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PROGRESS REPORT ON THE WORK OF THE SECRETARIAT IN CONNEXION WITH THE CHEMICAL INDUSTRY IN LATIN AMERICA

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I. GENERAL BACKGROUND

On more than one occasion, the secretariat has been instructed by the Commission to undertake research with a view to shedding further light on the development and prospects of the chemical industry in Latin America.[1/] The Commission's interest was justified, not only because this is an important branch of the manufacturing industry - and also one of those which have displayed very dynamic growth in recent years - but also because imports of chemicals carry great weight in the regional balance of payments. It has become all the more necessary to obtain more detailed information on this subject because of the increased importance which the chemical industries will doubtless assume in the process of establishing and consolidating a Latin American common market.

The secretariat's efforts in this direction have partially taken shape during the last two years as a result of the work done by a joint group composed of ECLA officials, personnel from the Chilean Development Corporation (Corporación de Fomento de la Producción - CORFO) and representatives of the United Nations Technical Assistance Administration.[2/] So far the initial draft of a comprehensive report covering all the most important aspects of the problem has been prepared.

In spite of the broad scope of this provisional document, it was felt unwise to submit it now for various reasons. Firstly, at this initial stage of the inquiry, the problem has been viewed - partly because of the actual composition of the joint group entrusted with the task - from the particular standpoint of Chile. This does not mean that research has been confined to this country alone. On the contrary, practically equal weight

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1/ See particularly ECLA resolutions 59 (V) of 24 April 1953 and 97 (VI) of 15 September 1955.

2/ The project was begun as part of the research programme of the ECLA/TAA economic development training course and then continued as a joint undertaking of the organizations mentioned. The contribution of the Chilean Development Corporation was particularly valuable because a number of its professional staff took part on a permanent basis and at a high level of responsibility.

/is being

is being given to considerations relating to Argentina, Brazil, Chile, Mexico and Venezuela. Partial references are also made to other Latin American countries. Even so, the selection of Chile as the starting-point may exert some influence on such matters as the choice of products so far included. Specific items or processes of greater interest to other countries of the region may perhaps have been omitted.3/ Secondly, an inquiry of this kind cannot be expected to arrive at more or less final conclusions unless close contact is maintained with the specific problems and backgrounds of the different countries. Hence, the first report must be carefully revised as soon as the information and data used can be supplemented by additional on-the-spot inquiries.

This report is intended to give a very general idea of the purport of the preliminary inquiry with particular emphasis on those provisional conclusions which emerge as regards the region as a whole and on the methods to be used in tackling the problem. The comparative advantages of certain specific locations in Latin America are not dealt with in great detail because the conclusions on this point might be further modified as a result of further research. The discussion of this kind of problem will be one of the most important aims of the final study.

II. SOME FIGURES WHICH ILLUSTRATE THE MAGNITUDE OF THE PROBLEM

As it exists at present, the Latin American chemical industry is concentrated mainly on the manufacture of traditional consumer goods - toiletries, soaps, matches, oils and fats - and has done little to develop its output of intermediate products. However, besides the long-standing demand for consumer goods placed on the chemical industry, there is now a demand for plastic materials and synthetic fibres on a scale which is not only large in absolute terms but which is also growing very rapidly.

3/ The initial phase covered 46 items chosen from an original list of 89, considered in the United States as the most important, on the grounds that, at first sight, they seemed to require scales of economic production likely to be attained in Latin America. Of the 46, 22 are end products (plastic resins, synthetic fibres, alkalis, detergents, rubber, fertilizers, etc.) and 24 intermediate products used in their manufacture.

/There is

There is too an increasing demand for chemicals for agriculture, such as synthetic fertilizers, insecticides and fungicides. At the same time, industrialization is giving rise to a strong demand for intermediate chemical products. The motor-vehicle and tyre industry requires synthetic rubber and lampblack; the textile industry consumes growing quantities of detergents; the metal transforming industry needs abrasives; mining involves the use of explosives; and, as a result of general economic development, the demand for alkalis and basic acids is rising rapidly.

The growing demand for chemical products such as plastics, fibres, fertilizers and intermediate materials for industrial and mining purposes implies that the chemical industry itself will have to meet numerous requirements for "heavy" chemicals such as alkalis and basic acids; aromatic products like benzene, toluene and xylene; basic petrochemicals like ethylene, propylene, butylene and acetylene; carbochemicals like cresols, naphthalene, etc.; and products of synthesis like ammonia and methanol.

It is therefore hardly surprising that a tentative estimate of the demand for chemical products in a few years' time gives a remarkably high figure. Indeed, it may be reckoned that towards 1965 the total demand for chemical products in the region will amount to some 4,500 million dollars a year and by 1975 to more than 8,200.

The 46 products chosen in the initial stage of the inquiry represent only 25 per cent of the total demand for chemicals in the region. Even so, if an attempt were made to satisfy surplus requirements[4/] with imports from outside Latin America, it would mean an annual outflow of foreign currency of between 550 million and 600 million dollars. Yet, this large sum would not cover such important items as potassium fertilizers, explosives, many dissolvents, anti-detonants, numerous salts and a wide range of costly pharmaceutical products (most antibiotics, hormones and vitamins). Their inclusion would boost total import requirements to some 1,000 million dollars a year.

4/ These are obtained by deducting from the consumption projected for 1965 the present installed capacity plus certain smaller quantities of chemicals which, it is considered, will still have to be imported because of special quality requirements or very strict specifications.

