# Long term world prospects for petrochemicals up to 1990 : scenarios of world petrochemicals. 1 : Construction of the base

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# long term world prospects for petrochemicals up to 1990



## scenarios of world petrochemicals

### volume 1 : construction of the base

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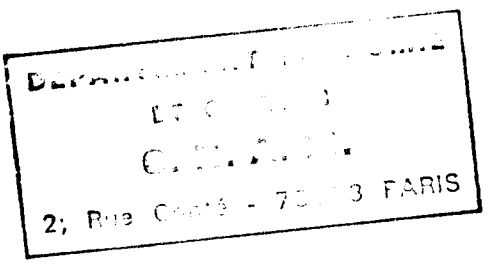


# LONG TERM WORLD PROSPECTS FOR PETROCHEMICALS UP TO 1990

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## SCENARIOS OF WORLD PETROCHEMICALS

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## VOLUME 1 - CONSTRUCTION OF THE BASE

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# INTRODUCTION

The purpose of this report is to describe the work carried out to date as part of the study "Long term prospects for petrochemicals" which will serve as a basis for the construction of scenarios for the development of the industry to the year 1990.

The petrochemical industry, after having enjoyed almost uninterruptedly high growth since its birth, is reaching a period of maturity. The rate of technological and economic change in the industry is slowing down, and as the rate of penetration of petrochemical products into the various consuming sectors increases, so the potential further growth of demand, at least in the established markets, inevitably drops. As markets have increased, more and more firms have entered the field of petrochemicals manufacture, and the market has become more competitive.

At the same time as the petrochemical industry is progressing into a new phase of its existence, the world economic environment, which must exercise a strong influence on the former, is currently in a state of some disarray. The economic euphoria of the 1950s and 1960s, when more of less sustained and high rates of economic growth were taken for granted, at least in the developed countries, has given way to uncertainty and disquiet. It is widely thought that the worldwide depression of 1974-75 may not just be a conjunctural disturbance, but could mark a watershed in the economic development of the world.

For these reasons, a forecasting approach based merely upon the extrapolation of past trends is quite inadequate. Rather, an examination must be made of the environment in which the petrochemical system is situated and of the interactions between the former and the latter, and the mechanisms which exert an influence on the development of the system. The actors either within or outside the petrochemical system whose behaviour determines the evolution of the system must be identified.

In order to describe possible developments of world petrochemicals up to the given time horizon, SEMA will use the scenarios method. A scenario is a schematic picture of the system studied, as at the time horizon set, which describes those aspects of the system which are important from the viewpoint of the study, together with a description of the paths leading up to it. The scenarios method consists of the construction of a set of plausible, contrasted scenarios. It recognises that there is no unique future, waiting to be unveiled by some sufficiently powerful scientific forecasting method. The future depends on the actions of policymakers and others which have not yet been taken, and this fact provides the future with its degrees of freedom.

While there is no unique future, it is nevertheless necessary that the scenarios constructed should be sensible, consistent and plausible. In order to provide for this, SEMA has developed an integrated approach which provides for the most relevant variables and mechanisms to be identified, and leading to the choice of suitable hypotheses which will characterize the scenarios.

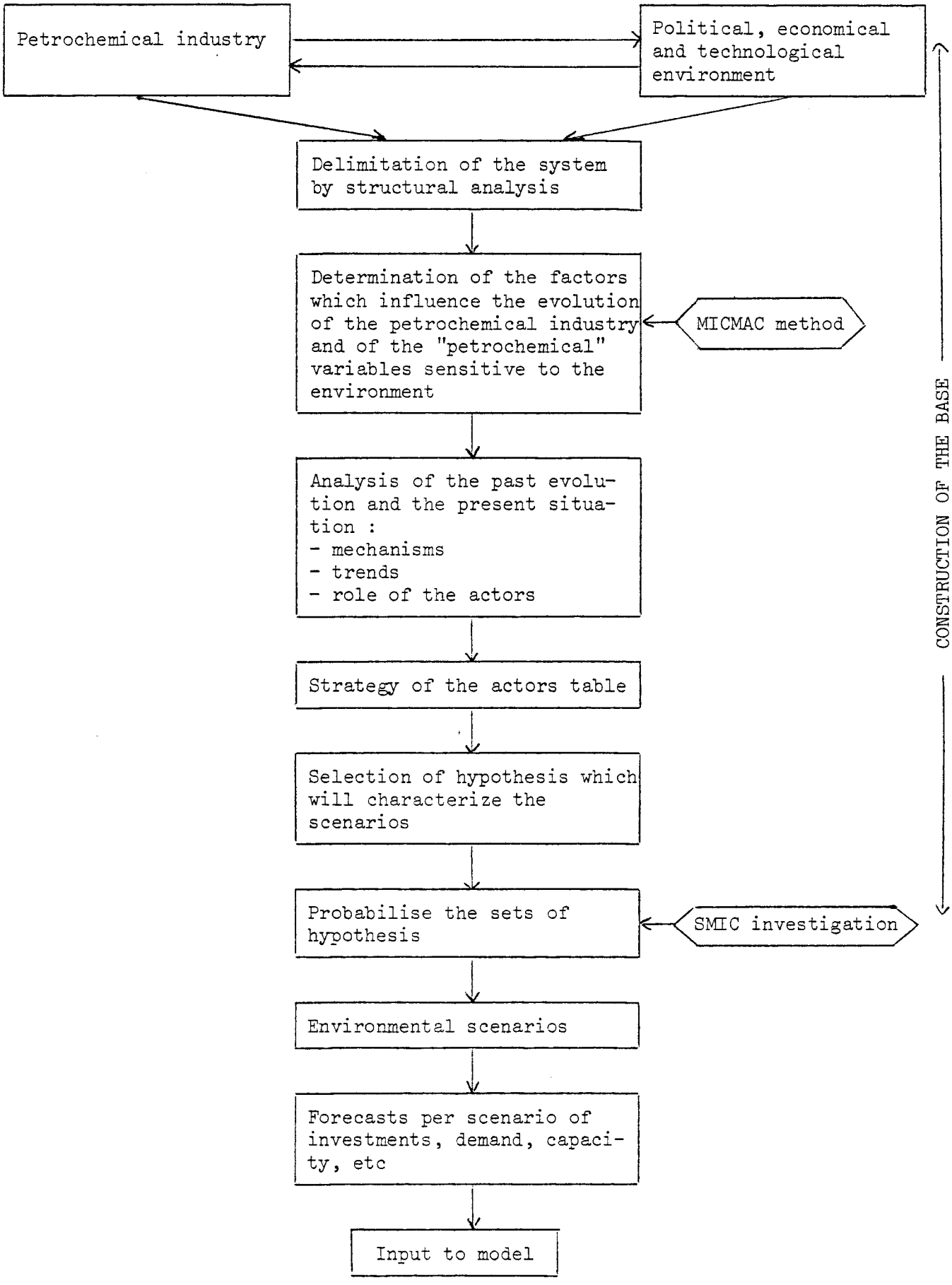
This approach is summarised in the diagram overleaf, and comprises two main phases :

- the construction of the base, in which the petrochemical industry and its future development is placed in a wider context, and in which the present working and past development of the system thus constituted is studied, so that the various mechanisms can be understood, and future prospects of development identified.

- the elaboration of scenarios, in which, starting from the base developed above, estimated probabilities of realization of the different possible images are obtained, thus allowing a reference scenario to be chosen from amongst the most likely. This is complemented by contrasting scenarios which express divergent but nevertheless plausible lines of development.

The work carried out to date and described in this report comprises the first of these phases.

# METHODOLOGICAL DIAGRAM OF SCENARIOS METHOD



In its turn,this first phase, the construction of the base, involves four stages, i.e.,

- The delimitation of the system by structural analysis. The main variables which describe the system made up of the world petrochemical industry and its economic, social and legislative environment are identified. The causal relationships between the variables are then brought out, through the construction of a "structural analysis matrix". This work is presented in chapter I.

- The study of this system, with a view to identifying the relative importance of these different variables in the dynamics of the system, which of the external or environmental variables influence the petrochemical industry most strongly, and which of the petrochemical variables are most sensitive to the environment. The results of this study are contained in chapter II.

- The analysis of the explanatory role played by these variables in the past, through a "retrospective analysis", and by describing the important actors, or participants, in the system, their objectives, possible conflicts and convergences of interests, and the means of action which they have upon one another. This explanatory analysis has, for convenience, been split up into two chapters, chapter III containing the retrospective analysis and chapter IV containing the study of the strategy of the actors.

- Finally, while the likely direction of evolution of some of the variables of the system will be clear, there will be uncertainty about many others. In order to resolve the degrees of freedom thus subsisting in the system, hypotheses are formulated which will either be realized or not. The opinions of experts as to the likelihood of realization of each of these hypotheses is sought by means of a questionnaire. Using the data thus collected, likely scenarios can be constructed, characterized by the outcomes of the different hypotheses.

Although the above methods use certain quantitative analytical techniques, they are essentially qualitative in type, the objective being to gain insight into the structure of the system, the mechanisms which operate, the factors likely to influence the evolution of the system and bring about changes in a descriptive and qualitative way.

While the techniques are designed to provide for as systematic and exhaustive a treatment as possible, there are inevitably some respects in which judgement or subjective choice must be relied upon. Thus, for example, in the case of the structural analysis, judgement must be exercised as to which of the variables are the most important, what level of disaggregation is necessary, whether they should be formulated in relative or absolute terms, and so on. Similarly, in the actors' strategy stage, there are various possible forms of typology or grouping which could be made, and different levels to which the data could be disaggregated. Finally, in choosing the hypotheses to be retained as a basis for the construction of scenarios, there is no absolute hard and fast rule for making the selection ; the choice is to some extent subjective.

When subjectivity enters into the methodology, then by definition a different team applying this methodology could arrive at somewhat different results. It is necessary to satisfy oneself, at these points in the analysis, that the fundamental validity of the work would not be called into question by such differences. Expressed differently, the results must be reasonably robust. This has been done as far as possible at the relevant junctures in the work, and the efforts made to ensure robustess are described in the relevant sections.

# I - THE MATRIX OF RELATIONSHIPS

## A - Introduction - The petrochemical industry and its environment

The system to be studied comprises the petrochemical industry and its "environment". By petrochemical industry is meant that activity which is directed towards manufacturing petrochemical products as defined in this study, and thus the firms, whether privately owned, who carry out this activity.

The "environment" of the petrochemical industry is that system which is external to the petrochemical industry, within which the industry must operate, and which impinges on it in various ways. Thus the environment includes, downstream, the market for petrochemicals, and all the phenomena affecting the demand for and prices of petrochemical products, and upstream, everything which affects the availability and costs of feedstock, capital, investments, technological knowhow, labour, transportation facilities, and so on, and also government and other institutions who make laws or constrain their behaviour in other ways, support them financially or otherwise, and so on.

In general there is a clear dividing line between the petrochemical industry and its environment, although obviously some entities are at the frontier between them. Thus sales of petrochemical products, seen as an expression of the demand by the market for petrochemical products can be regarded as being an environmental variable, but looked at as a quantity equal to petrochemical production, can be thought of as being internal to the petrochemical industry. The existence of such variables on the margin between the petrochemical industry and its wider analysis, however does not upset the analysis.

## B - Enumeration of variables

The first stage in the structural analysis is to construct a list of variables which can be regarded as characterizing the petrochemical industry and its environment.

A variable is a qualitative or quantative entity which describes an aspect of the system, and may take the form, either of a state of fact which is either true or false at a given time, or alternately, by a particular quantitative or qualitative value.

The identification was carried out by conducting an extensive literature search, from which all apparently relevant variables were extracted. Brainstorming sessions were also held, involving participants from different disciplines, during which the list was complemented.

Of course, an almost unlimited number of variables can be listed as being of some relevance, but as has already been pointed out, structural analysis is a tool intended for use at a broad, structural level, rather than being concerned with the finer mechanisms involved, and the choice is therefore limited to those variables appearing most important. Experience has shown that an appropriate number of variables to be handled by this method is of the order of one hundred.

Therefore, after a first crude list of variables has been prepared, the list is refined by ensuring that the variables are at a roughly comparable level of detail and are complementary, that a reasonably consistent approach to disaggregation of variables has been taken, and so on.

In fact, the list of variables finally adopted amounted to precisely 100, although the fact that it came out to this round number exactly was fortuitous.

## 1 - The variables of the petrochemical industry

These are the variables which characterize and delimit the world petrochemical system as under study.

An aspect of the study is the eventual need to disaggregate the description of the system between geographical zones, and between different petrochemical products. The level to which these disaggregations should be observed in the choice of variables is a matter of discretion, but in general the disaggregation was carried out to a level consistent with the level of detail implicit in the other variables, i.e. at a level to which differential effects might be perceptible.

The variables relating to the petrochemical system ("internal" variables) finally adopted amounted to 49, grouped according to :

- variables of technology,
- variables of production,
- variables of the market and its organization.

These variables are

Technological

1. Technological development of processes
2. Technological development of plant and machinery
3. Flexibility of processes in regard to feedstock (ability to use naphtha, gas-oil, natural gas, crude, etc.)
4. Flexibility of processes downstream (ability to adjust proportions of different products output, e.g. ethylene, propylene, butadiene, aromatics)
5. Rate of technological obsolescence of plant (plant becomes technologically obsolescent when, as a result of technological developments, it becomes uneconomical to use. This may be because a cheaper process has been discovered, because of the advent of newer, much larger plant realizing considerable

economies of scale, because the demand for the relevant product has disappeared and so on).

6. Ability to meet quality levels required by the market
7. Variation in the average size and complexity of petrochemical units
8. Physical integration and concentration of petrochemical processes -primary, intermediate and final transformations, vertically and horizontally - (this refers to a tendency towards large integrated petrochemical complexes on a single site, as opposed to a more fragmented mode of production)
9. Breakdown of total costs between fixed and variable - The importance of this variable is that it is one of the main determinants of the capacity of realizing economies of scale
10. Physical integration of refining and petrochemical industries
11. Research effort
12. Valorization of by-products (the replacement of a valueless or low-value by-product by a marketable by-product, either through the modification of a given process, or by carrying out further elaboration. This will have the effect of lowering costs and therefore increasing the competitivity of the process i.e. creating difficulties to those who do not valorise)
13. Emergence of new base products

Products

14. Evolution in the proportions of feedstocks used (natural gas, naphtha, gas-oil, other feedstocks)
15. Emergence of new final products
16. Competition characteristics of petrochemical final products (changes in the characteristics, i.e. mainly price and quality, which affect their competitivity against non-petrochemical products e.g. synthetic against natural fibres, plastic against paper for packaging,etc.)
17. Ratio up-time/down-time (the proportion of time during which a given plant is available for production if so required, i.e. is not out of commission for technical reasons

18. World production of plastics
19. World production of synthetic rubber (quantities)
20. World production of synthetic fibres (quantities)
21. World production of nitrogenous fertilizers (quantities)
22. World production of detergents, paints, solvents (quantities)
23. Share of LDC without hydrocarbon resources in the total production of base products
24. Share of LDC with hydrocarbon resources in the total production of base products
25. Share of Eastern bloc in the total production of base products
26. Share of LDC without hydrocarbon resources in the total production of final products
27. Share of LDC with hydrocarbon resources in the total production of final products
28. Share of Eastern bloc in the total production of final products

Market organization

29. Degree of fragmentation of production - horizontal integration - (whether the market tends to be characterized by a large number of small producers or a small number of large producers)
30. Degree of vertical integration of petrochemical companies with oil companies
31. Distribution agreements between producers - for upstream and downstream products - (the tendency for producers to make agreements between themselves as to the geographical zones in which they will market their products)
32. Openness of the market (relative importance of free markets, captive markets, long-term delivery agreements, etc.)
33. Degree of price competition between firms (Are prices genuinely determined by free competition or is there a certain amount of price-fixing, either tacit or overt, between firms ?)

34. Use of locally-available resources by petrochemical firms (the preference for strategic reasons shown by firms for using feedstocks obtained from locally available resources, even where these are not the lowest cost)
35. Importance of brokers (and other intermediaries)
36. International trade in base products (volume)
37. International trade in intermediate products (volume)
38. International trade in final products (volume)
39. Production costs (includes investment and operating costs, but not distribution costs)
40. Real prices of base products (international or reference price, but not spot price)
41. Real prices of final products (international or reference price, but not spot price)
42. Relative profitability of different geographical zones
43. Ability to self-finance - Extent to which capital requirements can be met out of retained profits
44. Rate of technological transfer (the speed with which technical know-how and expertise is transferred from industrialized countries to the developing countries wishing to enter the petrochemical industry or to consolidate their position )
45. Level of investment in petrochemical industry (amount of money invested at a given moment)
46. Profitability of petrochemical industry in base products
47. Profitability of petrochemical industry in final products
48. Degree of surplus capacity in the petrochemical industry (extent to which productive capacity of the industry exceeds actual production)
49. Difficulty for a new comer to penetrate market (an intermediate variable resulting from many different factors, summarising the ease or difficulty of entry into the petrochemical industry by a new enterprise).

