrochemical industries. Such assistance should be aimed at promoting arrangements for the sharing of technological know-how and managerial skills, and the utilization of marketing and distribution facilities of the foreign chemical companies which may already be established in the export markets.

UNIDO, in co-operation with the UN regional economic commissions, should render technical assistance in the establishment of regional industrial projects for the benefit of more than a single country in a developing region, profiting by the advantages accruing from economies of scale and larger regional markets.

UNIDO should give priority of technical assistance to developing specific branches of the chemical and petrochemical industries in developing countries, linked to their agricultural production.

UNIDO, in co-operation with the ILO, should expand its activities for the training of technical and managerial personnel for the chemical and petrochemical industries in developing countries, and where appropriate, promote in-plant training programmes both in industrially advanced countries and developing countries.

UNIDO should render assistance to the developing countries in the transfer of technology, without prejudice to patent rights, and assistance in facilitating arrangements for bilateral or international credit.

---

[32] From *Report of the International Symposium on Industrial Development, Athens 1967* (ID/11) (United Nations publication, Sales No.: 69.II.B.7).

UNIDO should undertake to promote the dissemination of information to enable both developing countries and industrially advanced countries to exchange information on potential projects in the basic chemical and petrochemical industries and should also encourage the dissemination of technical and economic documentation of mutual interest to these countries with regard to these industry sectors.

UNITED NATIONS ACTION AND OTHER ACTIONS TO PROMOTE THE DEVELOPMENT OF THE CHEMICAL INDUSTRY[33]

As in other industrial sectors, the activities of UNIDO connected with the chemical industry are partly concerned with operations in the field and in part consist of supporting activities. The latter include symposia, seminars, workshops and expert group meetings; in-plant training; and the preparation of publications dealing with various aspects of setting up and operating industries in the developing countries. There is a continuous interaction between the two parts of this programme: surveys and reports from the field lead to the preparation of special studies and the organization of meetings to pinpoint the main obstacles to industrial development and establish the lines along which solutions must be sought. Meetings and the publication of their proceedings lead in turn to requests for operations in the field.

Salt, particularly marine salt, obtainable by solar evaporation, is a potential resource of many developing countries and can form the raw material basis for a number of basic chemicals. An Expert Group Meeting on Modernization and Mechanization of Salt Industries based on Sea Water was organized by UNIDO and held in Rome in 1968. The publication of its conclusions and recommendations has already led to a number of requests for technical assistance and over ten projects are already under way.

A number of technical assistance projects have been requested from UNIDO for the establishment of the production of basic chemicals generally. Certain problem areas are seen to be common to many developing countries, particularly the question of scale of production in relation to the size of markets. An interregional seminar on basic chemicals is being organized for 1970, to be held in the USSR. The linkages between

---

[33] Excluding the manufacture of fertilizers, for which see Monograph No. 6: *Fertilizer Industry*.

basic chemical products and a number of industrial sectors will be carefully examined. It is hoped that this seminar will provide guidelines to the developing countries in formulating requests for technical assistance in regard to basic chemicals. It is anticipated that ILO, FAO and the regional economic commissions will participate in the seminar. As a follow-up, it is expected that a survey will be made in a particular region during 1971 to examine the desirability of manufacture on the basis of a regional or sub-regional market, in view of the effects of economy of scale.

The second Interregional Symposium on the Development of Petrochemical Industries was organized by UNIDO in Baku, USSR, in October 1969; the first had taken place in Tehran in 1964. In planning the symposium at Baku extensive use was made of experience gained in various field projects. In the field of petrochemicals, UNIDO's action has been especially linked to the requirements for production of plastics, man-made fibres and synthetic rubber. The need has also been shown for in-plant training in the repair and maintenance of machinery and equipment for the production of petrochemicals. The future programme is expected to include studies of the production of proteins from petroleum raw material.

During the period 1967 to 1969, UNIDO provided technical assistance to several countries for the evaluation of possibilities to develop the production of essential oils. In view of the high cost of transport to overseas markets in relation to the price of the bulk materials, several developing countries plan to improve their position by extending the processing into semi-finished or finished products. Investigations have already shown the need to assess the impact of synthetic substitute materials, to distinguish the different qualities of natural essential oils required by different markets and to solve some problems of processing and packaging.