Of course the complete substitution of these imports would not represent a net saving of foreign exchange of equivalent magnitude but neither would the corresponding deductions be very high. Almost the only outflow of foreign exchange would be for capital charges on plant necessary for import substitution. No deductions would be necessary for imports of raw materials because nearly all of them are available in the region.5/

The figures which have just been quoted suffice to show how big the Latin American market may soon become, and the foreign exchange requirements which would be involved in supplying it from outside if a powerful stimulus is not given to Latin American industry. In contrast to these needs, progress has so far been very limited. True, significant achievements have been made in specific cases - for example, the plastics industry in Brazil and fertilizer output in Mexico - but some more ambitious projects have not yet reached the production stage. This is true of the petrochemical industry in Venezuela. Similar projects in Argentina, Chile, Colombia and other Latin American countries are progressing even more slowly.

The situation as regards the production of alkalis, especially of Solvay soda, is perhaps even worse. The countries of the region import nearly all the sodium carbonate they consume and are only partly self-sufficient in electrolytic soda. As compared with aggregate imports of sodium carbonate into the region, the amounts produced from natural sources in Chile and Mexico are of secondary importance. The Solvay plant in Colombia is also small. After many years of preparation, it is announced that the sodium carbonate plant at Cabo Frio, Brazil, will start operating in 1960. The Chilean project for the establishment of a Solvay plant which will cover the entire domestic consumption of alkalis has taken more than ten years to mature. The production of basic materials for the manufacture of synthetic fibres and schemes for the production of synthetic rubber have generally not passed beyond the preliminary planning stage.

5/ In so far as Brazilian and Venezuelan reserves of phosphoric rock (together with other smaller quantities available in the region) prove inadequate or uneconomic, limited amount at the most would have to be imported.

The manufacture of lampblack within the region has only just been started and is confined to Brazil.

This brief review suggests that considerable difficulties will have to be overcome and long delays faced before new branches of the chemical industry can be established in the countries of the region.

It is therefore all the more necessary to expedite inquiries in order to shed further light on the problem, which will become much more acute in the context of a Latin American common market.

III. CERTAIN BASIC CHARACTERISTICS OF CHEMICAL INDUSTRIES IN GENERAL

At the international level, the chemical industry presents certain very special characteristics which must form the basis of any discussion of its long-term development in Latin America.

Perhaps one of the primary considerations concerns economies of scale. Indeed, it is a well known fact that in the modern chemical industry production costs tend to fall rapidly as plant size increases. The corresponding savings are derived mainly from the reduction in the capital charges connected with production and, to a much lesser extent, from the smaller labour requirements per unit of product.

The less than proportional growth of the initial investment, as compared with the size of the plant, may be illustrated in general terms by stating that - within certain margins - if productive capacity is doubled, the initial investment increases by only 50 per cent; if the former is trebled, the latter tends only to double.[6/] Thus if the plant size is increased, the investment per unit of product declines considerably; hence, capital charges, which is one of the most important items in production costs, are also reduced. Changes in labour costs are governed by a similar law but in this case the saving is not so great because this item usually represents a fraction of total cost much lower than capital charges.

6/ The ratio is in fact somewhat more complex and really comes nearer to an exponential function. Of course, it is not homogeneous and may fluctuate considerably if different processes are compared.

/This high

This high sensitivity to scales of production costs in the chemical industry is extremely important when considering the prospects of the industry in Latin America. It is not merely a question whether one or several separate national markets can become big enough to justify plants of a reasonably economic scale. Indeed, to judge by the preliminary inquiry, several of the products considered would come into this category. Their manufacture might be launched in certain countries even in conditions which would enable them to compete with the present rival sources of supply abroad. However, from a more general viewpoint, large-scale economies which might benefit the region as a whole, as well as opportunities for more rapid development, might thus be lost. At the same time, so far as may be judged from existing conditions, the modification of certain factors now affecting the international market might change evaluations of profitability. These factors will be dealt with at a later stage.

The example of the European chemical industry, where the scales of production are generally lower than in the United States, is often quoted as an argument against the view that the Latin American chemical industry must or ought to be developed on a large production scale often greater than that of any single Latin American national market. However, the European chemical industry has been able to compete in many fields with that of the United States largely because certain plants were established much longer ago. Since they work with equipment that is already amortized, it does not matter that the original investment per unit of installed capacity was greater than the more recent expenditure of their competitors on non-amortized plant. In other cases, subsidies and State protection exert an influence.

While each separate European country represents a much smaller market than that of the United States, the major European countries still constitute considerably larger markets than those of Latin America because they are more populous and have a higher level of per capita income. Moreover, the maintenance and enlargement of existing chemical industries, such as those in Europe, is quite different from the establishment of new industries, which must face keen international competition with world prices based ultimately on production costs in high-capacity or already amortized plant.

/Another factor

Another factor which must be borne in mind is that any modern chemical enterprise requires a level of profitability much higher than is normal in most industrial branches, if it is to extend over the long term or even maintain its market position. The reason is to be found in the highly dynamic character of this industry where production methods and even the nature of the finished article are continually subject to revolutionary changes. As a result acute financial problems arise. In order to cope with these changes, the industry must have a large internal source of capital, which allows the progressive horizontal expansion of established plant and enables it to keep pace with the rapid tempo of technological development. If, for each innovation, the Latin American chemical industry had to await State action and support, or the flow of new capital from other sectors of the economy, it would be foredoomed to failure. It could not possibly compete with the large foreign companies which can develop and improve their industries by continually ploughing back the high profits guaranteed by production costs that are on the average are much lower than world prices.

A clearer idea of the high level of profitability necessary in the chemical industry will be obtained if it is remembered that the industry's price policy is based on the so-called "life cycle pricing" of individual products. When a new article is first marketed, the company producing it enjoys a brief quasi-monopoly. It can therefore charge very high prices, which are normally justified by the need for the rapid amortization of research and initial investment costs. Furthermore, the few commercially very successful products must bear the financial burden of the inevitable failures. However, the initial period in which prices are much higher than production costs is only temporary. Although they are heavily protected by secret processes, patent rights and gradual quality improvements, the large chemical firms make their financial plans on the assumption that prices will have to fall systematically during the later life of the product to a point at which they bear a closer relation to production costs. This is due partly to direct competition from other producers and partly to a commercial strategy of discouraging in advance, by progressive price reductions, the entry of too many additional producers into the market for the new product.