## 2 - The variables of the environment

Similarly, the environment is described by 51 variables, grouped into :

- variables of the political and economic context,
- variables describing the market for petrochemicals,
- variables of infrastructure, labour, transport, capital,
- variables describing legislative and similar constraints.

These variables are :

### Political and economic context

50. East-West economic cooperation
51. North-South economic cooperation
52. Development of regional economic cooperation (South-South)
53. Degree of liberalism/protectionism in world trade
54. Rate of growth of world GNP
55. Relative growth of developing and industrialized countries
56. Industrialization of the Third World
57. Political weight of Eastern bloc
58. Leadership of the USA in the Western world
59. Solidarity/break-up of OPEC
60. Solidarity/desolidarity of Third world
61. Power of the oil multinationals
62. Influence of oil companies on petrochemical firms
63. Development of the balance-of-payments of the OPEC countries
64. Stability of the international monetary system

### World market for final products

65. World demand for plastics
66. World demand for synthetic rubbers
67. World demand for nitrogenous fertilizers

68. World demand for synthetic fibres
69. World demand for other products (detergents, solvents paints)
70. Geographical spreading of the consumption of final products (emergence of new markets)
71. Demand for automobiles (rate of growth)
72. Demand for textiles (rate of growth)
73. Demand for building material (rate of growth)
74. Agricultural income
75. Changes in characteristics of non petrochemical products (i.e. mainly price and quality which affect their competitivity against petrochemical products - cf. variable 16)
76. New outlets for existing petrochemical products
77. Relative prices of oil and non-energy raw materials - rubber, fibres, phosphates, bauxite, wood,etc - (the idea behind this variable is that of obtaining a relative measure of costs of the original raw material for the petrochemical, i.e. oil - and natural gas which can be assumed to follow it - and for the output of competing products, i.e. rubber, fibres, bauxite - for aluminium competing with plastic - etc.)
78. Real price of oil (reference price or international price)
79. Real price of natural gas (reference price or international price)
80. Cost of energy substitutes(nuclear energy, shale, tar sands, etc)
81. Proven level of world hydrocarbon reserves
82. Preservation of hydrocarbons (the will, on the part of countries with hydrocarbon reserves, to restrict production with a view to preserving their resources for a longer time period)
83. Relative availability of petrochemical feedstocks (naphtha, gas-oil, natural gas)
84. The use of new feedstocks (coal, vegetal waste, shale)

85. Geographical variation in the availability of feedstocks
86. Relative prices of feedstocks (the relative prices of the different feedstocks, either used at present or possible substitutes, thus not only natural gas, naphtha, gas-oil, but also coal, SNG, shale, etc.)
87. Local departures from world prices of feedstocks
88. Changes in equilibrium between demands made by energy and petrochemical sectors for raw materials (conflicts in demand between these two sectors)

Infrastructure, labour, transport, capital

89. Local variations in building costs (including those due to different infrastructural and environmental conditions)
90. Availability of technicians in the LDC
91. Transport-related constraints (technology, costs)
92. Availability of capital
93. Cost of capital
94. Availability of capital equipment for petrochemicals (this variable expresses constraints on the investment side ; if the pace of investment either worldwide or locally rose beyond a certain threshold, the capacity of the investment-supplying sectors could be reached, thus leading to bottlenecks).

Constraints (legislative and others)

95. Environmental constraints, anti-waste movement, etc.
96. Anti-monopolistic legislation
97. Fiscal constraints (taxes, repatriation of profits, customs duties, etc.)
98. Supranational regulation of new investment projects. For example, if the EEC tried to rationalize new projects by regulating and coordinating different plans in member countries
99. State intervention in the petrochemical industry (nationalizations, participations, policy definition,

guidelines on activity levels, security of supplies, etc.)

100. Labour constraints (unemployment, legislation, strikes, trade unions, etc.)

## C - Identification of relationships

A variable, in a system, only exists by virtue of its relationships. It is in fact the intuitively felt presence of certain relationships which led us to include certain variables in the foregoing list.

In order to show the relationships between the variables, it is necessary to use a structural analysis matrix : this is a square table, with a line and a column for each variable.

This table of variables against variables is then filled in by inserting a "0" or a "1" in each square, so indicating the absence or presence of a direct relationship between the corresponding variables.

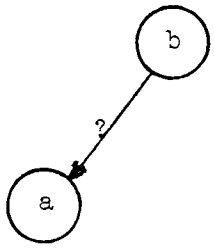
Indicating a relationship between two variables assumes that one has previously identified the direction of the relationship, and that one has determined whether it involves a direct relationship (a variation in one variable results directly in a variation of the other) or an influence which passes through other intermediate variables.

In fact it is probable that most of the variables retained in the list have some influence on each other, and an indiscriminate listing of these relationships of influence would result in much too confused a pattern of the system being studied.

The sensing of a relationship between two variables a and b cannot lead to the identification of a direct causal link (a acts on b) until one has asked the following three questions :

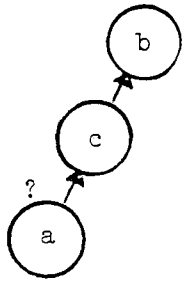
- Does variable b act on a ?

Intuition of a correlation between two variables a and b sometimes leads to an incorrect appreciation of the direction of the action. Conversely the recognition of an action of b on a does not necessarily mean that a has no influence on b.



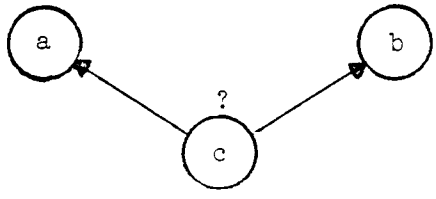

- Does the variable a act on b through a third variable ?

The action of variable a on variable b can be found to be indirect ; the pathway from a to b may pass via other variables. It is therefore necessary to consider the possibility of the influence of variable a on variable b through a third variable c. The existence of an intermediate variable does not necessarily rule out the possibility of a direct action relationship between the two variables a and b.




- Are variables a and b themselves acted on by the same variable c ?

Correlation does not indicate causality. Two correlated variables a and b may not be linked by any causal relationship when these variables are both acted on by the same variable c. Conversely the direct action of one variable c on the two variables a and b does not exclude any other linkage between these two variables.



However this procedure does not always make it possible to decide definitely between the existence or not of a direct relationship between two variables (particularly reciprocal actions, or potential actions which could occur between now and 1985).

One is therefore led to introduce potential actions into the structural analysis matrix, and these are the object of specific treatment.

The working group filled in the structural analysis matrix following the procedure described above.

When the group members were unanimous as to the existence or otherwise of a direct relationship between two variables, the appropriate square in the matrix was completed. When, however, after discussion, disagreement subsisted within the group, or when the existence of a relationship seemed likely in the future, rather than at present, a potential action between the two variables was noted.

The completing of the matrix is a considerable task if conscientiously done involving the asking of 100 x 100 = 10,000 questions. The work of completing the matrix was carried out by a working group comprising experts in petrochemicals and in the prospective methodology, and lasted about two weeks of elapsed time. Many of the questions which arose during the sessions were far from easy to answer, and involved considerable discussion within the working party. It would be impractical to try to summarise this very voluminous discussion here, and indeed inappropriate, as the resulting matrix represents the distillation of all the work carried out. This matrix is presented in Appendix 1.

## D - Difficulties encountered

Two types of problem occurred during this stage :

- the definition of the variables

As exhaustive and accurate a description as possible of the world petrochemical industry and its environment had to be obtained, subject to the constraint of not exceeding approximately one hundred variables, since beyond that number, the process becomes cumbersome, and the interpretation of the results, which is already delicate with one hundred variables, becomes awkward.

We also strived to obtain a reasonable homogeneity in the variables, although there were disparities in some cases. Thus, for example, North-South cooperation is "wider" than the research effort made by the petrochemical industry.

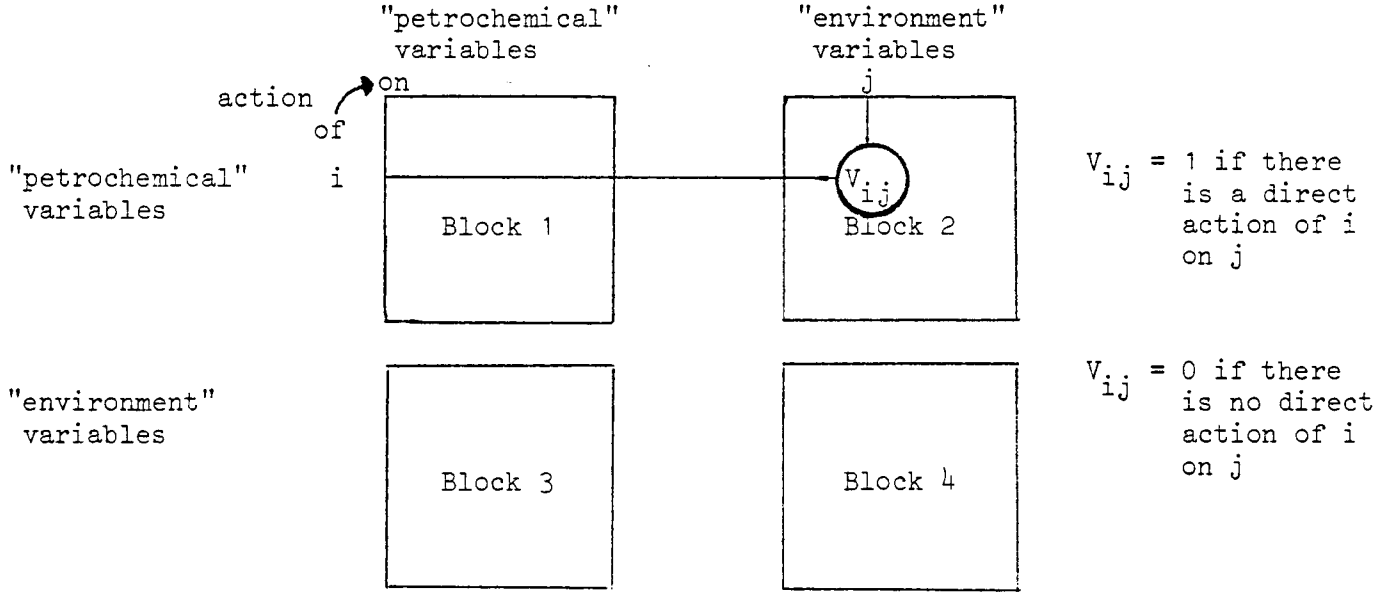
Similarly the incorporation of the geographical dimension is difficult : the disaggregation by zones (or products) of variables of production, consumption, trade, price, etc. would have led to several hundred variables (in any case taken account of subsequently in the model) and the apparent gain resulting would have been spurious, since the analysis is quantitative in kind. We therefore sought to bring out in the analysis the role of the different factors at a fairly global level (production, demand), and to take account of the relative aspect of the variables when this seemed the most interesting. It would undoubtedly have been possible to arrive at lists which differed in some respects from that adopted, but the one herein described appears to adequately meet the main objective of the structural analysis, which is to identify those factors of evolution, amongst a hundred or so, most important inducing changes in the system comprising the petrochemical industry and its environment.

- the establishment of the relationship

The way that the matrix is completed is undoubtedly conditioned by the technical and cultural background of the working group, and is therefore marked with a certain subjectivity.However, the procedure of systematic interrogation adopted obliges the group to question its underlying assumptions, leading each member to ask questions which he is not accustomed to ask, or which he normally asks differently. Finally, the special treatment reserved for the "potential" relationships constitutes a check on the stability of the system. If their inclusion does not unduly disturb the results, then it may be concluded that another team, which had introduced new relationships (or had removed others), would have arrived at reasonable similar conclusions.

E - The structural analysis matrix

The structural analysis matrix, when completed in this way, can be seen to consist of four blocks (cf. diagram below).




Block 1 represents the action of the petrochemical system on itself

Block 2 represents the action of the petrochemical system on the environment.

Block 3 represents the action of the environment on the petrochemical system.

Block 4 represents the action of the environment on itself.

The completed structural analysis matrix is contained in Appendix 1. For presentational purposes, a direct action is indicated by a solid black circle, the absence of such an action is indicated by a blank square, and a potential relationship is indicated by a hollow ring.

# II - RESULTS OF STRUCTURAL ANALYSIS

## A - General outline

Before examining the results of the various MICMAC orderings (i.e. overall system, interplay between environment and internal sub-system, interactions inside the overalls system), we shall take a look at and elucidate two general schemas in which are graphically exposed the major results relative to motricity and dependence.

### 1 - Regrouping of the variables

The first schema consists of polyform shapes, each representing variables (see explanation below) which relate to the same aspect : market, international trade, oil policy, technological context, etc.

Simplified (*), this schema affords a clear-cut vision of the petrochemical industry/environment structure. It underlines certain basic results of the analysis :

- the "petrochemical industry/environment system" is characterized by a certain instability,
- its evolution is strongly conditioned by the worldwide politico-economic context, rather than by the products context (raw materials, market, trade).

Attention may first be drawn to the variables contained in the upper right portion of the schema, within the polyform "politico-economic context" (**). Characterized by both high motricity and extreme dependence, these variables are factors of instability within the politico-economic context, and are also related to the evolution of production capacity localization.

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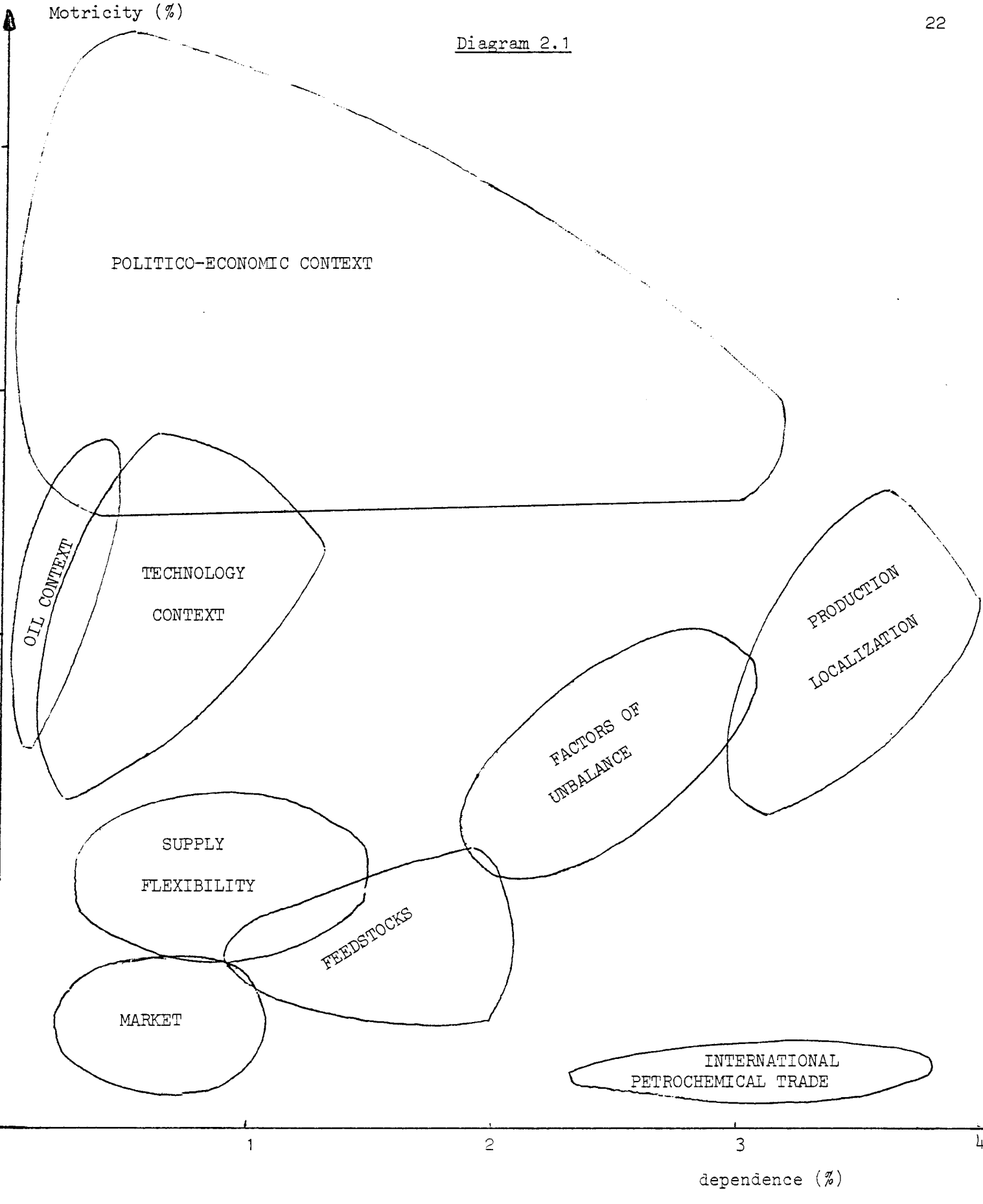
(*) the initial 100 variables are not all included in the various variable groups

(**) such variables constitute factors of instability inso far as any single variation or change taking place among them causes evolution throughout the system hence motricity, which evolution in turn effects the variable having provided the motricity (boomerang effect), the latter being at the same time extremely dependent.