At the other end of the chain of processing, UNIDO is engaged in a number of technical assistance projects relating to pharmaceuticals. Activities in this field are expected to grow steadily and work is being co-ordinated with WHO. In most developing countries it is desirable to start with small packaging operations and develop gradually the more sophisticated activities of raw material preparation and product testing. An expert group which met in Budapest in 1969, in which representatives of WHO and FAO participated, pointed out that there were important economies of scale at these later stages and suggested that consideration should be given to the possibility of pharmaceutical production on a sub-regional basis. Furthermore, it was essential to establish appropriate legislation controlling the purity of pharmaceutical formulation and to ensure the training of sufficient qualified pharmacists to render these controls effective. UNIDO is giving increasing attention to the linkages between the manufacture of pharmaceuticals, medical supplies and equipments. A pharmacological institute already established in one developing country may serve as a model for other similar projects.

The manufacture of industrial products by fermentation is also receiving attention. The non-food applications of the fermentation processes include organic acids, glycerine and antibiotics. These activities are particularly well suited to many developing countries because the required equipment can be simple in design and construction and also relatively inexpensive, while the agricultural or waste products needed as raw materials are usually available within the country. An Expert Working Group met in Vienna in 1969 to study this subject and *inter alia*, reviewed the results of technical assistance projects now in progress. It was stressed that some industrial products obtainable through fermentation can be manufactured more cheaply by a petrochemical industry and any decision to manufacture such products by fermentation would seem to imply a permanent protection by import duties against competition from petrochemicals.

The UNIDO programme for development of the chemical industry is financed under various United Nations operational programmes in which UNIDO participates. These are: the Regular Programme of technical assistance devoted to industry, the funds for which are drawn from the United Nations budget (RP); the Special Fund component of the United Nations Development Programme UNDP/SF); and the Technical Assistance component of the United Nations Development Programme (UNDP/TA). UNIDO receives, in addition, voluntary contributions from Governments for the financing of the Special Industrial Services Programme (SIS), a programme limited mainly to urgent short-term missions. Some projects may also be financed from funds in trust, deposited by Governments for specific projects, or other direct voluntary contributions. In all these programmes assistance is given only at the request of the Government concerned. Annex 1 contains a selection of the major technical assistance projects with which UNIDO has been concerned since its establishment in 1967.

Basic general approaches

Apart from technical assistance in specific branches of the chemical industry there are various types of project that embody a general approach. Projects are in operation in some of these areas, while other areas might form the object of future UNIDO activities.

Consultant and trouble-shooting groups

The organization of consultant and trouble-shooting groups, that could be made available upon request for limited periods at very short notice, would respond to the complaint by some developing countries that international technical assistance is not made available quickly enough in those cases where its whole value depends on the speed with which it is given. The main functions of such groups would be:

Advising Governments on selection and submission of projects for technical assistance;

Assisting governmental and other organizations in developing countries in the negotiation of technical aid agreements and licensing agreements with enterprises or institutions in industrially advanced countries;

Assisting Governments of developing countries in the negotiation of regional co-operation and integration agreements amongst each other;

Emergency technical and managerial trouble-shooting.

The periods of assignment of such groups would be kept short as a matter of policy and they would avoid involvement in policy making and long-term planning. Individuals or organizations who act as the national counterparts to such short-term international teams could be provided with long-term support in the form of training activities or advice from resident technical assistance experts.

Research, development and process engineering

A wide-ranging effort is needed in most developing countries to establish a reasonable degree of technological independence in the chemical industries. Because of the significant economies of scale that characterize chemical research, development and process engineering, it is unlikely that these functions can be successfully undertaken except in close association with large-scale production facilities of a technically advanced nature. The following appear to be the desirable lines of further action:

To establish chemical research, development and process engineering institutions located at the sites of the largest available petrochemical or other chemical complexes, closely integrated with the production activities of these complexes—common international institutions serving a region or sub-region are likely to be the most efficient solution where this can be arranged;

To associate these institutions with the major universities offering professional training in chemistry, chemical engineering and process equipment design—likewise on a regional or sub-regional basis if possible;

To commit these institutions to the task of devising technological changes (new techniques and adaptations) that will benefit the chemical industry of the country or group of countries; and to make them responsible for transmitting full details of these changes to the manufacturing enterprises as quickly as possible;

To emphasize the role of domestic engineering enterprises in supplying a growing proportion of the equipment required for new chemical projects, expansion and replacements, stimulating those technological adaptations that are geared to the capabilities of the engineering sector.