/Given the

Given the structure of world chemical prices and the consequent high profitability of the industry, the importance of cutting costs in the Latin American chemical industry may be realized. This is another problem which will be difficult to solve without the establishment of a common market and the selection of the best localities or countries for this purpose from the point of view of raw material prices and the factors of production.

Moreover, any analysis of the profitability and prospects of the industry in which short-term factors such as current levels of international prices were taken into account side by side with the more fundamental factors would be highly dangerous. At the moment, world chemical prices are generally speaking much higher than production costs in the main United States, European or Japanese firms, because of the policy of "life cycle pricing" followed by the large producers. The effect of this policy is reinforced by the lack of strong competition on the world market, except from time to time in a few special items. In some cases, the high level of world prices might favour the establishment of new chemical industries in Latin America without State protection (or with a lesser degree of it), although their margin of profitability might be moderate. However, it would be very risky to base the future of the Latin American chemical industry on the expectation that the present very vulnerable price level will be maintained. In any prudent evaluation of the prospects of the chemical industries in the region, two factors should be taken into account:

(a) The likelihood of a systematic decline in the prices of newly-introduced products - particularly those of petrochemical origin - as a result of the price policy followed by the large producers;

(b) The real and immediate possibility of a marked fall in the general price level of chemicals as one of the consequences of the formation of the European common market.

With the integration of the European markets, the chemical industry of Europe may well be able to re-equip itself completely, replacing the older and smaller - and hence less economic and efficient - plants with plants as large and economic in operation as those normal in the United States - or more so. In all probability, competition on the world

chemicals market would then become more acute and prices would fall. Obviously, one of the first effects of a chemicals price war between the United States, Europe and Japan would be to jeopardize the national industries of Latin America nurtured by painstaking development schemes. The low degree of protection which would be acceptable on the basis of the present price level would be very difficult to sustain, and given their high production costs and the low world prices, most of the chemical industries based on narrow local markets would be faced with the prospect of dying a lingering death.

/IV. METHODOLOGICAL

IV. METHODOLOGICAL PROBLEMS

A study of the kind in view inevitably raises many methodological problems, which have to be borne in mind since the decisions and criteria adopted may affect the final conclusions of the enquiry, at least so far as the quantitative aspects are concerned. It would therefore seem desirable to explain here in some detail the methodology which has been used in the initial phase of the study and on which subsequent enquiries will be based.

1. Scope of the study

The study seeks to examine the conditions in which the Latin American chemical industries may develop in the future and to consider what countries (and what locations within them) would be best suited to the growth of the basic chemical sectors. This problem is analysed on the assumption that the plans for the establishment of a common market will be brought to a successful conclusion before 1965.

So far, investigations have been confined to Argentina, Brazil, Chile, Mexico and Venezuela, these countries having been selected after a brief preliminary review of the market conditions and natural resources of the region. However, although the demand for chemicals and the supplies and costs of raw materials seem less favourable in the other countries, later research will undoubtedly show that there are also interesting possibilities for developing the chemical industries in Colombia, Cuba and Peru, and perhaps also in Bolivia and other countries.

Apart from this geographical limitation, a restriction was placed from the outset on the number of chemicals to be considered in greater detail. During the first stage, 46 products, chosen from an original list of 89 regarded as the most important in the United States, were studied, from the standpoint of the possibility of economic manufacture. As a basic principle of selection, and in order to ensure that the study of the development of the chemical industry should be made in the light of real possibilities, it was decided to consider only those products for which aggregate demand in Latin America is expected to exceed the minimum economic scales of production by 1965. Since the minimum economic scales

applicable specifically to Latin America can emerge only after the study of the production costs and market prices of each chemical product at the regional level, it was assumed as a first approximation that these minimum scales will be the same in Latin America as in the United States.

The products having been selected, the first task was to study to what extent industries in Latin America would be able to compete with the extra-regional industries - of all of which the United States industries may be regarded as representative. For this purpose, production costs in the five countries studied were calculated and compared with United States prices on a percentage basis. Unfortunately, it was impossible to set actual costs against costs, so that the percentage ratios referred to could be based only on approximate indices of the level of efficiency of the chemical industries within the region as compared with that of the industrial centres outside the region.

Next, an examination was made of the criteria which would have to govern the location of the chemical industry in the event of the establishment of the common market and the abolition of customs restrictions and other impediments to free trade in chemicals. In this respect, it was felt that the basic aim should be to seek geographical areas where costs would be most favourable, or, more exactly, where the greatest possible net profits could be expected. In order to determine where these areas would be located, on the basis of the data available on the costs of the factors of production, freight costs and market prices, "profitability curves" were plotted for each product selected, comparison of these curves indicating what countries would be better equipped within the common market to compete in a given line of production. Profitability is a percentage ratio between profits and necessary investment. The figure for profits is obtained by subtracting (a) the cost of production in a given locality plus the freight charges for transport to the respective market from (b) the international market price plus the costs of transport to the Latin American markets to be supplied from the particular locality. The profitability curve is worked out on the basis of different scales of production which, in their turn, correspond to the aggregate of several or all of the Latin American markets.

/Profitability curves

Profitability curves of this type provide answers to questions such as these: Would local production based solely on the domestic market be able to compete with imports from other regions? What degree of protection would be required? What would be the order of magnitude of the advantages which would be obtained with a higher scale of production based on a common market? Given a common market, what would be the best locations, from the standpoint solely of the calculated margins of profitability, assuming more or less ideal conditions and disregarding other possibly relevant real and institutional factors? Up to now, all that has been attempted along these lines has been to determine the basic and spontaneous trends affecting geographical location, leaving for future studies such factors as the possible survival of certain restrictions on foreign trade between the Latin American countries which might be tolerated in the basic common market agreement; the different regulations relating to foreign capital; the varying taxation or subsidy policies; matters connected with the political climate and social legislation; the complex development of backward areas in certain countries where the establishment of chemical industries would inevitably form part of larger development plans; and many other questions too numerous to mention.