Diagram 2.1




Schema 1 - GROUPING OF VARIABLES

To be pointed out next are the high motricity variables (upper left of schema) contained in the groups headed "politico-economic context", "oil policy" and "technological context".

Subsequently to be noted are variables which are at once internal and external, relating to supply, international trade, and appearing rather as results or phenomena of adaptation to the system rather than explanatory factors in its dynamics.

Finally should be observed the relative position of the figure "Factors of unbalance" which is seen to be a meeting-ground between factors of instability and result variables.

Enumeration of the variables entering the various contexts

- Politico-economic context

  North-South economic cooperation,
  Development of the balance-of-payments of OPEC countries,
  Solidarity/break-up of OPEC,
  Degree of liberalism - protectionism in world trade,
  Industrialization of the Third World.
  Development of regional economic cooperation,
  Stability of the international monetary system,
  Government intervention,
  East-West economic cooperation,
  Leadership of the USA in the Western world.

- Production localization

  Share of LDC with hydrocarbon resources in the total production of base products,

  Share of LDC with hydrocarbon resources in the total production of final products,

  Share of LDC without hydrocarbon resources in the total production of base products,

  Share of LDC without hydrocarbon resources in the total production of final products.

- Factors of unbalance

Difficulty encountered by newcomers in market penetration,
Availability of technicians in LDC,
Relative profitability of different geographical zones,
Geographical variations in the availability of raw materials.

- Oil policy

Real price of oil,
Real price of natural gas,
Power of the oil multinationals,
Proven level of world hydrocarbon reserves.

- Technological context

Physical integration and concentration of petrochemical processes,

Physical integration of refining and petrochemical industries

Stream factor,

Technological evolution of processes,

Variation in the average size and complexity of petrochemical units.

- Flexibility of feedstock supply

Share of local resources in supplying firms,
Utilization of other raw materials,
Flexibility of processes in regard to feedstock,

Relative availability of feedstock,

Evolution in the proportions of feedstock used (natural gas, naphtha, gas-oil, other feedstocks),

Relative prices of oil and non-energy raw materials (rubber, fibres, phosphates, bauxite, wood, etc..)

Changes in equilibrium between demands made by energy and petrochemical sectors for raw materials.

- Market

World supply of final products,
World demand of final products,
Openness of the market
Distribution agreements between producers,
Geographical spreading of the consumption of final products,
Real prices of final products,
Emergence of new products,
Competition characteristics of petrochemical products/other products.

- International petrochemical trade

International trade in base products (volume),
International trade in final products (volume),
International trade in intermediate products (volume).

2 - Positioning of certain key variables

In the second schema figure a certain number of variables which either do or do not appear in the first schema, and whose positioning is particularly worth noting.

The positioning of the various crosses (+) is the index of motricity and dependence characterizing each variable ; it is a graphical representation of the analysis by which potential links, or relationships, are grouped.

In order to facilitate reading the schema, the plan is divided into four zones :

- Zone I includes variables with little motricity and little dependent : these variables have little action on the essential dynamics of the system, or else have little explanatory value to its basic development.

- Zone II includes variables which are chiefly dependent : either result or intermediate variables, strongly conditioned by the rest of the system.

- Zone III includes variables which are characterized by both motricity and dependence and therefore represent factors of instability to the system : these require close study.

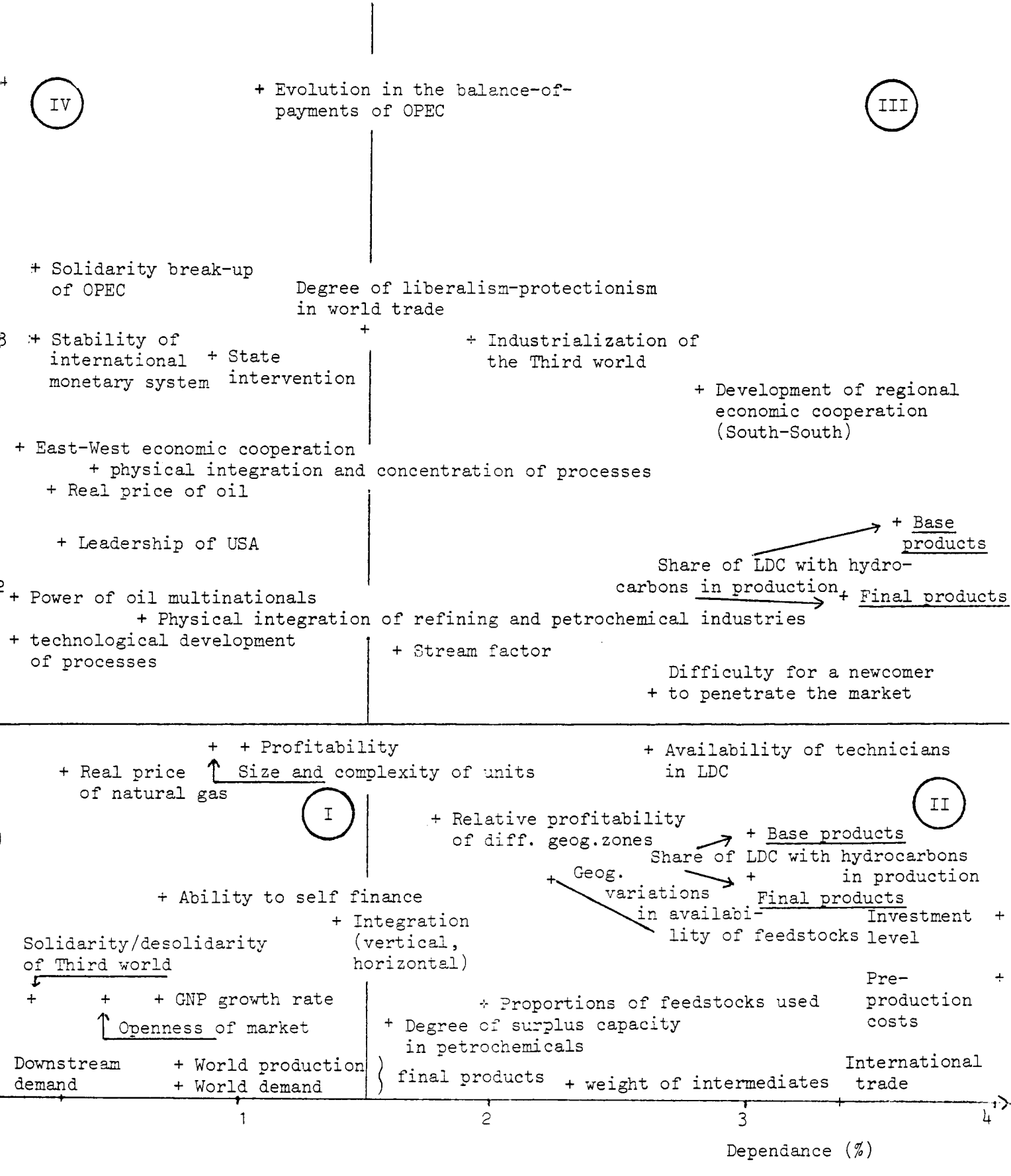
- Zone IV includes variables whose chief characteristic is motricity : these variables are strong factors of development, and as such should be taken into account in constructing scenarios.

It is interesting to compare the two analyses. They give nearly equivalent results when potential relationships are not taken into account, except in the case of a few variables, particularly "North-South economic cooperation", with less motricity (4.5%), "Economic cooperation", much less dependent (0.9%), "USA leadership", with less motricity (1.2%).
This point confirms that the analysis is robust and stable, in the sense that the inclusion or exclusion of a set of more marginal relationships does not basically affect the results.

+ North-South economic cooperation

Motricity (%)

Diagram 2.2




Positioning of chief variables

Full comprehension of the schema calls for a few explanatory remarks :

- Instability factors all relate to the same pheomenon : the emergence of the Third World countries as industrial powers, increasingly taking part in international trade, particularly through their petrochemical production. For this reason, close attention should be paid to the strategy of the LDC processing petroleum resources, as well as to the terms of their implantation : the necessity of meeting technical constraints (stream factors, availability of technicians) together with their ability to penetrate the market.

- Among the variables characterized by high motricity are found well at the head of the list, not only those variables relating to certain world economic context, but also variables relating to certain actors of the system and whose role is essential : OPEC, governments, oil multinationals. Found here also are variables pertaining to the technological context and thus relating to the structure and organization of the petrochemical industry.

- Investment levels and production costs, which are in principle (especially the former) control levers for the petrochemical industry, appear to be variables having little motricity and being very dependent : this is an important result defying normal supposition which should normally mean that the dynamics of the petrochemical industry are not simply economic and that other factors (especially political ones, tied to the actors' strategy) have an important impact.

- International trade is basically dependent : it takes place for the purpose of palliating disequilibrium (natural or artificial), and is therefore mainly a phenomenon of result. The surplus capacity-level of the petrochemical industry does not appear to be a factor of instability (weak motricity).

In reality, it is geographical capacity distribution which creates unbalance with surplus capacity on a worldwide scale appearing here as a result.

- Supply and demand variables, and other variables in general which relate to market organization by this analysis, are shown to possess very little motricity, which is an additional counter intuitive result and which reinforces an observation previously made : the explanatory factors in the development of petrochemicals are not solely the standard market mechanisms. In other words, the petrochemical industry creates, to a large extent, its own demand.

## B - Analysis of results

The detailed analysis of the various orderings brings out and clarifies these different points.

In each analysis, the variables submitted to two orderings, or rankings :

- direct ranking (left side), in which the variables are classed according to number of direct relationships they have with the system or structure,

- MICMAC ranking (right side), in which the variables are classed according to the influence they exercise on the system (including indirect effects),

The variables are identified by the rank they hold in the MICMAC ordering.

### 1 - Global analyses

General ranking establishes the hierarchy of all variables in the system in terms of both motricity and dependence.

General motricity

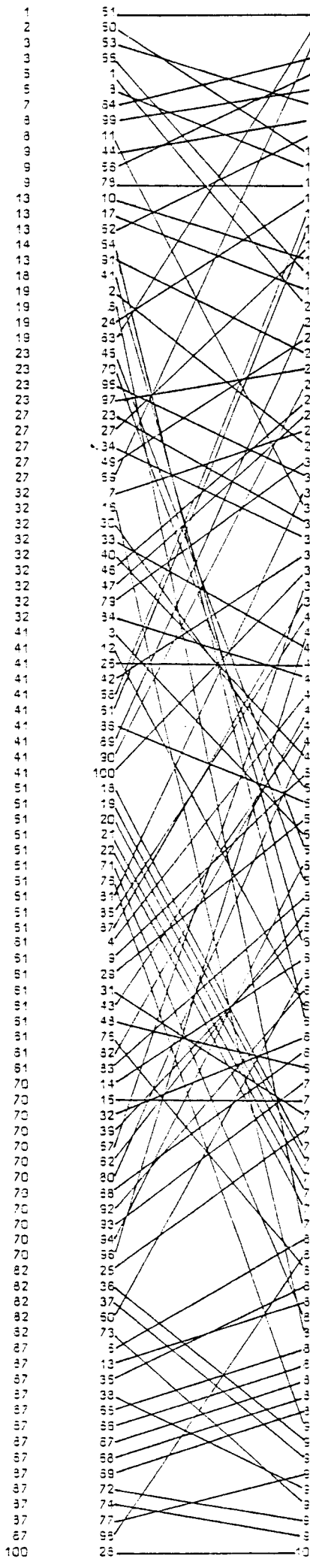
The leading variables are environment variables relating to the worldwide politico-economic context.

Evident is the advance in rank of all the policy variables : OPEC solidarity/break-up (3rd), USA leadership (14th), power detained by oil multinationals (15th), political weight of Eastern block (38th).

The advance in rank of certain technology variables is also visible : local variations in building costs (21st), availability of technicians in the LDC (25th).

The importance of still other technology variables finds confirmation : rate of technological transfer (8th), physical integration and concentration of petrochemical processes (11th), stream factor (19th), technological development of processes (20th), transport-related constraints (23rd), variation in the average size and complexity of petrochemical units (28th), technological development of plants and machinery (29th).