Annex 1

UNIDO ASSISTANCE IN DEVELOPING CHEMICAL INDUSTRIES

A. Areas relating to the development of the chemical industry in which UNIDO is in a position to provide technical assistance

Feasibility and pre-investment studies;

Establishment of various sectors of the pharmaceutical industry;

Assistance in establishing sectors of pulp and paper industry;

Assistance in the use of natural products as sources of basic chemicals;

Use of fermentation principles as viable industrial sources of basic chemicals;

Production of solar salt and production of basic chemicals from salt;

Evaluation of inland brines and minerals as source of chemicals;

Establishment of petrochemical complexes;

Improvement in petrochemical processes using up-to-date technology;

Utilization of domestic raw materials, petroleum, natural gas and natural products in combination with petrochemicals;

Production of protein from petroleum and natural gas;

Improvement in fabrication of plastics, synthetic fibres and synthetic rubbers;

Assistance in the application of plastics in agriculture, building, packaging and engineering industries;

Market evaluations;

Assistance in quality control, testing and standards.

B. Selected major technical assistance projects

The projects listed below relate to the activities of the United Nations Industrial Development Organization since its establishment in 1967. The list excludes projects carried out under the predecessor organization of UNIDO (the former Division of Industrial Development up to 1962 and the Centre for Industrial Development up to 1967). Since the projects are listed for illustrative purposes, the names of countries have been omitted. The respective programmes under which the projects are implemented are shown as:

SIS	Special Industrial Services of UNIDO
UNDP/TA	United Nations Development Programme, Technical Assistance Component
UNDP/SF	United Nations Development Programme, Special Fund Component
RP	Regular Programme

(1) *Projects implemented or under implementation by UNIDO in areas related to the development of the chemical industry*

AFRICA

The establishment of pharmaceutical manufacturing industry (SIS)
Utilization of inland brines for the production of basic chemicals (SIS)
Establishment of essential oils industry (SIS)
Pre-investment studies in the use of natural gas (UNDP/SF)
Utilization of natural gas (UNDP/TA)
Establishment of pharmaceutical industry sectors (SIS)
Production of essential oils (SIS)
Production of solar salt (SIS)
Production of potash (SIS)
Marketability of basic chemicals (SIS)
Pharmaceutical advice to study centres (SIS)

THE AMERICAS

Advisory services on the production of soda ash (SIS)
Production of caustic soda and chlorine (SIS)
Production of chemicals from furfural (SIS)
The production of salt from seawater (SIS)
The manufacture of essential oils (SIS)
Application of plastics in agriculture (SIS)
Production of PVC and polyethylene (SIS)
Advice on petrochemical policy (SIS)
Selection of petrochemical products for export (SIS)

The application of plastics for the building and packaging industries (SIS)

Establishment of plastics technology centre (UNDP/SF)

Production of solar salt (SIS)

EUROPE AND THE MIDDLE EAST

Rehabilitation of solar salt industry (SIS)

Advice on and industrial utilization of sodium chloride from rock salt (SIS)

Advice and planning on a pharmaceutical industry (SIS)

Advice and planning a chemical complex based on salt (SIS)

Production of unsaturated polyesters (SIS)

Advice on polymer technology (UNDP/SF)

A study on catalytic reactions (UNDP/TA)

Advice on calculation of petrochemical processes (UNDP/TA)

Production of solar salt (SIS)

Chemical complex based on salt (SIS)

ASIA AND THE FAR EAST

Development of salt-based industries (SIS)

Advice on the production of caustic soda and chlorine from natural resources (SIS)

Advice on the development of basic chemical industries (SIS)

Advice on industrial fermentation (SIS)

Improvement in quality of synthetic fibres (SIS)

Establishment of Plastics Technical Service Centre (SIS)

Production of synthetic adhesives (SIS)

Production of dyestuffs (UNDP/TA)

Production of synthetic polymers for application in the leather industry (RP)

Advice on techniques of polymer chemistry (SIS)

Establishment of pharmaceutical industries (SIS)

Disposal of industrial effluents and trade wastes (SIS)

(2) *Projects in preparation or under discussion with Governments in areas related to the development of the chemical industry*

AFRICA

Assistance in plastics fabrication (SIS)
Advice on the development of petrochemical industries (SIS)