Undoubtedly, these institutional factors will have important - and sometimes unfavourable - effects on the basic trends brought out in this survey, and therefore undoubtedly deserve study. To quote only one specific example, it might be important to consider how the profitability comparisons would have to be modified to take into account the possibility that industries already existing in countries like Brazil and Argentina could be enlarged without perhaps requiring additional investments equal to those necessary for completely new installations, for example, in Chile or Venezuela. But it has so far not been possible to tackle this aspect of the enquiry.

The ideal conditions which, as has been mentioned, were assumed to prevail in order to achieve a high degree of comparability between production costs in the various countries, were that unlimited capital (at specified interest rates) and unlimited foreign currency (at specified exchange rates) would be forthcoming; that the standard of mechanization and operation in the chemical sectors studied and the branches linked with

them would be equivalent to that of the most advanced industries at the international level; and that rail, road and sea transport would be the best available. However, the real situation in all these fields is of great significance, and should therefore be dealt with as fully as possible in subsequent studies.

2. Methodology

The study of the development of the chemical industry has been carried out in the following stages:

(a) Firstly, in the market analysis, the magnitude and diversity of the demand for chemicals within the region and the geographical distribution of the outlets were examined. On the basis of this information, the level and break-down of the demand for the chemicals chosen was projected for the year 1965.

(b) The technological problems connected with the productive processes used for making these chemicals were then analysed, the corresponding manufactures being grouped into industrial complexes in order to allow for the economies of scale obtainable in the production of intermediate chemicals.

(c) On the basis of these technological data, the needs for intermediate products and raw materials corresponding to the projected demand for the final goods considered were worked out.

(d) On the basis of the information obtained on raw material requirements and of a detailed enquiry into their availability in the countries considered, the localities in Latin America likely to be best suited for the establishment of chemical industries were selected.

(e) The next stage was to determine the typical costs of raw materials, services and labour, taking into account the current prices of these inputs and their opportunity costs. At the same time, the market prices of the chemicals studied and the transport costs of raw materials and finished articles were compiled.

(f) Using all this material, an analysis was made of the profitability of the manufacture of the products studied at the locations selected. 7/

7/ In connexion with the comparative study of profitability levels, it should be pointed out that an analysis designed to determine the optimum geographical distribution of production produces slightly different results according to whether it is based on (a) a comparison of costs, which is tantamount to presupposing that the Latin American price structure is determined by the interaction of production costs in the region with world prices or (b) on a comparison of profitability levels calculated exclusively on the basis of the present world price structure. For the purposes of this study, the latter hypothesis was adopted as being simpler and more realistic.

/In the

In the calculation of profitability levels, the crucial problem was to determine the balance between the economies of scale which might be achieved in production costs by increasing the size of plants and the additional freight charges which would be entailed by the geographical extension of markets.

In considering this latter point, it was assumed to start with that the ratio between capital and labour inputs, on the one hand, and plant size, on the other, can be assimilated into a general ratio which may be expressed in the following equation:

$$\frac{L}{L_o} = \left(\frac{E}{E_o}^{f}\right)$$

where L_o is the magnitude of the productive factor on the base scale E_o, L is the magnitude of the labour or capital factor which is to be calculated on the scale E, and f is the empirical exponential coefficient of variation, which may fluctuate numerically between the limits 0 and 1.

The exponential coefficients f being known for each process - on the basis of practical experience in the chemical industry - the economies in capital and labour resulting from any increase in production scales may be measured, always provided that basic information is available on capital and labour inputs for any given plant capacity. These coefficients, together with the technological coefficients relating to the inputs which increase linearly as production rises, must be known in advance and can then be integrated into a kind of input-output model for the chemical industries.

(g) Once the problem of measuring economies of scale has been solved and data relating to linear inputs are available, it is easy to trace the profitability curves. These will reflect the combined effect of such economies - as also the linear costs of production, transport costs and sales prices - as the size of the plant increases and the geographical area supplied by it extends. Of course, the solution of the problems connected with economies of scale and the availability of technological data on linear inputs do not render the compilation of data on the unit

/costs of

costs of raw materials and factors of production and the unit costs of transport of raw materials and finished products any the less essential.

(h) The difficulties of calculating the capital and labour inputs necessary for various plant sizes having been overcome, the problem of estimating many of the costs which depend on these two items, or which may be expressed as percentages of them, may be roughly solved. Following the established practice in several United States chemical industries, costs such as plant maintenance, capital and operating equipment, indirect production costs, general office expenditure, insurance, capital charges and depreciation may be calculated by expressing them as suitable percentages of fixed investment and labour (in which originally only direct labour was included). For the purposes of this study, supervision was reckoned as 10 per cent of direct labour, worked out for all the countries on the basis of direct labour costs in Venezuela, which are the highest in Latin America. In actual fact, this signifies an additional weighting, designed to allow for the shortage of highly qualified staff throughout the region. Plant maintenance was estimated as 4 per cent per year of fixed investment, while capital and operating equipment was taken as 15 per cent of fixed investment. Indirect production costs were calculated as representing 50 per cent of the total of direct labour, supervision, plant maintenance and capital and operating equipment. General office expenditure was reckoned as 10 per cent of the same total used for calculating indirect production costs. In general, depreciation was taken as 15 per cent of fixed investment, except in the manufacture of sodium carbonate, caustic soda, bicalcium phosphate, triple superphosphate and sodium tripolyphosphate, the production costs of which were calculated on the basis of a depreciation rate of only 5 per cent, in view of the technological characteristics of plants of the types in question. The interest rates taken as basis for the calculations were 10 per cent for Venezuela, 15 per cent for Argentina, Brazil and Chile, and 12 per cent for Mexico.