Diagram 2.3




| rank | variable | rank | variable | |
|---|---|---|---|---|
| 1 | 51 | 1 | 51 | North-South economic cooperation |
| 2 | 60 | 2 | 63 | Development of the balance-of-payments of the OPEC countries |
| 3 | 53 | 3 | 59 | Solidarity/break-up of OPEC |
| 3 | 65 | 4 | 64 | Stability of the international monetary system |
| 5 | 1 | 5 | 56 | Industrialization of the Third World |
| 5 | 3 | 6 | 99 | State intervention in the petrochemical industry |
| 7 | 64 | 7 | 53 | Degree of liberalism/protectionism in world trade |
| 8 | 99 | 8 | 44 | Rate of technological transfer |
| 8 | 11 | 9 | 52 | Development of regional economic cooperation (South-South) |
| 9 | 44 | 10 | 50 | East-West economic cooperation |
| 9 | 58 | 11 | 8 | Physical integration and concentration of petrochemical processes |
| 9 | 79 | 12 | 78 | Real price of oil |
| 13 | 10 | 13 | 24 | Share of LDC with hydrocarbon resources in the total production of base products |
| 13 | 17 | 14 | 58 | Leadership of the USA in the Western World |
| 13 | 62 | 15 | 61 | Power of the oil multinationals |
| 14 | 54 | 16 | 27 | Share of LDC with hydrocarbon resources in the total production of final products |
| 13 | 31 | 17 | 10 | Physical integration of refining and petrochemical industries |
| 18 | 41 | 18 | 55 | Relative growth of developing and industrialized countries |
| 19 | 2 | 19 | 17 | Ratio up-time/down-time |
| 19 | 5 | 20 | 1 | Technological development of processes |
| 19 | 24 | 21 | 89 | Local variations in building costs |
| 19 | 83 | 22 | 49 | Difficulty for a newcomer to penetrate market |
| 23 | 45 | 23 | 91 | Transport-related constraints |
| 23 | 70 | 24 | 97 | Fiscal constraints |
| 23 | 95 | 25 | 90 | Availability of technicians in the LDC |
| 23 | 97 | 26 | 46 | Profitability of petrochemical industry in base products |
| 27 | 23 | 27 | 47 | Profitability of petrochemical industry in final products |
| 27 | 27 | 28 | 7 | Variation in the average size and complexity of petrochemical units |
| 27 | 34 | 29 | 2 | Technological development of plant and machinery |
| 27 | 49 | 30 | 79 | Real price of natural gas |
| 27 | 69 | 31 | 95 | Environmental constraints, anti-waste movement, etc. |
| 32 | 7 | 32 | 81 | Proven level of world hydrocarbon reserves |
| 32 | 15 | 33 | 11 | Research effort |
| 32 | 22 | 34 | 23 | Share of LDC without hydrocarbon resources in the total production of base products |
| 32 | 33 | 35 | 34 | Use of locally-available resources by petrochemical firms |
| 32 | 40 | 36 | 42 | Relative profitability of different geographical zones |
| 32 | 48 | 37 | 100 | Labour constraints |
| 32 | 47 | 38 | 57 | Political weight of Eastern block |
| 32 | 73 | 39 | 87 | Local departures from world prices for feedstocks |
| 32 | 84 | 40 | 85 | Geographical variation in the availability of feedstocks |
| 41 | 3 | 41 | 96 | Anti-monopolistic legislation |
| 41 | 12 | 42 | 33 | Degree of price competition between firms |
| 41 | 26 | 43 | 26 | Share of LDC without hydrocarbon resources in the total production of final products |
| 41 | 42 | 44 | 84 | The use of new feedstocks (coal, vegetal waste, shale) |
| 41 | 88 | 45 | 4 | Flexibility of processes downstream |
| 41 | 61 | 46 | 82 | Preservation of hydrocarbons |
| 41 | 86 | 47 | 43 | Ability to self finance |
| 41 | 89 | 48 | 80 | Cost of energy substitutes |
| 41 | 90 | 49 | 40 | Real prices of base products |
| 41 | 100 | 50 | 9 | Breakdown of total costs between fixed and variable |
| 51 | 18 | 51 | 20 | Degree of vertical integration of petrochemical companies with oil companies |
| 51 | 19 | 52 | 86 | Relative prices of feedstocks |
| 51 | 20 | 53 | 29 | Degree of fragmentation of production (horizontal integration) |
| 51 | 21 | 54 | 3 | Flexibility of processes in regard to feedstock |
| 51 | 22 | 55 | 45 | Level of investment in petrochemical industry |
| 51 | 71 | 56 | 94 | Availability of capital equipment for petrochemicals |
| 51 | 75 | 57 | 70 | Geographical spreading of the consumption of final products |
| 51 | 81 | 58 | 83 | Relative availability of petrochemical feedstocks |
| 51 | 85 | 59 | 62 | Influence of oil companies on petrochemical firms |
| 51 | 87 | 60 | 39 | Production costs |
| 61 | 4 | 61 | 41 | Real prices of final products |
| 61 | 9 | 62 | 14 | Evolution in the proportions of feedstocks used |
| 61 | 28 | 63 | 60 | Solidarity/desolidarity of Third World |
| 61 | 31 | 64 | 92 | Availability of capital |
| 61 | 43 | 65 | 12 | Valorisation of by-products |
| 61 | 48 | 66 | 54 | Rate of growth of world GNP |
| 61 | 76 | 67 | 32 | Openness of the market |
| 61 | 82 | 68 | 88 | Changes in equilibrium between demands made by energy and petrochemical sectors for |
| 61 | 85 | 69 | 48 | Degree of surplus capacity in the petrochemical industry / raw materials |
| 70 | 14 | 70 | 93 | Cost of capital |
| 70 | 15 | 71 | 15 | Emergence of new final products |
| 70 | 32 | 72 | 31 | Distribution agreements between producers |
| 70 | 39 | 73 | 25 | Share of Eastern block in the total production of base products |
| 70 | 57 | 74 | 18 | World production of plastics |
| 70 | 62 | 74 | 19 | World production of synthetic rubber |
| 70 | 80 | 74 | 20 | World production of synthetic fibres |
| 70 | 88 | 74 | 21 | World production of nitrogenous fertilizers |
| 70 | 92 | 74 | 22 | World production of detergents, paints, solvents |
| 70 | 93 | 75 | 6 | Ability to meet quality levels required by the market |
| 70 | 94 | 76 | 5 | Rate of technological obsolescence of plant |
| 70 | 98 | 77 | 98 | Supranational regulation of new investment projects |
| 82 | 25 | 78 | 75 | Changes in characteristics of non-petrochemical products |
| 82 | 36 | 79 | 35 | Importance of brokers |
| 82 | 37 | 80 | 13 | Emergence of new base products |
| 82 | 60 | 81 | 71 | Demand for automobiles |
| 82 | 73 | 82 | 16 | Competition characteristics of petrochemical/other products |
| 87 | 6 | 83 | 65 | World demand for plastics |
| 87 | 13 | 84 | 66 | World demand for synthetic rubbers |
| 87 | 35 | 85 | 67 | World demand for nitrogenous fertilizers |
| 87 | 38 | 86 | 68 | World demand for synthetic fibres |
| 87 | 65 | 87 | 69 | World demand for other products |
| 87 | 66 | 88 | 76 | New outlets for existing petrochemical products |
| 87 | 67 | 89 | 36 | International trade in base products |
| 87 | 68 | 90 | 37 | International trade in intermediate products |
| 87 | 69 | 91 | 77 | Relative prices of oil and non-energy raw materials |
| 87 | 72 | 92 | 38 | International trade in final products |
| 87 | 74 | 93 | 73 | Demand for building materials |
| 87 | 77 | 94 | 72 | Demand for textiles |
| 87 | 96 | 95 | 74 | Agricultural income |
| 100 | 26 | 100 | 28 | Share of Eastern block in the total production of final products |

Among the variables having less motricity than could be expected there is only one environment variable : rate of growth of world GNP (regressing from 13th to 66th place ) Also found here are two variables relating to firm strategy : research effort (9th to 32nd place), and level of investment in petrochemical industry (23rd to 55th place).

Most of the variables in this category, however, are market variables : geographical spreading of the consumption of final products (57th), real prices of final products (61st), ability to meet quality levels required by the market (79th), competition characteristics of petrochemical products/other products (32nd to 86th place).

Variables relating to supply, situated mid-way in direct ranking, regress by about 20 places, while demand variables remain at the bottom of the list.

Market organization therefore has, in general, a less marked influence than first supposed.

General dependence

Among the variables most affected by the development of the overall system are found two variables having great importance for the petrochemical industry : level of investment in the petrochemical industry (amount of money invested at a given moment), and production costs (includes investment and operating costs, but not distribution costs) (*). To be found here also are trade variables, together with local supply variables (LDC and Eastern countries).

The high sensitivity of the variable "Development of regional economic cooperation (South-South)" (10th) may be surprising ; in the analysis which excludes consideration of potential relationships, this variable is much less dependent. It is important, therefore, to be careful in drawing conclusions concerning the position of this variable.

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(*) Compare with the advance in position of variables "Profitability of petrochemical industry in base products" and "Profitability of petrochemical industry in final products", whose sensitivity is considerably on the increase, taking into account indirect effects (from 47th to 30th place, and 46th to 33rd, respectively).

GLOBAL DEPENDENCE

Diagram 2.4

| Direct ranking rank | variable | MICMAC ranking rank | variable | |
|---|---|---|---|---|
| 1 | 39 | 1 | 45 | Level of investment in petrochemical industry |
| 2 | 45 | 2 | 39 | Production costs |
| 3 | 37 | 3 | 37 | International trade in intermediate products |
| 4 | 24 | 4 | 24 | Share of LDC with hydrocarbon resources in the total production of base products |
| 4 | 38 | 5 | 38 | International trade in final products |
| 6 | 14 | 6 | 27 | Share of LDC with hydrocarbon resources in the total production of final products |
| 6 | 25 | 7 | 26 | Share of LDC without hydrocarbon resources in the total production of final products |
| 6 | 27 | 8 | 23 | Share of LDC without hydrocarbon resources in the total production of base products |
| 6 | 36 | 9 | 36 | International trade in base products |
| 6 | 49 | 10 | 52 | Development of regional economic cooperation (South-South) |
| 11 | 23 | 11 | 90 | Availability of technicians in the LDC |
| 11 | 42 | 12 | 49 | Difficulty for a newcomer to penetrate market |
| 13 | 3 | 13 | 35 | Importance of brokers |
| 14 | 95 | 14 | 95 | Geographical variation in the availability of feedstocks |
| 14 | 85 | 15 | 14 | Evolution in the proportions of feedstocks used |
| 16 | 84 | 16 | 56 | Industrialization of the Third World |
| 17 | 17 | 17 | 42 | Relative profitability of different geographical zones |
| 17 | 87 | 18 | 48 | Degree of surplus capacity in the petrochemical industry |
| 17 | 88 | 19 | 17 | Ratio up-time/down-time |
| 17 | 89 | 20 | 30 | Degree of vertical integration of petrochemical companies with oil companies |
| 21 | 7 | 21 | 9 | Breakdown of total costs between fixed and variable |
| 21 | 96 | 22 | 25 | Share of Eastern block in the total production of base products |
| 21 | 90 | 22 | 28 | Share of Eastern block in the total production of final products |
| 24 | 29 | 24 | 3 | Flexibility of processes in regard to feedstock |
| 24 | | 25 | 41 | Real prices of final products |
| 24 | 44 | 26 | 29 | Degree of fragmentation of production (horizontal integration) |
| 24 | 52 | 27 | 53 | Development of the balance-of-payments of the OPEC countries |
| 24 | 99 | 28 | 84 | The use of new feedstocks (coal, vegetal wasts, shale) |
| 29 | 3 | 29 | 53 | Degree of liberalism/protectionism in world trade |
| 29 | 11 | 30 | 47 | Profitability of petrochemical industry in final products |
| 29 | 12 | 31 | 99 | State intervention in the petrochemical industry |
| 29 | 43 | 32 | 7 | Variation of the average size and complexity of petrochemical units |
| 29 | 53 | 33 | 46 | Profitability of petrochemical industry in base products |
| 29 | 54 | 34 | 31 | Distribution agreements between producers |
| 29 | 58 | 35 | 33 | Degree of price competition between firms |
| 36 | 5 | 36 | 40 | Real prices of base products |
| 36 | 16 | 37 | 20 | World production of synthetic fibres |
| 36 | 26 | 38 | 18 | World production of plastics |
| 36 | 28 | 39 | 67 | World demand for nitrogenous fertilizers |
| 36 | 30 | 40 | 21 | World production of nitrogenous fertilizers |
| 36 | 31 | 41 | 22 | World production of detergents, paints, solvents |
| 36 | 33 | 42 | 65 | World demand for plastics |
| 36 | 34 | 43 | 19 | World production of synthetic rubber |
| 36 | 40 | 44 | 94 | Availability of capital equipment for petrochemicals |
| 36 | 41 | 45 | 58 | World demand for synthetic fibres |
| 36 | 66 | 46 | 44 | Rate of technological transfer |
| 36 | 79 | 47 | 43 | Ability to self-finance |
| 46 | 8 | 48 | 69 | World demand for other products |
| 46 | 10 | 49 | 70 | Geographical spreading of the consumption of final products |
| 48 | 55 | 50 | 34 | Use of locally-available resources by petrochemical firms |
| 48 | 60 | 51 | 66 | World demand for synthetic rubbers |
| 48 | 61 | 52 | 54 | Rate of growth of world GNP |
| 48 | 63 | 53 | 92 | Availability of capital |
| 48 | 70 | 54 | 87 | Local departures from world prices for feedstocks |
| 48 | 71 | 55 | 10 | Physical integration of refining and petrochemical industries |
| 48 | 75 | 56 | 55 | Relative growth of developing and industrialized countries |
| 48 | 77 | 57 | 11 | Research effort |
| 48 | 83 | 58 | 74 | Agricultural income |
| 48 | 87 | 59 | 100 | Labour constraints |
| 48 | 92 | 60 | 98 | Supranational regulation of new investment projects |
| 61 | 6 | 61 | 32 | Openness of the market |
| 61 | 13 | 62 | 75 | Changes in characteristics of non-petrochemical products |
| 61 | 32 | 63 | 62 | Influence of oil companies on petrochemical firms |
| 61 | 42 | 64 | 83 | Relative availability of petrochemical feedstocks |
| 61 | 45 | 65 | 8 | Physical integration and concentration of petrochemical processes |
| 61 | 47 | 66 | 68 | Changes in equilibrium between demands made by energy and petrochemical sectors for raw materials |
| 61 | 51 | 67 | 72 | Demand for textiles |
| 61 | 62 | 68 | 16 | Competition characteristics of petrochemical/other products |
| 61 | 72 | 69 | 12 | Valorisation of by-products |
| 61 | 74 | 70 | 79 | Real price of natural gas |
| 61 | 78 | 71 | 13 | Emergence of new base products |
| 61 | 86 | 72 | 5 | Rate of technological obsolescence of plant |
| 61 | 88 | 73 | 51 | North-South economic cooperation |
| 61 | 98 | 74 | 39 | Local variations in building costs |
| 75 | 1 | 75 | 58 | Leadership of the USA in the Western World |
| 75 | 15 | 76 | 77 | Relative prices of oil and non-energy raw materials |
| 75 | 59 | 77 | 71 | Demand for automobiles |
| 75 | 73 | 78 | 64 | Stability of the international monetary system |
| 75 | 100 | 79 | 50 | Solidarity/desolidarity of Third World |
| 80 | 4 | 80 | 86 | Relative prices of feedstocks |
| 80 | 9 | 81 | 97 | Fiscal constraints |
| 80 | 18 | 82 | 59 | Solidarity/break-up of OPEC |
| 80 | 20 | 83 | 73 | Demand for building materials |
| 80 | 24 | 84 | 82 | Preservation of hydrocarbons |
| 80 | 22 | 85 | 6 | Ability to meet quality levels required by the market |
| 80 | 50 | 86 | 78 | Real price of oil |
| 80 | 57 | 87 | 15 | Emergence of final products |
| 80 | 64 | 88 | 91 | Transport-related constraints |
| 80 | 76 | 89 | 93 | Cost of capital |
| 80 | 81 | 90 | 4 | Flexibility of processes downstream |
| 80 | 82 | 91 | 76 | New outlets for existing petrochemical products |
| 80 | 91 | 92 | 61 | Power of the oil multinationals |
| 80 | 93 | 93 | 1 | Technological development of processes |
| 80 | 94 | 94 | 60 | East-West economic cooperation |
| 80 | 97 | 95 | 2 | Technological development of plant and machinery |
| 96 | 2 | 96 | 57 | Political weight of Eastern block |
| 96 | 85 | 97 | 81 | Proven level of world hydrocarbon reserves |
| 98 | 80 | 98 | 80 | Cost of energy substitutes |
| 98 | 96 | 99 | 95 | Environmental constraints, anti-waste movement, etc. |
| 98 | 98 | 98 | 96 | Anti-monopolistic legislation |

The industrialization of the Third World is also fairly dependent on the development of the system, but probably more dependent on environment than on the internal system.

Equally to be found are consequence variables : "Degree of surplus capacity in the petrochemical industry" (18th),"Real prices of final products " (25th) (*), "Profitability of petrochemical industry in base products" (30th) and "Profitability of petrochemical industry in final products" (33rd), whose dependence is increasing.

Can be observed, a reduction in the dependence of demand variables, as well as a strong increase in the dependence of production variables ; these two being ultimately situated at the same level. To be seen there is a result which is, in fact, the system's answer to the instability which was pointed out earlier. Supply may exercise a regulating role (hence its sensitivity), translated by the possible emergence of surplus production capacities and evolutions in price, variables which are also very dependent (**).

Among little sensitive variables are a good number of political and economic ones, upon whom the evolution of the system has little effect :

"North-South economic cooperation" (73rd), "Leadership of USA in Western World" (75th), "Stability of the international monetary system" (78th), Solidarity/break-up of OPEC (82nd), "Power of the oil multinationals" (92nd), "Real price of natural gas (reference price, or international price)" (70th), "Real price of oil (reference price, or international price)" (86th), "Proven level of world hydrocarbon reserves" (97th), "Cost of energy substitutes (nuclear energy, shale, tar sands, etc.) (98th), "Relative prices of oil and non-energy raw materials (rubber, fibres, phosphates, bauxite, wood, etc.)" (80th).

---

(*) Which are more sensitive than variable "Real prices of base products" (36th).

(**) Neither supply nor demand are factors of instability, being variables possessing very little motricity.

Found here are also a fair number of technology variables : "Rate of technological obsolescence of plant" (72nd), "Local variations in building costs (including those due to different infrastructure and environmental conditions) (74th) "Transport-related constraints (technology, costs)" (88th), "Flexibility of processes downstream (ability to adjust proportions of different products output, e.g. ethylene, propylene, butadiene, aromatics)" (90th) (*), "Technological development of plants and machinery".

## 2 - Block analysis

The hierarchy of the variables (external and internal) being the same as in the former analysis, we shall concentrate here on the comparative results of the direct ranking analysis and the MICMAC ordering.

### a) Influence of environment

Motricity of environment variables in the internal infrastructure (sub-system)

- Observable is a very strong gain in position regarding both policy and energy-related variables : "Real price of oil"(10th), "Power of the oil multinationals" (12th), "Proven level of world hydrocarbon reserves" (20th), "Cost of energy substitutes (nuclear energy, shale, tar sands, etc.)" (28th), "Changes in equilibrium between demands made by energy and petrochemical sectors for raw materials" (37th).

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(*) while flexibility of processes in regard to feedstock is indeed a particularly sensitive variable (24th), variables relating to raw materials are, on the whole, fairly sensitive. This fact demands special attention.