THE AMERICAS

Assistance in planning for petrochemical industries (SIS)
Essential oil production (SIS)
Establishment of pharmaceutical industry sectors (SIS)
Quality control and testing of plastics (SIS)
Training of technicians for the plastics fabrication industry (SIS)
Production of solar salt (UNDP/SF)

ASIA AND THE FAR EAST

Establishment of pharmaceutical industries (SIS)
Establishment of synthetic fibre industries (SIS)
Demonstration plant for the production of plastics-wood products (UNDP/SF)
Assistance to plastics processing industries (SIS)
Demonstration plant for the production of synthetic fibres (UNDP/SF)
Utilization of waste products as sources of chemicals (SIS)

EUROPE AND THE MIDDLE EAST

Improvement in technology of polymer manufacture (SIS)
Establishment of petrochemical industries (SIS)
Natural gas development (SIS)

Annex 2

MEETINGS, SYMPOSIA AND WORKING GROUPS ORGANIZED BY UNIDO OR BY THE UNITED NATIONS PRIOR TO THE INCEPTION OF UNIDO

	Location	*Date of meeting*
United Nations Interregional Conference on the Development of Petrochemical Industries in Developing Countries	Tehran	November 1964
Expert Group Meeting on Modernization and Mechanization of Salt Industries based on Sea Water	Rome	September 1968
Expert Group Meeting on Development of Plastics (polymer) Industries in Developing Countries	Vienna	November 1968
Preparatory Meeting for the Second Interregional Symposium on Petrochemicals	Vienna	November 1968
Expert Group Meeting on Establishment of Pharmaceutical Industries in Developing Countries	Budapest	May 1969
Interregional Symposium on Development of the Petrochemical Industries	Baku	October 1969
Expert Working Group on Manufacture of Chemicals by Fermentation Processes	Vienna	December 1969
		Proposed dates
Interregional Seminar on Basic Chemicals	USSR	1970
Expert Group Meeting on Future Trends and Competition between Natural and Synthetic Rubber	London	1971
Seminar on Man-made Fibres	Latin America	1971
Expert Group Meeting on Use of Plastics in Agriculture		1971
Expert Group Meeting on Manufacture of Proteins from Hydrocarbons		1971
Expert Group Meeting on Essential Oils		1971

Annex 3

SELECTED LIST OF DOCUMENTS AND PUBLICATIONS ON THE CHEMICAL INDUSTRY[1]

UNITED NATIONS

CENTRE FOR INDUSTRIAL DEVELOPMENT (PREDECESSOR OF UNIDO)

Studies in Economics of Industry, No. 1, Cement/Nitrogenous Fertilizers Based on Natural Gas (ST/ECA/75) (Sales No.: 63.II.B.3).

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

"Preliminary Bibliography for Industrial Development Programming—Part II. Chemical and Related Industries", *Industrialization and Productivity* Bulletin No. 6, pp. 67—77 (ID/SER. A/6) (Sales No.: 63.II.B.1).

"Programming Data Summary for the Chemical Industry", by T. Vietorisz, *Industrialization and Productivity* Bulletin No. 10, pp. 7—56 (ID/SER. A/10) (Sales No.: 66.II.B.8).

Techniques of Sectoral Economic Planning: The Chemical Industries, Industrial Planning and Programming Series, No. 1 (ST/CID/14) (Sales No.: 66.II.B.17).

Studies in Petrochemicals, 2 vols. (ST/CID—4) (Sales No.: 67.II.B.2).

Profiles of Manufacturing Establishments, 2 vols., Industrial Planning and Programming Series, Nos. 4 and 5 (ID/SER. E/4 and ID/SER. E/5) (Sales Nos.: 67.II.B.17 and 68.II.B.13).

The Brazilian Synthetic Polymer Industry, Petrochemical Industry Series, No. 1 (ID/SER. J/1) (Sales No.: 69.II.B.13).

Studies in the Development of Plastics Industries, Petrochemical Industry Series No. 4 (ID/SER. J/4) (Sales No.: 69.II.B.25).

Establishing Standardization of Plastics in Developing Countries, Petrochemical Industry Series No. 5 (ID/SER. J/5) (Sales No.: 69.II.B.27).

---

[1] Symbols and Sales Numbers of United Nations documents and publications are given in parentheses after the titles.