3. Market study

The study of the demand for chemical products was initiated by selecting the main products already mentioned, which satisfactorily characterize the development of the basic industry and of petrochemicals throughout the

/region. Particular

region. Particular attention was given to petrochemicals because they constitute the most dynamic group within the modern chemical industry. Next, the demand for these products was projected, with due regard to the relation between the consumption of chemicals and income, problems of substitution and complementarity, and agricultural needs (fertilizers, insecticides etc.). Finally, the installed productive capacity now existing in the region was subtracted from the demand projections, in order to relate the whole analysis not to total demand but only to that segment of it which cannot be satisfied with present installed capacity. In some cases, certain small deductions were made in addition to allow for the possible need for imports from outside the region because of special requirements as to quality, purity, etc. In this way, the maximum capacities which could be reached by hypothetical projects in the various countries were obtained, and these will serve as the basis for the entire subsequent analysis.

4. Technological data and their organization

Study of the chemical industry being a complex matter, because of such problems as plant integration and competition between alternative processes and raw materials, the empirical data relating to costs must be organized in such a way as to facilitate the frequent repetition of calculations. Such repetition is necessary for various reasons, for example to permit (a) analysis of the effects on costs of different alternative processes, different raw materials or different degrees of integration, and (b) analysis of the effect of partial changes in the cost structure of the productive factors utilized.

To facilitate the alternative computations, the technological elements of the calculation must be differentiated from their economic expressions. For this purpose, the technological data were organized by employing the "activity vector" concept of linear programming. However, the use of vectors is merely an auxiliary method of assembling the material during the present phase. Mathematical techniques of linear programming cannot be applied because such important inputs as capital and labour are not linear. 8/

8/ The exponential functions of these inputs are neither linear nor convex. This gives rise to mathematical difficulties which still have not been solved for a general case. The practical solution followed in this study makes use of the specific mathematical properties of the particular case under review.

/This problem

This problem should be analysed in some detail because it is a fundamental and complex part of the study.

For present purposes, an activity is defined as the basic technological element of the integrated industrial complexes, i.e., a process of chemical transformation with inputs and products (of raw materials and factors) which are easily identificable and unique. Conventionally, it may be represented by a column of figures. For example, the process for producing chlorine may be expressed in the following form:

	Product (+) or input (-)
1. Chlorine (tons)	+ 100
2. Caustic soda (99 per cent) (tons)	+ 113.15
3. Hydrogen (tons)	+ 2.85
4. Salt (tons)	- 170
5. Graphite (tons)	- 0.3
6. Hydrochloric acid (100 per cent) (tons)	- 0.68
7. Mercury (tons)	- 0.02
8. Energy (thousands of kWh)	- 385
9. Steam (tons)	- 120
10. Water (thousands of gallons)	- 358.6

Mathematically, these vectors represent quotients strictly determined between the inputs and products of a specific technical process. It is also assumed that such quotients are constant. When a technical process allows a variable composition of raw materials and a variable distribution of products, the whole series of variations may be expressed by means of an adequate number of vectors of individual activities.

The vector described above includes the break-down of those inputs which expand in a linear direction, 9/ as production grows. In the case of chlorine, data on non-linear inputs -- labour and capital -- may be added as follows:

9/ For reasons too long to explain here, the inputs of steam, water and fuel gas are not, strictly speaking, linear in the chemical industry. However, in general studies (though not in the preparation of individual projects), they may be considered as such with an allowable margin of error.

/Non-linear

Non-linear inputs in the production of chlorine

(a)	Annual capacity	22,000 tons
(b)	Labour	5.08 man-hours/ton
(c)	Exponential labour coefficient	0.218
(d)	Investment	12,000 dollars
(e)	Exponential investment coefficient	0.75
(f)	Upper limit of validity of exponents	170,000 tons
(g)	Minimum economic scale	22,000 tons

Item (f) refers to the upper limit of the segment of the curve where the exponential coefficients for elasticity are still valid for establishing the fluctuating relationship between the non-proportional inputs and the size of the plant. With the above information and using the equation previously described, it is possible to calculate the capital and labour inputs for any plant capacity within the capacity range defined by items (f) and (g). 10/

In order to facilitate the cost calculations, the activity vectors, which include data on linear and non-linear inputs, were grouped together in an input-output model for the chemical industry. One of the relevant tables has been inserted here for illustrative purposes.

10/ Below the minimum economic scales noted, the validity of the exponential coefficients must be carefully examined in each case.