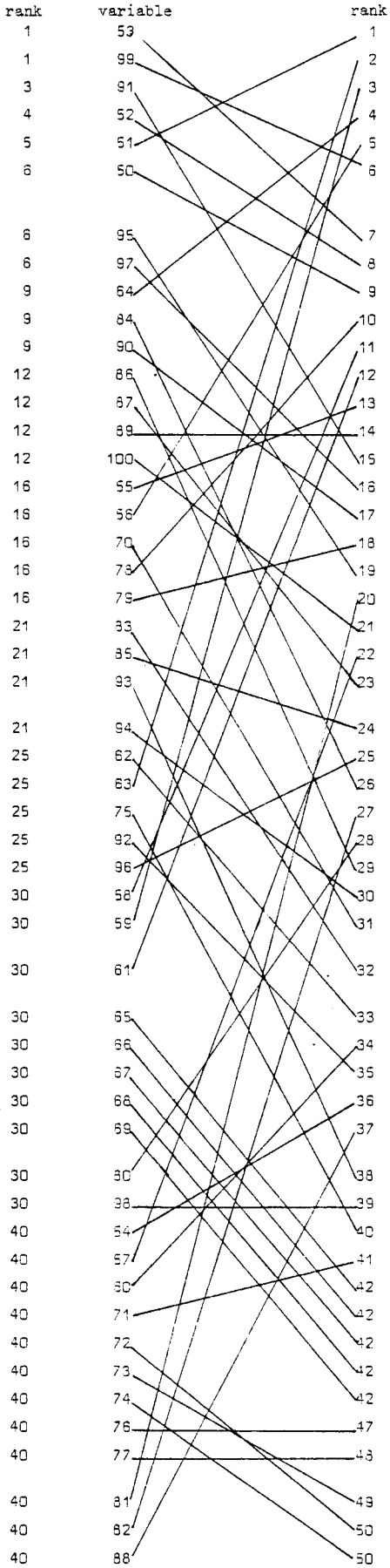
- Among variables having less motricity than supposed are : "Transport-related constraints" (15th), "Fiscal constraints" (16th), environmental constraints (19th). Here too are variables such as :"use of other raw materials"(locally available resources) (26th), "Relative prices of oil and non-energy raw materials"(29th).
  Also included are the various demand and market variables.

These phenomena of regressions in position, are on the whole of little significance, and are explained largely by the gains made by the policy and energy variables. It can be seen, then, that the future of the petrochemical industry is tied to the evolution of worldwide geopolitical problems, and in particular to those related to energy and oil.

Sensitivity of internal variables to environment

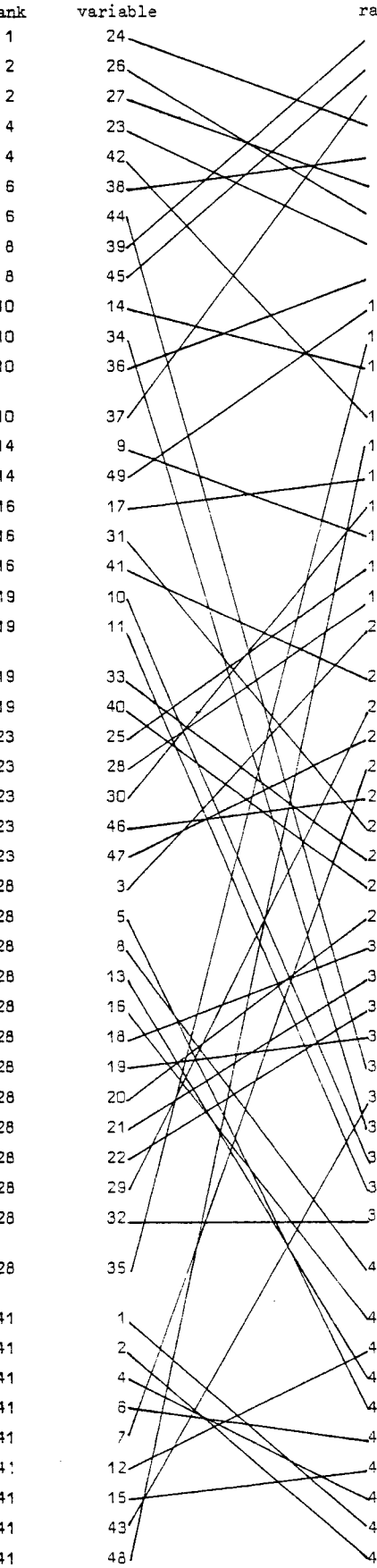
- At the head of the list are two key variables for petrochemicals : "level of investment in the petrochemical industry" (1st) and "Production costs" (2nd), results whose importance has been already underlined.

Diagram 2.5



| Direct ranking rank | Direct ranking variable | MICMAC ranking rank | MICMAC ranking variable | |
|---|---|---|---|---|
| 1 | 53 | 1 | 51 | North-South economic cooperation |
| 1 | 99 | 2 | 63 | Development of the balance-of-payments of the OPEC countries |
| 3 | 91 | 3 | 59 | Solidarity/break-up of OPEC |
| 4 | 52 | 4 | 64 | Stability of the international monetary system |
| 5 | 51 | 5 | 56 | Industrialization of the Third World |
| 6 | 50 | 6 | 99 | State intervention in the petrochemical industry (nationalizations) participations, policy definition, guidelines on activity levels, security of supplies, etc.) |
| 6 | 95 | 7 | 53 | Degree of liberalism/protectionism in world trade |
| 6 | 97 | 8 | 52 | Development of regional economic cooperation (South-South) |
| 9 | 64 | 9 | 50 | East-West economic cooperation |
| 9 | 84 | 10 | 78 | Real price of oil |
| 9 | 90 | 11 | 58 | Leadership of the USA in the Western World |
| 12 | 86 | 12 | 61 | Power of the oil multinationals |
| 12 | 87 | 13 | 55 | Relative growth of developing and industrialized countries |
| 12 | 89 | 14 | 89 | Local variations in building costs |
| 12 | 100 | 15 | 91 | Transport-related constraints |
| 16 | 55 | 16 | 97 | Fiscal constraints |
| 16 | 56 | 17 | 90 | Availability of technicians in the LDC |
| 16 | 70 | 18 | 79 | Real price of natural gas |
| 16 | 78 | 19 | 95 | Environmental constraints anti-waste movement, etc. |
| 16 | 79 | 20 | 81 | Proven level of world hydrocarbon reserves |
| 21 | 83 | 21 | 100 | Labour constraints |
| 21 | 85 | 22 | 57 | Political weight of Eastern block |
| 21 | 93 | 23 | 87 | Local departures from world prices for feedstocks |
| 21 | 94 | 24 | 85 | Geographical variation in the availability of feedstocks |
| 25 | 62 | 25 | 96 | Anti-monopolistic legislation |
| 25 | 63 | 26 | 84 | The use of new feedstocks (coal, vegetal waste, shale) |
| 25 | 75 | 27 | 82 | Preservation of hydrocarbons |
| 25 | 92 | 28 | 80 | Cost of energy substitutes |
| 25 | 96 | 29 | 86 | Relative prices of feedstocks |
| 30 | 58 | 30 | 94 | Availability of capital equipment for petrochemicals |
| 30 | 59 | 31 | 70 | Geographical spreading of the consumption of final products |
| 30 | 61 | 32 | 83 | Relative availability of petrochemical feedstocks |
| 30 | 65 | 33 | 62 | Influence of oil companies on petrochemical firms |
| 30 | 66 | 34 | 60 | Solidarity/desolidarity of Third World |
| 30 | 67 | 35 | 92 | Availability of capital |
| 30 | 68 | 36 | 54 | Rate of growth of world GNP |
| 30 | 69 | 37 | 88 | Changes in equilibrium between demands by energy and petrochemical sectors for raw materials |
| 30 | 80 | 38 | 93 | Cost of capital |
| 30 | 98 | 39 | 98 | Supranational regulation of new investment projects |
| 40 | 54 | 40 | 75 | Changes in characteristics of non-petrochemical products |
| 40 | 57 | 41 | 71 | Demand for automobiles |
| 40 | 60 | 42 | 65 | World demand for plastics |
| 40 | 71 | 42 | 66 | World demand for synthetic rubbers |
| 40 | 72 | 42 | 67 | World demand for nitrogenous fertilizers |
| 40 | 73 | 42 | 68 | World demand for synthetic fibres |
| 40 | 74 | 42 | 69 | World demand for other products (detergents, solvents, paints) |
| 40 | 76 | 47 | 76 | New outlets for existing petrochemical products |
| 40 | 77 | 48 | 77 | Relative prices of oil and non-energy raw materials |
| 40 | 81 | 49 | 73 | Demand for building materials |
| 40 | 82 | 50 | 72 | Demand for textiles |
| 40 | 88 | 50 | 74 | Agricultural income |

Diagram 2.6



| Direct ranking rank | variable | MICMAC ranking rank | variable | |
|---|---|---|---|---|
| 1 | 24 | 1 | 45 | Level of investment in petrochemical industry |
| 2 | 26 | 2 | 39 | Production costs |
| 2 | 27 | 3 | 37 | International trade in intermediate products |
| 4 | 23 | 4 | 24 | Share of LDC with hydrocarbon resources in the total production of base products |
| 4 | 42 | 5 | 38 | International trade in final products |
| 6 | 38 | 6 | 27 | Share of LDC with hydrocarbon resources in the total production of final products |
| 6 | 44 | 7 | 26 | Share of LDC without hydrocarbon resources in the total production of final products |
| 8 | 39 | 8 | 23 | Share of LDC without hydrocarbon resources in the total production of base products |
| 8 | 45 | 9 | 36 | International trade in base products |
| 10 | 14 | 10 | 49 | Difficulty for a newcomer to penetrate market |
| 10 | 34 | 11 | 35 | Importance of brokers |
| 10 | 36 | 12 | 14 | Evolution in proportions of feedstocks used |
| 10 | 37 | 13 | 42 | Relative profitability of different geographical zones |
| 14 | 9 | 14 | 48 | Degree of surplus capacity in the petrochemical industry |
| 14 | 49 | 15 | 17 | Ratio up-time/down-time |
| 16 | 17 | 16 | 30 | Degree of vertical integration of petrochemical companies with oil companies |
| 16 | 31 | 17 | 9 | Breakdown of total costs between fixed and variable |
| 16 | 41 | 18 | 25 | Share of Eastern block in the total production of base products |
| 19 | 10 | 18 | 28 | Share of Eastern block in the total production of final products |
| 19 | 11 | 20 | 3 | Flexibility of processes in regard to feedstock |
| 19 | 33 | 21 | 41 | Real prices of final products |
| 19 | 40 | 22 | 29 | Degree of fragmentation of production (horizontal integration) |
| 23 | 25 | 23 | 47 | Profitability of petrochemical industry in final products |
| 23 | 28 | 24 | 7 | Variation in the average size and complexity of petrochemical units |
| 23 | 30 | 25 | 46 | Profitability of petrochemical industry in base products |
| 23 | 46 | 26 | 31 | Distribution agreements between producers |
| 23 | 47 | 27 | 33 | Degree of price competition between firms |
| 28 | 3 | 28 | 40 | Real prices of base products |
| 28 | 5 | 29 | 20 | World production of synthetic fibres |
| 28 | 8 | 30 | 18 | World production of plastics |
| 28 | 13 | 31 | 21 | World production of nitrogenous fertilizers |
| 28 | 16 | 32 | 22 | World production of detergents, paints, solvents |
| 28 | 18 | 33 | 19 | World production of synthetic rubber |
| 28 | 19 | 34 | 44 | Rate of technological transfer |
| 28 | 20 | 35 | 43 | Ability to self-finance |
| 28 | 21 | 36 | 34 | Use of locally-available resources by petrochemical firms |
| 28 | 22 | 37 | 10 | Physical integration of refining and petrochemical industries |
| 28 | 29 | 38 | 11 | Research effort |
| 28 | 32 | 39 | 32 | Openness of the market |
| 28 | 35 | 40 | 8 | Physical integration and concentration of petrochemical processes |
| 41 | 1 | 41 | 16 | Competition characteristics of petrochemical/other products |
| 41 | 2 | 42 | 12 | Valorisation of by-products |
| 41 | 4 | 43 | 13 | Emergence of new base products |
| 41 | 6 | 44 | 5 | Rate of technological obsolescence of plant |
| 41 | 7 | 45 | 6 | Ability to meet quality levels required by the market |
| 41 | 12 | 46 | 15 | Emergence of new final products |
| 41 | 15 | 47 | 4 | Flexibility of processes downstream |
| 41 | 43 | 48 | 1 | Technological development of processes |
| 41 | 48 | 49 | 2 | Technological development of plant and machinery |

- Very sensitive also are localization variables (4th, 6th, 7th, 8th) and international trade variables - especially the weight of intermediate products (11th), which shows strong advancement - as well as the degree of surplus capacity in the petrochemical industry (14th).
- The reduced sensitivity of two variables is worth noting : "Rate of technological transfer" (dropping from 6th to 34th place), and "Use of locally available resources by petrochemical firms" (from 10th to 36th place). These are two variables which seem to depend more on very external factors (state politics or multinational firm policy).
- Also of interest is the gain of two structure variables : "Degree of fragmentation of production (horizontal integration)" (22nd) and "Variation in the average size and complexity of petrochemical units" (to be compared with the position occupied by the variable "level of investment in the petrochemical industry).

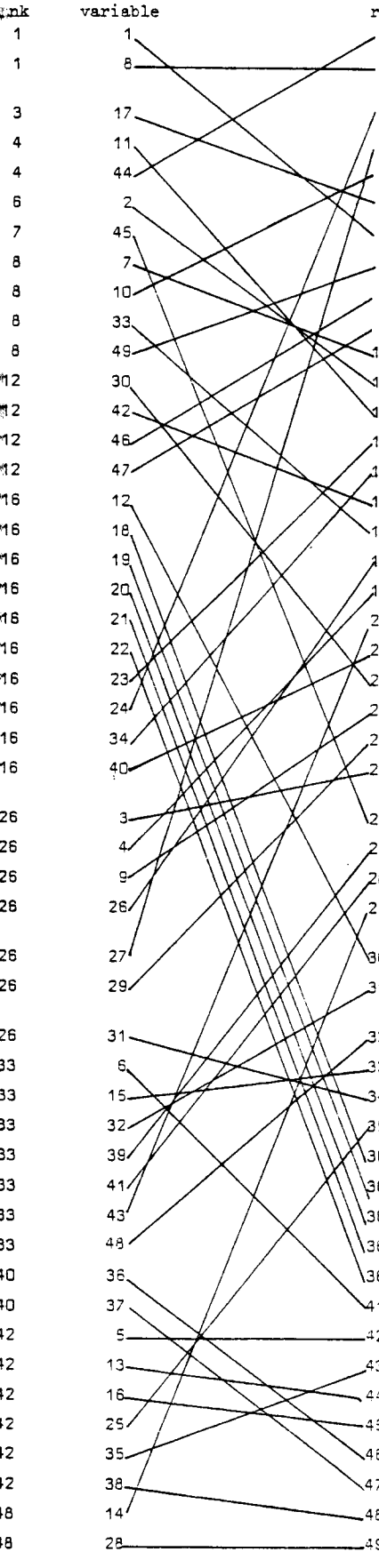
b) Influence of the internal system

The study of the two following analysis rankings (motricity and dependence of internal variables with regard to the internal system) confirms the results obtained in the foregoing analysis. It can be seen that the level of investment is less of a motricity factor than imagined (and more dependent, as already seen). The same is true of production variables. Two variables, however, "Evolution in the proportions of feedstocks used" (29th) and "Ability to self-finance" (20th), make here an important gain, and accordingly show an impact previously under-estimated.

Relative to the sensitivity of internal variables to the evolution of the internal system, the variable "Valorization of by-products" (42nd) has greatly regressed. The policy of finding outlets for by-products in order to discourage competition is a measure which merits following insofar as this policy is little apt to be compromised by evolution taking place within the internal system.

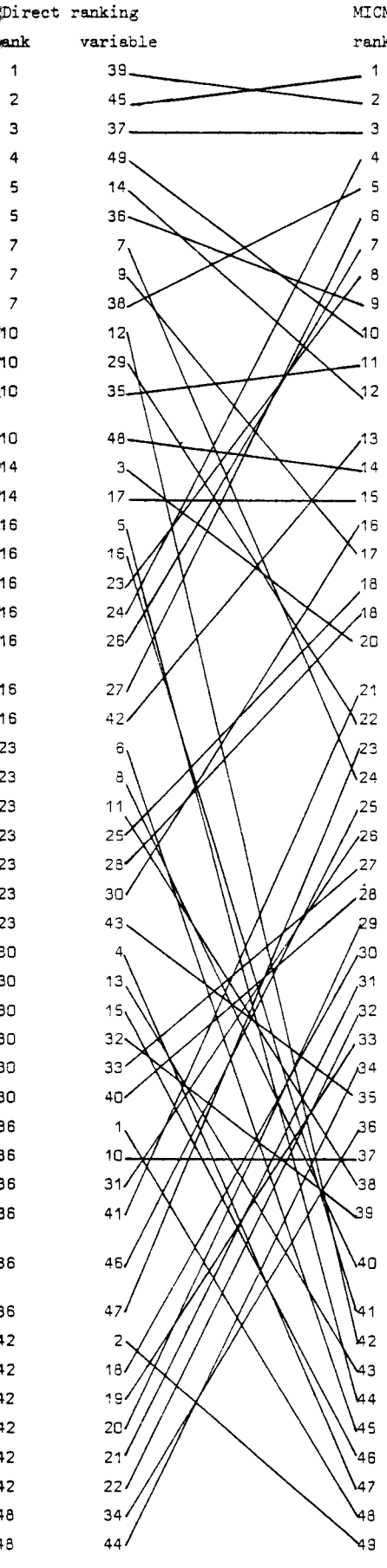
On the other hand, the rate of technological obsolescence of plants (44th) could possibly be a burdening trend rather than a conjunctural factor dependent on the evolution of the petrochemical industry.