Selection of Projects and Production Processes for Basic and Intermediate Petrochemicals in Developing Countries. Petrochemical Industry Series, No. 2 (ID/SER. J/2) (Sales No.: 69.II.B.28).

Studies in Plastics Fabrication and Application, Petrochemical Industry Series. No. 3 (ID/SER. J/3) (Sales No.: 69.II.B.32).

Modernization and Mechanization of Salt Industries Based on Seawater in Developing Countries, 1969 (ID/26).

Proceedings of the Expert Working Group Meeting on the Establishment of Pharmaceutical Industries in Developing Countries, held in Budapest from 4 to 5 May, 1969 (ID/35).

Sectoral Studies prepared for the Symposium: Chemical Industry, May 1967 (ID/CONF. 1/25) (mimeo.).

Economic Commission for Asia and the Far East

Development Prospects of Basic Chemical and Allied Industries in Asia and the Far East (Sales No.: 64.II.F.9).

Economic Commission for Latin America

La indústria química en América Latina (Sales No.: 64.II.G.7).

OTHER SOURCES

Airov, J., *The Location of the Synthetic Fiber Industry*, M.I.T. Press and John Wiley and Sons, New York, 1957, 844 p.

Aries, R. S. and R. D. Newton, *Chemical Engineering Cost Estimation*, McGraw-Hill, New York, 1955.

Backman, J., *Competition in the Chemical Industry*, Manufacturing Chemists Associates, Washington, D.C., May 1964.

Chilton, C.H., "Six/Tenth Factor Applied to Complete Plant Costs", *Chemical Engineering* (New York), No. 57, pp. 112—114, April 1950.

Faith, W. L., D. B. Keyes and R. L. Clark, *Industrial Chemicals*, 2nd ed., John Wiley and Sons, New York, 1957, 844 p.

Isard, W. and E. W. Schooler, *Location Factors in the Petrochemical Industry*, US Government Printing Office, Washington, D.C., 1955.

Isard, W., E. W. Schooler and T. Vietorisz, *Industrial Complex Analysis and Regional Development*, M.I.T. Press and John Wiley and Sons, New York, 1959, 194p.

Manne, A. S., Ed., *Investments for Capacity Expansion—Size, Location and Time Phasing*, M.I.T. Press, Cambridge, Mass., 1967.

Markham, J. W., *The Fertilizer Industry: Study of an Imperfect Market*, Vanderbilt University Press, Nashville, Tenn., 1958, 249 p.

Shreve, R. N., *The Chemical Process Industries*, 2nd ed., McGraw-Hill, New York, 1956, 1004 p.

US State Department, Agency for International Development, *Industry Fact Sheets: Industry Profile*, loose-leaf, periodically revised.

Vietorisz, T. and A. S. Manne, "Chemical Processes, Plant Location and Economies of Scale", in A. S. Manne and H. M. Markowitz, eds., *Studies in Process Analysis: Economy-Wide Production Capabilities* (Cowles Foundation Monograph, No. 18), John Wiley and Sons, New York, 1963, pp. 136—158.

Waddell, R. M., P. M. Ritz, N. J. Dew and M. K. Wood, *Capacity Expansion Planning Factors—Manufacturing Industries*, National Planning Association, Washington, D.C., 1966.

UNIDO MONOGRAPHS ON INDUSTRIALIZATION OF DEVELOPING COUNTRIES: PROBLEMS AND PROSPECTS

No. 1. Non-ferrous metals industry
No. 2. Construction industry
No. 3. Building materials industry
No. 4. Engineering industry
No. 5. Iron and steel industry
No. 6. Fertilizer industry
No. 7. Textile industry
No. 8. Chemical industry
No. 9. Food-processing industry
No. 10. Industrial research
No. 11. Small-scale industry
No. 12. Standardization
No. 13. Industrial information
No. 14. Manpower for industry
No. 15. Administrative machinery
No. 16. Domestic and external financing
No. 17. Industrial planning
No. 18. Regional co-operation in industry
No. 19. Promotion of export-oriented industries
No. 20. General issues of industrial policy
No. 21. Technical co-operation in industry

Printed in Austria — Price: $U.S. 0.50 (or equivalent in other currencies) — United Nations publication

69-3346—July 1970—4,500 — Sales No.: E. 69. II. B. 39, Vol. 8

ID/40,8

74. 10. 7