/Table

Table

INPUTS AND PRODUCTS OF DERIVATIVES OF SYNTHESIS GAS

Linear inputs (-) and products (+)		Ammonium nitrate (1)	Ammonium sulphate (2)	Urea-formaldehyde resin (3)	Nitric acid (4)	Ammonia from coking gas (5)	Ammonia from natural gas (6)	Ammonia from refinery gas (7)	Sulphuric acid (100 per cent) (8)	Urea (through NH_3 from natural gas) (9)	Formaldehyde (from methanol) (95 per cent) (10)	Carbon dioxide (purification) (11)	Methanol from coke-ovens (12)	Methanol from natural gas (13)	Methanol refinery gas (14)
1. Ammonium nitrate	TT lbs.				+12.000										
2. Nitric acid	"	-7 600			-2.900	+10.000	+10.000	+10.000							
3. Ammonia	"	-2.400	-2.600						+10.000	-5.800					
4. Ammonium sulphate	"		+10.000												
5. Sulphuric acid (100 per cent)	"		-7.600												
6. Urea-formaldehyde resin	"			+10.000											
7. Urea				-3.380						+10.000					
8. Formaldehyde (95 per cent)				-2.750							+10.000				
9. Coking gas	TTT Cal.					-69.596									
10. Natural gas	TT cu.ft.						-170.000								
11. Refinery gas	TTT Cal.							-31.500							
12. Lubricating oil	TT lbs.					-0.003			-3.440						
13. Sulphur	"									-7.500	-11.250	+10.000	-0.00432	+10.000	-55.200
14. Carbon dioxide	"												-18.632	-118.100	+10.000
15. Methanol	"														
16. Sodium carbonate	"												+10.000	+10.000	+10.000
													-0.125		
Water for cooling	TT Gal.	-9.100	-25.000	-78.500	-21.800	-275.000	-11.000	-20.000	-4.680	-100.000	-400.000	-21.900	-420.000		
Electric power	TT kWh	-0.200	-0.140	-0.597	-0.500	-4.800	-5.500	-0.340	-0.119	-1.600	-3.700	-4.000			
Fuel gas	TTT Cal.				-0.04636		-1.260	-5.673	-0.284	-4.232					
Steam	TT lbs.	-6.500	-2.000			-36.700	-45.000	-4.000	-28.000	-0.000	-100.000	-30.000	-30.000		
Process water	TT Gal.		-25.000												
Non-linear inputs															
a. Annual capacity	TT lbs./year	400	460	7	150	614	614	614	490	70	23	16.500	18.786	18.656	18.663
b. Labour	Manhours/year	54.618	21.586	17.704	23.618	97.834	134.289	134.289	12.034	46.092	39.116	0.4	0.4	0.4	0.4
Exponent		0.27	0.2	0.2	0.2	0.2	0.4	0.4	0.2	0.2	0.2	375	327	686	686
c. Investment	T US$	1 555	764	187	156	29 250	33 389	33 389	2 522	2 601	695	0.63	0.81	0.81	0.81
Exponent		0.68	0.65	0.65	0.6	0.7	0.81	0.81	0.63	0.65	0.6				
Range of capacity	TT lbs./year	50-400	50-460	2-25	50-150	700-1 000	66-800	14-450	70-300	5-240	Unknown	60-250	60-600	2-25	2-25

T = 1 000.
TT = 1 000 000.
TTT = 1 000 000 000.

On the basis of the technological coefficients assembled in this model and certain special empirical criteria, it was possible to group the products studied into production complexes in order to facilitate their analysis. These include the acetylene complex, the caustic soda-bicalcium phosphate complex, the complex of phosphoric acid derivatives, that of ammonia derivatives, the ethylene complex and benzene complex.

Certain end products like silicon carbide, sodium carbonate and lampblack were not included in the complexes, since there are no sound technological or economic reasons for considering the integration of their manufacture with that of other products.

The input-output model was also used to calculate the intermediate products and raw materials required by each of the complexes considered. A body of data essential for the survey of raw material supplies for the chemical industry in the countries of the region was thus assembled.

5. Determination of raw material costs and other inputs

The final aspect to be considered in connexion with the methodological problems of the survey is the evaluation of raw material costs and other inputs, which, in the final analysis, form the basis for calculating profitability.

The problem is very simple as regards inputs from abroad, since their prices in each locality may be defined as equivalent to the f.o.b. price (port or place of shipment) plus freight costs. For the majority of countries, fuel oil, phosphoric rock, sulphur and coal (partly) fall within this category.

Unfortunately, the comparison of costs of such local inputs as natural gas, salt, limestone, labour, etc., is much more complicated and uncertain. In addition to the difficulties which are inherent in any compilation of costs, practical procedures must be found for estimating the prices of raw materials without distortions of an institutional character, because the institutional elements affecting prices are subject to frequent changes. In other words, costs should be studied without tax charges, direct or indirect subsidies, or any other factor which may invalidate a comparison of costs designed to reveal persistent regional differences. Strictly

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speaking, the starting point in every case should be a careful calculation of the opportunity price, arrived at after an analysis of the economic possibilities of the alternative uses competing for each input. Since such a study was impossible, the authors of the report decided to base the relevant estimates on original cost data combined with evaluations supported by a wide variety of empirical criteria. For example, in the case of the cost of natural gas, the opportunity prices in several countries were estimated on the basis of the possibilities of alternative uses. In Magallanes, Chile, where the only possible use of large quantities of gas would be in the petrochemical industry itself, gas was assigned a price equal to its production cost, excluding prospecting and drilling expenditure; in Argentina and Brazil, in view of the heavy demand for fuel, it was assigned a price equal to its calorific equivalent in fuel oil; in Venezuela, the price was equated to the production cost plus the freight to Puerto Cabello, the locality selected in the study for the petrochemical industry; and in Mexico, the alternative possibility of selling gas to the United States was taken into account. In the case of labour, the present wage levels in industries producing coal and petroleum derivatives were used as a general bench-mark. Certain changes were introduced to allow for specific situations.

Some of the elements of the cost structure must be converted from national currencies to dollars for the purpose of comparability and in order to determine profitability. For this purpose exchange rates were used that were estimated with the help of various weighting factors based on parity rates and those actually in force for foreign trade at the end of 1957, the base year generally used for all cost studies.

Generally speaking, the costs used in the study are somewhat lower then present real prices. The differences are due to the fact that in working out the costs of raw materials and services, certain estimated reductions were made on the grounds that the increase in scales of production resulting from the integration of markets would lead to more efficient operating methods and cheaper freight. At the same time, allowance was made for increased mechanization in exploiting natural resources. The differences in respect of prevailing prices may thus be substantial,

/especially when

especially when the above factors are combined with price reductions achieved by excluding those institutional charges which boost the prevailing prices of many raw materials in nearly all the countries of the region.