Diagram 2.7



| Direct ranking | | MICMAC ranking | | |
|---|---|---|---|---|
| rank | variable | rank | variable | |
| 1 | 1 | 1 | 44 | Rate of technological transfer |
| 1 | 8 | 2 | 8 | Physical integration and concentration of petrochemical processes |
| 3 | 17 | 3 | 24 | Share of LDC with hydrocarbon resources in the total production of base products |
| 4 | 11 | 4 | 27 | Share of LDC with hydrocarbon resources in the total production of final products |
| 4 | 44 | 5 | 10 | Physical integration of refining and petrochemical industries |
| 6 | 2 | 6 | 17 | Ratio up-time/down-time |
| 7 | 45 | 7 | 1 | Technological development of processes |
| 8 | 7 | 8 | 49 | Difficulty for a newcomer to penetrate market |
| 8 | 10 | 9 | 46 | Profitability of petrochemical industry in base products |
| 8 | 33 | 9 | 47 | Profitability of petrochemical industry in final products |
| 8 | 49 | 11 | 7 | Variation in the average size and complexity of petrochemical units |
| 12 | 30 | 12 | 2 | Technological development of plant and machinery |
| 12 | 42 | 13 | 11 | Research effort |
| 12 | 46 | 14 | 23 | Share of LDC without hydrocarbon resources in the total production of base products |
| 12 | 47 | 15 | 34 | Use of locally-available resources in petrochemical firms |
| 16 | 12 | 16 | 42 | Relative profitability of different geographical zones |
| 16 | 18 | 17 | 33 | Degree of price competition between firms |
| 16 | 19 | 18 | 26 | Share of LDC without hydrocarbon resources in the total production of final products |
| 16 | 20 | 19 | 4 | Flexibility of processes downstream |
| 16 | 21 | 20 | 43 | Ability to self-finance |
| 16 | 22 | 21 | 40 | Real prices of base products |
| 16 | 23 | 22 | 30 | Degree of vertical integration of petrochemical companies with oil companies |
| 16 | 24 | 23 | 9 | Breakdown of total costs between fixed and variable |
| 16 | 34 | 24 | 29 | Degree of fragmentation of production |
| 16 | 40 | 25 | 3 | Flexibility of processes in regard to feedstock |
| 26 | 3 | 26 | 45 | Level of investment in petrochemical industry |
| 26 | 4 | 27 | 39 | Production costs |
| 26 | 9 | 28 | 41 | Real prices of final products |
| 26 | 26 | 29 | 14 | Evolution in the proportions of feedstocks used |
| 26 | 27 | 30 | 12 | Valorisation of by-products |
| 26 | 29 | 31 | 32 | Openness of the market |
| 26 | 31 | 32 | 48 | Degree of surplus capacity in the petrochemical industry |
| 33 | 6 | 33 | 15 | Emergence of new final products |
| 33 | 15 | 34 | 31 | Distribution agreements between producers |
| 33 | 32 | 35 | 25 | Share of Eastern block in the total production of base products |
| 33 | 39 | 36 | 18 | World production of plastics |
| 33 | 41 | 36 | 19 | World production of synthetic rubber |
| 33 | 43 | 36 | 20 | World production of synthetic fibres |
| 33 | 48 | 36 | 31 | Distribution agreements between producers |
| 40 | 36 | 36 | 22 | World production of detergents, paints, solvents |
| 40 | 37 | 41 | 6 | Ability to meet quality levels required by the market |
| 42 | 5 | 42 | 5 | Rate of technological obsolescence of plant |
| 42 | 13 | 43 | 35 | Importance of brokers |
| 42 | 16 | 44 | 13 | Emergence of new base products |
| 42 | 25 | 45 | 16 | Competition characteristics of petrochemical/other products |
| 42 | 35 | 46 | 36 | International trade in base products |
| 42 | 38 | 47 | 37 | International trade in intermediate products |
| 48 | 14 | 48 | 38 | International trade in final products |
| 48 | 28 | 49 | 28 | Share of Eastern block in the total production of final products |

Diagram 2.8



| Direct ranking rank | variable | MICMAC ranking rank | variable | |
|---|---|---|---|---|
| 1 | 39 | 1 | 45 | Level of investment in petrochemical industry |
| 2 | 45 | 2 | 39 | Production costs |
| 3 | 37 | 3 | 37 | International trade in intermediate products |
| 4 | 49 | 4 | 24 | Share of LDC with hydrocarbon resources in the total production of base products |
| 5 | 14 | 5 | 38 | International trade in final products |
| 5 | 36 | 6 | 27 | Share of LDC with hydrocarbon resources in the total production of final products |
| 7 | 7 | 7 | 26 | Share of LDC without hydrocarbon resources in tht total production of final products |
| 7 | 9 | 8 | 23 | Share of LDC without hydrocarbon resources in the total production of base products |
| 7 | 38 | 9 | 36 | International trade in base products |
| 10 | 12 | 10 | 49 | Difficulty for a newcomer to penetrate market |
| 10 | 29 | 11 | 35 | Importance of brokers |
| 10 | 35 | 12 | 14 | Evolution in the proportions of feedstocks used |
| 10 | 48 | 13 | 42 | Relative profitability of different geographical zones |
| 14 | 3 | 14 | 48 | Degree of surplus capacity in the petrochemical industry |
| 14 | 17 | 15 | 17 | Ratio up-time/down-time |
| 16 | 5 | 16 | 30 | Degree of vertical integration of petrochemical companies with oil companies |
| 16 | 16 | 17 | 9 | Breakdown of total costs between fixed and variable |
| 16 | 23 | 18 | 25 | Share of Eastern block in the total production of base products |
| 16 | 24 | 18 | 28 | Share of Eastern block in the total production of final products |
| 16 | 26 | 20 | 3 | Flexibility of processes in regard to feedstock |
| 16 | 27 | 21 | 41 | Real prices of final products |
| 16 | 42 | 22 | 29 | Degree of fragmentation of production (horizontal integration) |
| 23 | 6 | 23 | 47 | Profitability of petrochemical industry in final products |
| 23 | 8 | 24 | 7 | Variation in the average size and complexity of petrochemical units |
| 23 | 11 | 25 | 46 | Profitability of petrochemical industry in base products |
| 23 | 25 | 26 | 31 | Distribution agreements between producers |
| 23 | 28 | 27 | 33 | Degree of price competition between firms |
| 23 | 30 | 28 | 40 | Real prices of base products |
| 23 | 43 | 29 | 20 | World production of synthetic fibres |
| 30 | 4 | 30 | 18 | World production of plastics |
| 30 | 13 | 31 | 21 | World production of nitrogenous fertilizers |
| 30 | 15 | 32 | 22 | World production of detergents, paints, solvents |
| 30 | 32 | 33 | 19 | World production of synthetic rubber |
| 30 | 33 | 34 | 44 | Rate of technological transfer |
| 30 | 40 | 35 | 43 | Ability to self-finance |
| 36 | 1 | 36 | 34 | Use of locally-available resources by petrochemical firms |
| 36 | 10 | 37 | 10 | Physical integration of refining and petrochemical industries |
| 36 | 31 | 38 | 11 | Research effort |
| 36 | 41 | 39 | 32 | Openness of the market (relative importance of free markets, captive markets, long-term delivery agreements, etc.) |
| 36 | 46 | 40 | 8 | Physical integration and concentration of petrochemical processes |
| 36 | 47 | 41 | 16 | Competition characteristics of petrochemical/other products |
| 42 | 2 | 42 | 12 | Valorisation of by-products |
| 42 | 18 | 43 | 13 | Emergence of new base products |
| 42 | 19 | 44 | 5 | Rate of technological obsolescence of plant |
| 42 | 20 | 45 | 6 | Ability to meet quality levels required by the market |
| 42 | 21 | 46 | 15 | Emergence of new final products |
| 42 | 22 | 47 | 4 | Flexibility of processes downstream |
| 48 | 34 | 48 | 1 | Technological development of processes |
| 48 | 44 | 49 | 2 | Technological development of plant and machinery |

## C - Conclusion

The distribution of variables from the standpoint of motricity/dependence, and comparisons made between direct-ranking analysis and MICMAC ordering result in the following conclusions :

a. World petrochemical scenarios for 1990 should accord great importance to the development of international relationships namely

- the terms of industrial development applicable to developing countries,

- Government policies towards petrochemicals, protectionism, energy and oil multinationals,

- OPEC solidarity, and the evolution of its financial situation.

b. Important factors of instability are revealed : the creation of local production units and, in particular, the production share of LDC with hydrocarbon resources, along with the stream factor.

Consequently, for constructing a stimulation model, means are needed for adapting production capacities to the evolution of both the economic and political contexts (N.B. the level of investment in the petrochemical industry is the most dependent of all the variables).
The same is true for international trade.

c. Among the actors either directly or indirectly involved in the fundamental variables are :

- the multinational oil firms,

- the petrochemical firms, distinguishing independent multinational petrochemical companies (non-affiliates of oil multinationals), independent national petrochemical companies (*) and petrochemical firms which are affiliates of oil multinationals,

- the government of industrialized countries with market economies, distinguishing the USA and the various OECD countries,

- the government of socialist countries

- the governments of developing countries with hydrocarbon reserves, distinguishing the LDC with/without internal markets,

- the governments of developing countries without hydrocarbon reserves,

- oil multinational consumers of final products.

Within each group of actors, there obviously exist differences which are sometimes important ; nevertheless, each actor of a given group has objectives and means which more closely resemble those of the other actors of the same group than those of other groups.

The purpose of the next phase of the study is to identify the projects, strong points and weaknesses of each actor in order to determine to what degree their role could appreciably change the evolution of the petrochemical system, and which hypotheses should therefore be formulated.

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(*) State controlled national firms are not actors, but rather, means of action utilized for State benefit.

# III - PETROCHEMICAL INDUSTRY - RETROSPECTIVE

## A - Purpose of retrospective analysis

Having presented the variables which characterize the petrochemical industry and its environment, and brought out which of these are the most motor and which are the most sensitive, the purpose of this section is to show the way in which the more important of these variables have evolved in the past, what impact they have had on the petrochemical industry, and why. The aim is thus not to give a detailed historical account of the development of the world petrochemicals industry, which would be in any case a most formidable task, outside the scope of this report.

This retrospective analysis is carried out at a level of detail broadly commensurate with that embodied in the list of variables, thus at a rather general level. The objective is to look at the mechanisms which have influenced the industry in the past, so that a judgement can be made as to whether they will continue to operate in the future, and so on.

## B - Introduction - Rise of petrochemicals

While several of the major synthetic polymers were discovered in the nineteenth century, it was not until the late 1920s and early 1930s that commercial production began, and that their chemistry came to be properly understood. Most of the pioneering commercial activity was carried out in Germany and the USA. The second world war gave some impetus to the synthetic polymer industry, but a major constraint was the relatively high manufacturing costs. Until the 1950s these products derived essentially either from coal, passing through a variety of processes, or were produced by fermentation, wood distillation, etc. With the rise of the petroleum and natural gas refining industries, however, new and attractive feedstocks became available for the manufacture of artificial polymers, and during the 1950s these new feedstocks rapidly displaced the older processes for the manufacture of organic chemicals.

Early demand for petrochemical products came from the automobile industry, which created requirements for special paints, anti-freeze, and fuel additives. Later on, synthetic rubber, synthetic fibres, and plastics began to be manufactured. Because of their favourable characteristics in terms of cost, and often quality, these latter products were able to create enormous markets for themselves by at least partially supplanting their competitors, i.e. natural fibres, natural rubber, wood, paper, etc, on the basis of improved cost or quality. In many other cases, petrochemicals have succeeded in creating new markets by developing products with qualities not previously available, for example.

Since the war, the world has witnessed an explosive growth in the petrochemical industry. Table 3.1 shows how the consumption of the most important groups of petrochemical final products has increased since the inception of the industry.

Table 3.1 - Growth in world demand for principal petrochemical final products (million of tons)

| | 1959 | 1960 | 1970 | 1976 |
|---|---|---|---|---|
| Plastics | 1.5 | 7.0 | 30.0 | 42.6 |
| Synthetic fibres | 0.1 | 0.7 | 5.1 | 9.3 |
| Synthetic rubbers | 0.7 | 2.0 | 5.9 | 7.7 |
| Detergents | 0.7 | 3.5 | 9.0 | 14.8 |
| Nitrogenous fertilizers* | | 12.0 | 29.0 | 43.3 |

* In tons of N

Thus growth rates for petrochemicals have been historically far higher than the general rate of world economic growth, and higher also than the growth of inorganic chemicals. The growth has not been restricted to volumes, but also affected the numbers and qualities of products. Technical improvements in the processes, and the discovery of new processes have made available whole ranges of new products.

Up until the present, the petrochemical industry has largely been confined to the industrialized countries. Thus in 1973, for example, about 88% of world production of ethylene, 86% of plastics, and 88% of synthetic fibres, occurred in industrialized countries in the West, with Eastern block countries accounting for over half the balance in each case.

Factors which particularly characterize the petrochemicals industry are as follows :

- capital intensiveness
- high technology
- large scale
- energy intensiveness
- vitally dependent on feedstock provided by the energy sector

Most of these factors are considered further below.

## C - Location of industry, geographical distribution of supply and demand

As already explained, petrochemical industry has hitherto located itself predominantly in the industrialized countries. Table 3.2 gives a breakdown of the way in which the geographical distribution of production has evolved for some of the main petrochemical products or product groups.

In order to appreciate the reasons for the historical concentration in the industrialized countries, the criteria governing its location must be considered. The most important criteria for locational decisions are as follows :

### (i) Proximity to markets

In general, petrochemical products are not sold directly for consumption by private households, but are sold to various processing industries which transform them into utilisable goods. Thus synthetic

Table 3.2 - World capacity for certain major petrochemical product groups
Million of tons

| | North America | | | Western Europe | | | Eastern Europe | | | Others | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 67 | 72 | 76 | 67 | 72 | 76 | 67 | 72 | 76 | 67 | 72 | 76 | 67 | 72 | 76 |
| Olefins | 11.5 | 19.4 | 23.7 | 6.7 | 19.8 | 23.6 | 0.5 | 3.0 | 5.8 | 3.4 | 11.3 | 13.5 | 22.1 | 53.5 | 66.6 |
| Aromatics | 7.6 | 12.0 | 14.7 | 3.0 | 8.2 | 10.4 | 0.3 | 2.0 | 3.6 | 1.3 | 5.8 | 7.1 | 12.2 | 28.0 | 35.8 |
| Ammonia | 12.8 | 16.5 | 18.7 | 7.5 | 16.6 | 18.5 | 7.7 | 13.6 | 27.0 | 5.7 | 13.3 | 18.4 | 33.7 | 60.0 | 82.6 |
| Plastics (*) | 4.8 | 9.1 | 12.4 | 8.1 | 11.9 | 15.8 | 0.5 | 1.5 | 2.9 | 2.6 | 6.1 | 9.9 | 16.0 | 28.6 | 41.0 |
| Synthetic fibres | 1.7 | 2.6 | 3.5 | 1.3 | 2.5 | 3.3 | 0.2 | 0.6 | 1.0 | 0.7 | 1.8 | 2.7 | 3.9 | 7.5 | 10.5 |
| Synthetic rubber | 2.0 | 2.7 | 2.8 | 0.9 | 1.9 | 2.3 | 0.6 | 0.8 | 1.5 | 0.7 | 1.4 | 1.6 | 4.2 | 6.8 | 8.2 |
| Nitrogenous fertilizers | 7.5 | 11.2 | 12.7 | 9.1 | 11.2 | 12.1 | 7.4 | 14.3 | 20.9 | 4.0 | 7.0 | 9.1 | 28.0 | 43.7 | 54.8 |

(*) Includes only : high and low density polyethylene, PVC, polystyrene and propylene.