In order to draw the profitability curves, it was also necessary to ascertain not only raw material and labour costs but also the costs of transport from the various hypothetical industrial sites to the Latin American consumer markets. The average sales cost in those countries also had to be estimated.

V. SOME OF THE MAIN GENERAL CONCLUSIONS

The initial phase of the survey, which so far it has been possible to complete, yields certain important conclusions concerning the chemical industries in Latin America as a whole. By and large, they are unlikely to be modified by more accurate calculations made at a later stage. This, however, is not true of the preliminary conclusions reached as regards comparing the relative advantages of various Latin American sites. Here, the tentative results do not, in some cases, reveal sufficiently important differences and, in others, take no account of additional factors which might perhaps considerably affect the conclusions. Hence, it was felt desirable to mention here briefly the general conclusions affecting the region as a whole. Those concerning the basic aspect of the survey, namely, the comparison of the relative advantages of the various Latin American sites suitable for the development of the chemical industries under some form of common market, have been left till a later stage.

As mentioned earlier, the demand for chemicals is very dynamic. Consequently, in the future - for example by 1965 -, population growth, increased levels of income and general economic development will probably boost chemical requirements to remarkable levels. However, to judge from the results of this preliminary study, although high in absolute terms, the demand in most of the Latin American national markets will obviously still be small compared with that in the other regions of the world.

Since it is demand which ultimately determines scales of production and since, in the case of the chemical industries, these scales have a decisive effect on costs, the relative paucity of national requirements

/will mean

will mean that the Latin American countries start off at a disadvantage in any free competition with non-Latin American chemical firms. In the case of certain very important chemicals, this statement holds good even for those countries with the largest national markets, such as Argentina, Brazil or Mexico.

On the other hand, these advantages would not be so serious if plants were built to serve the whole regional market. Their size would then compare very favourably with that of the usual factories in countries which possess the most highly developed chemical industries, e.g. the United States.

Although still based on certain provisional figures, a careful comparison of costs shows clearly that only a chemical industry directed towards supplying the regional market could, in the basic and more dynamic lines of production, ensure a sufficiently high level of profitability to sustain a rapid tempo of development. Such an industry could compete boldly with its foreign rivals without the need for customs protection. At the same time, the stimulating effect of such competition would remain, so that it could operate on the basis of an open-market policy. Economic conditions would thus be favourable enough to prevent the establishment of protected regional monopolies.

According to the preliminary survey, if the scale of production corresponds to the demand of the full regional market and if the geographical siting is the most favourable for the region, the costs of production (including 10 per cent interest on fixed and circulating capital) would be higher than United States prices (f.o.b. plant) in the case of only two of the chemicals considered. On the other hand, the costs of 28 of the 34 products examined would be lower by 30 per cent or more than the respective prices in the United States.

On the other hand, without the large scales of production based on the possibilities offered by the common market, the differences between costs and international prices would not be big enough to ensure the necessary levels of profitability for the newer branches of the chemical industry. Indeed, in such circumstances, production costs lower than 70 per cent of United States f.o.b. prices would be attained only in rare cases. Even in the larger countries like Argentina, Brazil and Mexico, such cases would cover merely 5, 7 and 12 products respectively, out of a total of 34

/chemicals examined.

chemicals examined. This result, which is far below that observed for the production costs corresponding to the optimum alternative for economic scales and geographic siting, means that the new Latin American chemical industries established exclusively on the basic of the respective national markets would have to operate as heavily protected monopolies in order to obtain the level of profitability necessary for their subsequent development. It would be idle to point out the disadvantages of such a policy both as regards the general costs of industrial production in the countries concerned and the long-term efficiency of such monopolies.

Certain over-all figures may now be quoted to illustrate the probable situation in 1965 if the chemical industry in Latin America were developed on the above lines. Firstly, the annual net saving of foreign exchange, attributable to the establishment of the fundamental and most modern branches of the chemical industry on a regional basis, would amount to roughly 750 million dollars. It is true that this assumption makes no allowance for the attainment of a certain degree of import substitution, even in the absence of a regional market. But if the chemical industry is not placed on a regional footing, such substitution would encounter the difficulties already described and hence only a fraction of actual needs would be covered.

What is more, a complete hypothetical substitution of imports with the help of national chemical plants would be a less favourable alternative in terms of foreign exchange expenditure than the establishment of a regional chemical industry. The corresponding national plants would involve a total investment in foreign currency higher by some 415 million dollars than that required for the larger factories which might be built within the setting of a common market. This would be one of the important effects of economies of scale. Besides this increased investment in foreign exchange, the annual capital charges payable in foreign exchange would rise by some 85 million dollars.

So far as production costs are concerned, the development of the chemical industries on a regional basis would represent by 1965 a gross saving of some 400 million dollars a year in foreign and domestic currency, as compared with the alternative of maintaining such industries on an exclusively national footing. Yet the freight expenditure involved in shipping chemicals in the regional market from their places of origin should be deducted from this figure. The net saving would then amount to 300 million dollars a year.

/The above

The above comparisons exclude the extreme alternative of building national plants in the countries where demand is weakest. This would have brought into prominence the much greater savings that would result from market integration. It was assumed that average production costs at the national level for Argentina, Brazil, Chile, Mexico and Venezuela would also prevail in the other countries of the region - Cuba, Colombia, Ecuador, Peru, Uruguay - as well through intra-regional imports. In so far as the real costs exceed this average or a proportion of imports come from outside the region - both these assumptions being very likely - the advantage of the regional industry will have been underestimated in the above calculations.

In view of these conclusions, it may now be asked if Latin America has sufficient raw material resources for the speedy development of the regional chemical industry and whether the conditions for utilizing them are propitious.