Table 3.3 - World consumption for cerain major petrochemical product groups
Million of tons

| | North America | | | Western Europe | | | Eastern Europe | | | Others | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 67 | 72 | 76 | 67 | 72 | 76 | 67 | 72 | 76 | 67 | 72 | 76 | 67 | 72 | 76 |
| Olefins | 9.5 | 16.2 | 17.2 | 5.4 | 12.7 | 16.7 | 0.4 | 2.3 | 4.3 | 3.2 | 8.2 | 10.6 | 18.5 | 39.4 | 48.8 |
| Aromatics | 4.7 | 8.6 | 10.2 | 2.8 | 5.7 | 6.8 | 1.2 | 2.0 | 2.8 | 1.2 | 3.5 | 4.7 | 9.9 | 19.8 | 24.5 |
| Ammonia | 8.8 | 12.8 | 13.7 | 8.6 | 11.5 | 11.6 | 7.3 | 12.7 | 21.0 | 5.1 | 9.2 | 11.7 | 29.8 | 46.2 | 58.0 |
| Plastics | 6.0 | 11.8 | 13.5 | 5.9 | 12.6 | 14.1 | 1.3 | 3.6 | 5.5 | 3.7 | 8.2 | 10.2 | 16.9 | 36.2 | 43.3 |
| Synthetic fibres | 1.1 | 2.6 | 3.1 | 0.8 | 1.9 | 2.4 | 0.2 | 0.8 | 1.4 | 0.6 | 1.6 | 2.5 | 2.7 | 6.9 | 9.4 |
| Synthetic rubber | 1.8 | 2.5 | 2.4 | 1.0 | 1.6 | 1.8 | 0.9 | 1.5 | 2.2 | 0.5 | 1.1 | 1.4 | 4.2 | 6.7 | 7.8 |
| Nitrogenous fertilizers | 5.7 | 7.6 | 9.5 | 5.3 | 7.6 | 8.6 | 6.7 | 11.7 | 16.5 | 3.9 | 6.5 | 10.0 | 21.6 | 33.4 | 44.8 |

rubber is sold to rubber processing or tyre manufacturing industries, plastics are sold to a variety of plastics processing industries for subsequent use in packaging, automobiles, building, and a host of other areas, synthetic fibres are sold to textile industry, and so on. Markets therefore exist where there are industrial, rather than demographic concentrations. (An important exception is fertilizers which, though not consumed by private households, are also not destined for centralized industrial markets, but rather for decentralized agricultural markets). In order to reduce transport costs, the petrochemical industry has therefore tended to establish itself near to great industrial poles in the world. This tendency has been reinforced by the rapid growth in the size of petrochemical units and complexes.

Apart from the question of transport costs, physical closeness to markets facilitates the control of those markets.

Table 3.3 gives a geographical breakdown of consumption of some major petrochemical products.

(ii) Availability of suitable feedstocks

The continuous availability of suitably priced feedstock is vital to the petrochemicals industry. The question of feedstocks is discussed further in section 4.3. Except in the United States, where the natural gas contains ethane in extractable quantities the world petrochemical production has been largely based on naphtha, one of the products from the refining of crude oil. Thus petrochemical industries, particularly outside the USA, have tended to situate themselves close to refineries which provide them with their feedstock. A notable exception to this is Japan, where the refining industry does not produce sufficient naphtha to satisfy the needs of the national petrochemical industry. Because in particular of the fact that crude oil is much cheaper and easier to transport than refined products, refineries have tended to be situated in industrialized countries more than in the producing countries. Thus the naphtha and gas-oil have tended to be available in the industrialized countries also.

Up until recently, the availability of crude itself has been of much less importance. Events of 1973/74 showed, however, that it cannot necessarily be assumed that there will always be a completely free and unconstrained market in crude oil.

(iii) Existence of a refining industry

Apart from the question of supply of feedstock, referred to above, there are other good reasons for situating a petrochemical industry in the vicinity of a refining industry. The latter enables many by-products of the petrochemical industry to be valorised, thus improving the economics of operation, and there is also a complementarity in the technologies of refining and the manufacture of base products.

(iv) Availability of skilled labour

The petrochemical industry covers a whole range of different types of manufacturing processes, but generally it is capital - rather than labour-intensive - particularly at the upstream end. On the other hand, the labour which is required generally needs to be high-grade,i.e. to have the experience and skill to operate highly complex plant effectively. Petrochemical plant is very costly, and there is therefore a high cost associated with shut-downs and stoppages. Indeed the differences in labour skills are the key aspect of the technological gap between industrialized and developing countries. The engineering skill required for construction of plant can usually be bought on the market.

(v) Existence of necessary infrastructure

Roads, suitable harbours, etc. are required to enable the necessary flows of feedstock and goods produced to and from the factory. The existence of reliable utilities, such as electricity and fresh water may be required. If the necessary infrastructure does not exist, then the capital cost of establishing a petrochemical installation could be enormously increased.

(vi) Spatial and environmental problems

The petrochemical industry is a large energy consumer, and can produce all kinds of polluting effluents. The larger the petrochemical industry in a given zone, the greater the strain placed on the assimilative capacity of the environment. Furthermore, as countries become wealthier, so the emphasis placed on a clean environment increases. Similarly, spatial problems are becoming significant in the densely populated countries of Western Europe.

The first five points have in the past all operated in favour of establishing the petrochemical industry in the industrialized countries. The sixth point would tend at least theoretically to work in the other direction, although there is little evidence that this factor is leading to a relocational effect in favour of less developed countries. However, in countries such as West Germany and the Netherlands, sheer physical congestion is becoming a real problem. The "big three" in West Germany ( Bayer, Hoechst, BASF) claim that it is hardly possible to find any more suitable sites in Germany. According to the Director of BASF :
"It is no longer possible to build a petrochemical factory in Germany that is not within 500 metres of someone. Furthermore, federal and local anti-pollution laws are the most severe in Europe, with the possible exception of the Netherlands legislation. If the cost becomes sufficiently large to threaten our profit margin, we shall have to invest elsewhere".

Any such diversion of investment projects, however, has up to the present tended to be towards other poles in industrialized countries under less pressure, rather than towards the developing countries.

The established geographical order of location is for the first time being challenged. Oil-rich developing countries, particularly in the Arab world, have announced their intention of moving into the production of base chemicals during the coming decade. For

example, even taking a reasonably conservative view of likely developments, the Middle East and North Africa could have an ethylene production capacity in 1990, based on projects under discussion or construction, of three to five million ton (the 1976 worldwide capacity was about 35 million tons).

## D - International trade in petrochemicals

In spite of the tendency previously described for the petrochemical industry to situate itself near industrial markets, there is still a substantial volume of international trade, which has the function of matching supply with demand on an international level, and of smoothing out local unbalance in the productive processes.

The main exporters are the USA, tne EEC countries, and Japan, although Canada and the Eastern block countries are of importance for some products.

Each of the former three main exporters are net exporters of most petrochemical products, with a few exceptions, for example, the USA imports butenes, butadiene and benzene. There is a very extensive internal trade between the various EEC members in petrochemicals. Table 3.4 below shows the total value of trade in petrochemicals (excluding fertilizers) for the three main manufacturing/exporting poles.

Table 3.4 - International trade in petrochemical products (excluding fertilizers) in 1972 (millions of dollars)

| | Exports | Imports | Balance |
|---|---|---|---|
| Western Europe | 11,450 (*) | 9,850 (*) | 1,600 |
| USA | 2,200 | 900 | 1,300 |
| Japan | 1,850 | 400 | 1,450 |

(*) These figures include intra-EEC trade amounting to $ 8,500 million.

The transport of ethylene is extremely expensive because of the low boiling points of these substances, and world trade is almost nil if transport by pipeline between EEC countries and between COMECON members is excluded. On the other hand, relatively large quantities of butenes and butadiene are exported from Europe to the USA.

There are substantial imports of aromatics into Europe from North America, and also significant movements from Eastern Europe into Western Europe.

Trade in final products tends to be higher than for base and intermediate products, with substantial exchanges of synthetic rubbers, plastics, fertilizers, and synthetic fibres all being exchanged in substantial volumes.

The EEC countries and Japan, in particular, are large exporters of plastics. The Eastern block countries, in contrast with their position as net exporters of aromatics, are substantial net importers of plastics.

The greater part of the exports of the three main exporting zones, however, are turned towards the countries of the Third World.

It is also of interest to compare the volume of international trade in the main petrochemical products with the total volume of world production. Such a comparison is presented in table 3.5 for some of the principal petrochemical products which are traded. The figures exclude intra-EEC trade.

Table 3.5 - Ratio of total exports/total production for some important petrochemical products - 1973

| Product | % |
|---|---|
| Ethylene | 0 - 0.2 |
| Propylene | 0.6 |
| Butadiene, butenes | 3 - 4 |
| Benzene | 5 |
| Toluene | 13 |

| Product | % |
|---|---|
| Xylenes | 6 |
| Styrene | 8 |
| Ethylene glycol | 11 |
| Cyclohexane | 9 |
| Caprolactam | 9 |
| Synthetic rubbers | 15 |
| Synthetic fibres | 15 |
| L.D. polyehtylene | 14 |
| H.D. polyethylene | 21 |
| PVC | 10 |

The figures show relatively greater importance of international exchanges for final products than for basic and intermediate products.

During the 1950s and 1960s the petrochemical industry was developing against an economic background of high growth, reasonable monetary stability, unemployment levels that on present standards look low, and a climate increasingly liberalist and free trade minded. Matters became more unsettled, however, in the 1970s. Inflation rates began to rise, the era of fixed currency exchange rates came to an end, and unemployment rates began to rise. More important, however, from the point of view of international trade, was the 1973/74 oil crisis and subsequent economic recession, which dislocated the trade balance of many countries, introducing chronic balance-of-payments problems in some cases. Associated with this is the petro-dollar phenomenon, which introduced an element of further potential instability into international money markets.

The twin pressures of balance-of-payments problems and rising unemployment has led to the appearance of a certain number of protectionist measures being adopted by some governments. Up until now, these have only been partial, ad hoc measures, limited to specific sectors, in particular, textiles and clothing, steel, shipbuilding, electronics, etc. However, an aggravation of the economic situation, or the persistence of high surplus capacity in the petrochemicals industry, could exert a depressive influence on international petrochemicals trade also.

## E - Factors relating to production

### 1 - Technology

As a young, high technology industry involving a great number of disparate processes and many hundreds of products, petrochemical has undergone continuous and rapid evolution since its birth. The number of products has progressively increased as new processes have been discovered and made operational, and new improved methods have been introduced for manufacturing existing petrochemical products. At the same time, as the technology has advanced it has been possible to improve the specifications and properties of products, making them more attractive to the market or reaching a wider market.

Part of the impetus has come from the identification of specific needs or demands, and an effort then being made to produce final products which meet these needs, but part has come from the supply side, that is, from the conscious desire to valorise by-products, particularly from the more upstream processes of petrochemistry. Indeed the whole industry can be said to have been born in the first place out of the desire to valorise some of the by-products of the oil refining process, in particular, naphtha. Each of the processes of primary transformation such as steam cracking or catalytic reforming produces significant quantities of residual by-products, the proportion of feedstock transformed into usable chemical products can be as low as 50% or even less, depending on feedstock, etc. Much effort has been devoted to finding ways of economically recuperating the by-products.

The high rate of technical evolution has been achieved at the cost of considerable expenditure in the field of research and development. Expenditures of up to 5% of turnover by chemical firms is common, and up to 10% is not unknown.

The 1960s and 1970s, have witnessed a huge increase in the size of petrochemical units, particularly in the area of primary transformation. Because of the capital intensiveness of many of the petrochemical processes (about one fifth of the total costs for steam cracking), and because capital costs do not rise proportionately with capacity, there is considerable scope for realizing economies of scale in petrochemical manufacture.

Technical progress in the field of plant engineering has permitted the resulting theoretical savings for large plants to be translated into practice.

Thus the mean size of steam crackers installed in 1960 was about 50,000 tons of ethylene per year. This has now risen to a level of 500,000 tons per year. Over the same period, the capacity of steam reformers has risen from 80,000 tons per year of ammonia to 500,000 tons per year.

Very significant cost reductions have been achieved by these increases in scale. However, there were other reasons operating in favour of larger production units. The extraction of co-products such as propylene, butadiene and the aromatics from the steam cracking process becomes more economic as the total volumes increase. Extraction units need to exceed a certain minimum size before they become viable in relation to other methods of manufacture ; their present size is still far from reaching the maximum capacities which technology allows.

Although size increases have been most spectacular for the primary transformation processes, units further downstream have also increased considerably in size.

The increasing size and complexity of petrochemical plants has not taken place without problems. Longer implementation periods for new plants are necessary, with the putting into

service of a new plant needing to be particularly well planned and conducted by specialists.

Similarly, the move towards larger units has meant a smaller number of units, and this involves a greater degree of risk associated with accidental shutdowns, because of the larger amount of capital tied up in single units.

The increasing size and complexity of petrochemical plant has had important implications for the accessibility of this industry to would-be newcomers (greater skill and capital required) and for relative costs between, for example, industrialized and developing countries. Thus for example, where 1 1/2 to 2 months might be required to put into service a huge ammonia plant in an industrialized country, 5 to 8 months might be required in a developing country with some such experience already gained, and one year for such countries without experience.

It should be noted that the capacity to realize economies of scale is essentially a function of the relative shares of the capital costs and the operating costs in the total. The higher the former, the greater the possibility of making savings through increasing unit sizes. The large increases in the cost of feedstocks in 1974 resulting from the quadrupling of oil prices caused the relative operating costs to rise, and therefore the relative capital costs to fall, thus taking some of the momentum out of the push towards higher unit sizes.

In technological terms, it is widely thought that the petrochemical industry is now reaching some kind of maturity, with the past vertiginous developments giving way to a more gradual evolution.

## 2 - Capital

The question of availability of capital is a key one for the petrochemical industry. As has already been pointed out, the industry is capital-intensive, so that substantial quantities of capital are required. Increases in size and complexity of plant have made the problem more acute.

Thus, at the present time, an integrated petrochemical complex centred around a steam cracker with a capacity of 400,000 tons per year of ethylene may require investments upward of $ 1 thousand million.

Access to means of financing the very large investments required has been an increasingly important element for the industry. In the 1960s, while competition was less intense and margins higher, companies were able to generate sufficient cash flow to meet a good part of their financing needs. More recently with increasing pressure on profit margins, and escalating unit capital costs, the finance problem has become more acute. This is particularly true for the smaller private companies. These companies, and many larger ones, are now being driven to seek finance from their own or other governments, from stronger chemical or oil groups, probably on a joint-venture basis, or from the banking and finance sector. In each case, a certain loss of control is involved.

As the oil majors have ventured into the petrochemical field they have been in a particularly priveleged position as regards finance, because of their enormous financial resources.

On a national level, total petrochemical investments are of course very important. Table 3.6 shows the evolution of investments in the principal manufacturing centres in recent years.

Table 3.6 - Investments in petrochemical industry (excluding fertilizers) in USA, Japan, Western Europe
Million of $

| | 1965 | 1970 | 1973 | 1974 |
|---|---|---|---|---|
| United States | 1,500 | 1,500 | 1,400 | 1,100 |
| Western Europe | 500 | 2,000 | 3,000 | 2,000 |
| Japan | 250 | 300 | 450 | 900 |

High increases in construction and other investment costs have occurred in recent years particularly. This phenomenon, in capital-intensive industry, has given rise to various anomalies in respect of profitability. Often petrochemical plants built several years ago are more "profitable" than those built very recently, in spite of being smaller and less efficient. This is either because capital costs have been completely amortised, or because capital costs on the older installation are much lower because of the historically lower cost of the investment.

3 - Feedstock

The whole range of petrochemical products derives essentially from a very limited number of hydrocarbon feedstocks, themselves coming from the processing of crude oil and natural gas. A continuous supply of feedstock at a reasonable price is absolutely vital to the petrochemical industry.

The petrochemical industry has developed along different lines in North America, as far as feedstock is concerned, than in the other major production centres. In the United States it has been largely based on natural gas, whereas in Europe and elsewhere petrochemicals have been predominantly derived from naphtha. There are a number of reasons for this. Natural gas prices in the United States have always been lower than those of oil. In addition, North American natural gas has significant quantities of ethane, capable of being extracted economically and there was unsignificant demand for products such es propylene and butadiene. Furthermore, the demand for automobile fuel in relation to other refined products in the United States is proportionately much greater than elsewhere, so that the domestic availability of naphtha is muck reduced.