The preliminary survey clearly shows that the Latin American countries have ample supplies of nearly all the basic raw materials for the chemical industry. Geological and petroleum prospecting has progressed considerably in recent years. The abundant petroleum resources of Venezuela and Mexico are well known. In Argentina, conditions exist for a large-scale expansion of petroleum production and the surveying of reserves. In little over a decade, Chile has become a producer of petroleum rapidly nearing self-sufficiency. From the point of view of the petrochemical industries, the discovery of extensive fields of natural gas, both in the countries mentioned and in others within the region, is of great importance. At the same time, the development of refining in the bigger Latin American countries is highly significant for the chemical industry.

So far as petrochemical raw materials are concerned, it is generally agreed that natural gas holds out the best prospects, particularly because in several countries it is available in enormous quantities and at very low cost. In 1956, the region had at its disposal proven natural gas reserves which reached the astronomical figure of 10^{12} cubic metres. Of this quantity 50,000 million cubic metres were in Argentina,

760,000 million

760,000 million in Venezuela and 180,000 million in Mexico. The Chilean reserve has been estimated at some 14,000 million cubic metres.

However, from the technological point of view, refinery gases are very favourable as raw materials for the petrochemical industry, especially in the production of such important intermediate products as ethylene, propylene and butylene. Unfortunately, the petroleum refineries of the region have achieved so far only a limited degree of development. The simpler operations predominate and produce relatively small quantities of gas. Its composition, moreover, is not the best suited for the chemical industry. Latin American supplies of ethylene, propylene and butylene, obtainable by separation and cracking from refinery gases, are limited. On occasion they may be enough to meet the petrochemical requirements of a specific national market, but only in exceptional cases would they enable established industries to satisfy integrated markets. During the next 10 years Mexico and Venezuela might constitute such exceptions.

In principle, liquid gases and other liquid petroleum derivatives are too costly to be used as raw materials for the manufacture of petrochemicals because they are in heavy demand for domestic, industrial and motor vehicle fuels. However, they may have to be employed in certain important manufactures.

As regards carbochemical raw materials, the following facts should be stressed:

(a) Supplies of such raw materials within the region depend almost entirely on the level of development achieved in the iron and steel industry, since they are obtained as by-products of coke. Conditions in Latin America do not favour coking operations designed specifically to obtain carbochemicals. Generally speaking, the region offers only limited prospects for the development of the carbochemical industry, a situation which is offset by the higher hopes which may be entertained for the manufacture of petrochemicals. By all accounts, the carbochemical industry will have to continue to be for some time yet an industry utilizing local by-products. The reasons for this conclusion are the existence of extraordinarily cheap raw materials for the

petrochemical industry, which competes strongly with that of carbochemicals, and the restricted demand for coke as a domestic fuel. In this respect, the position in the region is not comparable with that in Europe, where, mainly because there is less petroleum, detailed studies have been made of the various processes which may be used for obtaining liquid fuels and lubricants from coal.

(b) A projection for 1965 of the production of coking gas and carbochemical benzene, using alternative maximum hypotheses, has shown that Latin American supplies of these materials would cover only a minor fraction of the gas and benzene requirements of the chemical industries.

(c) Apparently, certain Latin American countries very rich in coal might become exporters of metallurgical coke. They would then have large quantities of raw materials available for the establishment of carbochemical industries. However, this possibility is somewhat remote because it is generally preferred to build coking ovens next to steel mills, even though they use imported coal, for the following reasons:

(i) The utilization of the poor gases from the blast furnace and the rich gases from the coking oven is better when the coking and steel industries are linked together.

(ii) Coke deteriorates when transported over long distances.

(iii) From the balance-of-payments point of view, imports of coal are usually more favourable than those of coke.

(iv) By importing coal rather than coke, each country may obtain at reduced cost a certain quantity of coke by-products.

To quote a specific example - the coal mines at Magallanes, Chile - the cost of coke at the minehead was compared with the cost of coke f.o.b. the steel mills of possible importers. In this case, the cost advantages of coke produced at the mine were not big enough to offset the disadvantages of importing coke on a large scale from Argentina and Brazil. If a similar calculation had been made for the coking of Colombian coal in the country itself and for its sale as metallurgical coke, the result would probably have been much the same.

Within a period of seven to ten years, important hydroelectric resources exploitable at low cost may well be discovered in Argentina,

/Brazil, Chile,

Brazil, Chile, Mexico and Venezuela, as well as in other countries of the region. At the same time, Chile, Mexico and Venezuela might generate large amounts of electric power in thermal stations using natural gas as fuel. The cost per kWh in such plants would probably not exceed that of hydroelectric power under the best local conditions of utilization. These facts are important for the development of the so-called "electrochemical" group of industries - especially electrolytic caustic soda and chlorine, silicon carbide, etc. - because of their high input of power. For these industries, all the countries mentioned would also have enough salt and limestone, while their geographical position would be fairly satisfactory.

As regards sulphur, only Mexico is favourably placed, with abundant supplies at prices somewhat lower than those on the international market. The other countries (with a few isolated exceptions involving the use of sulphurous gases given off in ore-roasting or petroleum-refining) either must import sulphur or produce it at costs exceeding import prices.

Finally, it has been established that most of the Latin American countries do not possess satisfactory deposits of phosphoric rock. They would therefore have to import it if they wished to produce phosphate fertilizers. Moreover, the costs in countries which do produce it are not lower than the price of imported rock in terms of units of the nutrient phosphoric element. This is also true of Brazil, which possesses the largest reserves in Latin America, although there are good prospects that this situation may change in the future.

To sum up, according to the preliminary survey, Latin America is perfectly equipped to undertake the large-scale development of a modern and efficient basic chemical industry, provided that some kind of regional agreement is reached which allows advantage to be taken of the large economies of scale and optimum siting. Otherwise, the region will soon have to use large amounts of foreign exchange to purchase chemicals from other regions, or will have to develop at great expense multiple industries based exclusively on national markets which are not big enough to ensure their maintenance and subsequent growth at economic levels.