In Europe, by contrast, much of the mumentum for the birth and growth of the petrochemical industry came from the natural gas was generally discovered and commercialized in Europe well after the petrochemical industry ures establishing itself, and in any case does not contain significant quantities of ethane. On the

other hand, European natural gas did come to be used, in the 1960s, for the manufacture of ammonia and methanol.

In 1973 in Europe about 93% of ethylene was produced from naphtha and a further 3% from gas-oil, the remainder being manufactured from LPG.

Europe has traditionally been in surplus in relation to naphtha, part of this surplus being exported to North America. This situation continued until very recently.

Japan, the third great petrochemical producing zone, is completely devoid of natural hydrocarbon resources. While ethylene production is wholly based on naphtha as feedstock, Japanese refineries do not produce sufficient of this material, and the shortfall has to be made up by imports.

In Eastern Europe methanol and ammonia production is largely based on natural gas, while the limited amount of ethylene production uses naphtha as feedstock. In developing countries, petrochemical production is still small, three-quarters of hydrocarbons destined for chemical use being devoted to the production of ammonia for fertilizer manufacture. Naphtha is mainly used for the manufacture of ethylene, although in Mexico, ethane derived from natural gas is utilised.

In recent years, pressures have come to bear on the established order of petrochemical feedstock usage in both the USA and Europe. The problems are largely attributable to the fact that petrochemical feedstock comes from the energy sector, i.e. from the refining of petrol or natural gas. Petrochemicals only take up a relatively small proportion of the total consumption of fossil fuels - 6% in North America, 12% in Western Europe, including fuel usage - so that is fairly marginal as far as the energy industry in concerned, but since the consumption of petrochemical feedstocks has been growing even faster than energy consumption, these figures have been growing and are continuing to grow. At the same time, availability and price of

feedstocks tend to affected strongly by developments in the energy world.

In the United States, while demand for feedstock has continued to grow, natural gas production has begun to decline due to the progressive exhaustion of American gas fields. As a result, there has already been some switching into more expensive oil-derived feedstocks.

US ETHYLENE PRODUCTION BY FEEDSTOCK (in %)

| | 1969 | 1976 | 1981 |
|---|---|---|---|
| Refining gases | 15 | 9 | 6- 7 |
| Naturel gas liquids (ethane, propane, butane) | 75 | 66 | 51-52 |
| Liquid feedstock (naphtha, gas-oil) | 10 | 25 | 44-45 |

Furthermore, almost all new steam crackers currently being installed in the United States are capable of accepting naphtha or gas-oil. Since the latter is already in a position of having to import part of its naphtha requirements, pressure on the latter is likely to intensify further.

Matters in Europe are less serious. However, after many years of being in surplus on naphtha, in 1975 there was not sufficient to meet the needs of European petrochemical industry, despite the poor performance of the latter. This occured because gasoline demand increased 7% in the face of reduced crude throughout, and the situation has persisted since. Further considerations which have become relevant with the disappearence of surpluses are the possibilities of conjonctural fluctuations due to factors affecting the refining industry, such as the severity of winters, or a change in the crude mix. These factors have driven many petrochemical manufacturers to seek feedstock flexibility so that either naphtha or gas-oil may be accepted, even though there is an associated capital cost penalty of the order of 10%.

It was mentioned earlier that feedstocks were strongly affected by developments in the energy field. A striking example of this is afforded by examining the movement of naphtha prices over a period including the oil crisis of 1973/74, as shown in table 3.7 below.

Table 3.7 - Price of naphtha, October 1969 to January 1975 in Rotterdam (CIF)

| | $ |
|---|---|
| October 1969 | 18.5 |
| June 1970 | 19 - 19.5 |
| August 1971 | 21 |
| August 1972 | 24 - 27 |
| April 1973 | 42.8 |
| July 1973 | 72.1 |
| November 1973 | 117.0 |
| January 1974 | 148.7 |
| April 1974 | 162.9 |
| June 1974 | 127.1 |
| September 1974 | 98 |
| January 1975 | 92.2 |

Changes in the price of hydrocarbons are extremely important for the costs of base products, since the former (feedstock plus fossil fuel) represent typically (in Europe) 80% of the manufacturing costs of ethylene and over 60% of those of ammonia.

This fact has important implications for the relative manufacturing costs between different zones. Before the oil crisis, Western Europe had access to naphtha at a price such that ethylene ex-naphtha was competitive with ethylene ex-ethane in the United States. An increase of 4 or 5 times the price for naphtha occurring meanwhile has conferred an advantageous position on American ethane crackers. While this advantage may not last long, it may be one of the reasons for the movement of emphasis towards the United States by new

petrochemical projects. Problems of relative cost advantage could become important in the context of new projects for base chemical manufacture in developing countries with substantial hydrocarbon resources.

### 4 - Labour

In general, petrochemical industry is capital intensive, with only very modest demands for labour. This is particularly true for the more upstream processes in the industry - in some downstream processes, such as manufacture of synthetic fibres, the labour requirements are somewhat higher.

Not only are labour requirements low, but of that which is required, a high proportion needs to be skilled. Thus the proportion of unskilled workers rarely exceeds 45% of the total, and may be much less than this. On the other hand, training, skill and experience on the part of the technicians and engineers is vital, and has become increasingly so as plants have increased in size and complexity.

The problem of labour is becoming a more important one as developing countries venture into petrochemical production. The profile of labour required is not at all well adapted to that available. Qualified technicians and skilled workmen often have to be imported from abroad, at a very high cost, so that the real cost of labour in developing countries may be substantially higher than in industrialized countries.

## F - Commercial structure of production

### 1 - Major petrochemical companies

While American companies carried out much of the pioneering of petrochemical production, European companies did not lag

far behind, encouraged by the surplus of low-cost naphtha available in Europe. Entry into petrochemicals was a natural step for companies already engaged in the manufacture of inorganic or organic chemicals.

Because of the large scope, and the high technology and capital-intensiveness of the industry, it tends to be highly concentrated, much of the production being carried out by giants with activities on an international scale. Table 3.8 shows the world's 12 largest petrochemical companies, ranked according to turnover (total, not specifically petrochemical).

Table 3.8 - The world's 12 largest chemical companies in 1976

| Company | Turnover in 1976 million $ |
|---|---|
| 1. Hoechst (W. Germany) | 9,333 |
| 2. BASF (W. Germany) | 9,203 |
| 3. Du Pont (U.S.) | 8,361 |
| 4. Bayer (W. Germany) | 8,298 |
| 5. I.C.I. (U.K.) | 7,452 |
| 6. Union Carbide (U.S.) | 6,346 |
| 7. Montedison (Italy) | 6,125 |
| 8. Dow (U.S.) | 5,652 |
| 9. Rhône Poulenc (France) | 4,521 |
| 10. Monsanto (U.S.) | 4,270 |
| 11. Akzo (Netherlands) | 4,068 |
| 12. Vebar Chemie (W. Germany) | 4,043 |

Source : Chemical Age Survey 24/6/77

It is to be noted that this list contains a preponderance of European firms, with the three West German giants in first, second and fourth positions.

## 2 - Entry of major oil companies into petrochemicals

In the early stages of the industry, production was carried out exclusively by chemical companies, the role of the oil companies being limited to the supply of feedstock. In the 1960s, however, the major oil companies began to take an interest in petrochemicals. It represented a direction of diversification which was both natural for them and held out attractive growth prospects. In the first place, the oil companies moved into the manufacture of base chemical products, and later on expanded downstream into some intermediate and finished products. Part of this was achieved through direct investment, and part through association of joint ventures with chemical companies. Thus BP collaborated with a number of chemical companies in various joint ventures, for example with Bayer (Erdölchimie in West Germany), Monsanto (Forth Chemicals in the U.K.), ICI in the construction of a steam cracker on Teeside, and so on. Table 3.9 shows the importance of the petrochemical activities for some of the leading oil companies.

Table 3.9. - Petrochemical activity of some oil companies in 1976

| Companies | Chemical turnover million $ |
|---|---|
| Shell (Netherlands/U.K.) | 3,298 |
| Exxon (U.S.) | 3,043 |
| Occidental (U.S.) | 1,582 |
| Standard Oil Indiana (U.S.) | 1,190 |
| Phillips Petroleum (U.S.) | 982 |
| Mobil (U.S.) | 909 |
| Gulf (U.S.) | 812 |
| B.P. (U.K.) | 735 |
| Standard Oil California (U.S.) | 714 |
| Ashland Oil (U.S.) | 623 |

Source : Chemical Age Survey 24/6/77

The importance of the oil majors in petrochemicals is understated by comparing their turnover with that of the chemical companies, since sales of the latter contain both non-petrochemical and petrochemical components. Thus the oil companies already account for over 60% of the production of base products in Europe (over 40% in the United States) and also have a significant share in the total production of final products.

The physical integration of refining processes with base chemical manufacturers can introduce significant economies, thus conferring an advantage on the oil companies.

The inevitable transition from ethane as the basic petrochemical feedstock in the United States, to oil-derived feedstocks such as naphtha and gas-oil will mean an increase in the influence of the oil companies in the petrochemical industry. Indeed the great majority of current investment in petrochemical base product capacity in the United States is accounted for by oil companies and their subsidiaries.

Notable in the above table is the higher commitment of the European oil majors (Shell and BP) to petrochemicals, relative to their total commitment, than the American majors. This reflects the different philosophy with regard to diversification, the American majors moving heavily into other energy sectors, while the European majors concentrate more on petrochemicals.

3 - Internationalization of companies' activities

Because the petrochemical industry was catering for a market occurring largely in industrialized countries, there was a tendency for enterprises to establish themselves most strongly in their home countries, exporting when appropriate,

particularly to meet demand in developing countries. However, in the 1960s, American firms began to see the large potential of European markets, and began to establish sites, particularly in the North European centres.

The early American settlements in Europe concentrated on the major estuary areas in North Europe, i.e. in Rotterdam, Terneuzen and Antwerp and also in the U.K.

Major implantations were established by Esso, Gulf, Dow and Phillips ; in the case of the oil companies, refineries were established first, with base product installations following on afterwards. These were followed by the other major American chemical companies.

During the 1960s, European companies, by contrast, remained relatively attached to their traditional sites. Although there was some investment outside national boundaries, for example BASF into Antwerp, Hoechst into the Netherlands, and ICI into the Netherlands and West Germany, there was little movement of European investment out of Europe. European tactics, in the face of the American penetration, were essentially defensive : heavy investment in their zones of origin, even at the risk of creating excess capacities, concentration on down-stream production in reply to American concentration on base products, and regrouping into stronger units.

In the 1970s matters have changed considerably. The oil crisis gave the United States a competitive advantage on feedstock costs. The gradual decline of the dollar has reduced relative costs in the United States, and also reduced costs of acquisitions. At the same time, the new pressures on the world and European markets have led European chemical firms to reappraise their policies, and in particular to internationalize their activities. Thus the trans-atlantic traffic of capital has been reversed, with European firms seeking to establish operations in the United States.

## 4 - Development of petrochemicals in developing countries

In the past, petrochemicals manufacture in developing countries has had a relatively slight impact on the overall world scene. Most activity has so far been centred in Iran, Algeria, Brazil, Venezuela, Mexico, South Korea and Taiwan. However, with the drive towards industrialization in these countries, many of those with significant hydrocarbon resources have announced their intentions of moving more seriously into petrochemical production.

At the focus of attention in recent times has been the Arab world. Very large figures for new base product capacity in the Middle East have been mentioned, but these have subsequently been moderated. U.S. multinationals are most heavily involved in the planning arena. Although U.S. partnership projects are under study in Iran, Kuwait and other OPEC countries, the greatest efforts are being devoted towards Saudi Arabia, with its massive supplies of feedstocks, and willingness to leave a large part of the control to its foreign partners. Japanese firms, keen to obtain greater security of supplies of feedstock for their own very dependent industry, are actively collaborating in projects in Iran.

Meanwhile, Algeria, Iraq and Libya are trying to build up their domestic industries with a minimum of outside intervention, i.e. by simply buying the technology on the market, but without entering into joint ventures with foreign partners.

The major European nations are forming agreements with smaller OPEC nations. Thus CdF Chimie is involved in a large ethylene/ polyethylene complex in Qatar, while BASF is in negotiations in Kuwait in regard to a large olefins and aromatics plant.

While much petrochemical production in the Middle East will be orientated towards exports, significant new investment projects have been declared which aim principally towards local markets. In Mexico, recent discoveries of oil and natural gas reserves have given impetus to the Mexican petrochemical industry, and self sufficiency within the next decade is being aimed for. The Andean pact countries (Venezuela, Colombia, Peru, Ecuador, Bolivia and Chile) are proceeding with a substantial development plan, due for completion in 1985. Complementarity between national programmes is aimed for. Venezuela will build up its basic petrochemical industry on the basis of its oil and natural gas reserves. In Bolivia, plants will be established to utilize natural gas reserves and to produce raw materials for the plastics industry. Peru will concentrate on synthetic fibres and raw materials for the plastics and synthetic rubber industry.

Many other projects are planned in developing countries, and in particular, a very large increase in the world capacity in ammonia manufacture for fertilizers is forecast.

## 5 - Competition between companies and prices

As the petrochemical industry developed, prices of most products tended to fall in real terms. During the 1950s and 1960s this occurred not so much due to competition between manufacturers as because of technological improvements in the processes, the increasing size of markets, economies of scale due to the increasing size of units, and so on. Thus until the later part of the 1960s, price competition was only moderate, and margins did not suffer from the downward trends in prices.

However, as the scale-up process began to occur, those producers with large plants were able to make handsome returns on their investments, allowing the smaller operators to provide a "price umbrella" sheltering them from competition. This could not last for ever, however, and as producers saw the advantages to be gained from large plants, a race developed which has recently

translated itself into worldwide overcapacity for many products, considerable competition, and strong downward pressure on margins. Thus at present, prices are more in line with the level needed to allow investment, and often below. This has, in particular, reduced the cash flow of the smaller companies to a level where there are problems in raising the necessary finance for future investment.

6 - Structure of production, relations between producers

The petrochemical industry is complex and diverse. It embraces several thousand highly varied products. In order to create a final product starting from feedstock such as naphtha or ethane, several transformation stages are involved, and there are often several routes to this final product. Thus there is a great deal of flow of products (basic and intermediate products) within the industry itself, either within an enterprise itself, or between petrochemical companies.

Since continuity of supplies is important for petrochemical processes, operators sought to guarantee their supplies by making agreements on deliveries with suitable producers. Such contracts have become a widespread feature of the market, and are established typically for periods of three to five years. In earlier times, these agreements covered both quantity and price. Nowadays, with the high volatility of the latter, it is normally provided that prices be renegotiable, sometimes on some fixed basis, at three monthly intervals. Apart from these specific agreements, there have been developed many tacit agreements regarding one-way or reciprocal deliveries that further diminish the freeness of the market in petrochemical products.

Completely free markets in petrochemical products are thus often very limited. They are dealt with by the "spot" market, which is handled by brokers and traders. The spot market may see perhaps only 10% of the total production of a specific product. Because of the thinness of this market, spot prices tend to be very volatile, falling, for example, in times of extensive over-capacity, as low as marginal production costs.

This type of market structure has increased the difficulty for an aspiring producer to enter the market, since so little of it is directly available to him, but on the other hand, has probably had a stabilising influence on prices overall.

# IV - STRATEGY OF THE ACTORS

## A - Introduction

The object of this section is to identify the principal actors participating in or impinging on the petrochemical system, to analyse their objectives, to look at their relationships with one another, to study actual or potential conflicts and communities of interest between them, and to examine the means of action which they have on one another.

This synthesis will permit the stability of the system to be assessed, and sensible inferences to be drawn about the possible future evolution of the petrochemical industry resulting from the interplay of the strategies of the actors and the balance of force between them.

The main actors identified are as follows :

1 - The major oil multinationals, who provide most of the petrochemical feedstocks derived from crude oil (hereinafter referred to, for convenience as the "Majors")

2 - Non-publicly owned petrochemical companies, which can usefully be divided into three main groups, i.e.

(i) the chemical multinationals (the "Multinationals"),

(ii) petrochemical subsidiaries of the major oil multinationals (the "Subsidiaries"),

(iii) petrochemical companies whose industrial activities are largely confined within their own national boundaries (the "Nationals").

3 - The developed countries of the market economy type, subdivided into :

(i) the USA, unique by virtue of its special relationship with the multinationals of American origin, and of being by far the largest producer and consumer of petrochemicals in the world, as well as being a substantial producer of crude oil,

(ii) the other developed countries, in particular Japan and EEC countries,

4 - Countries with an economy of the centrally planned type, in particular the USSR and countries of Eastern Europe (the "Socialist countries").

5 - Developing countries, subdivided into :

(i) countries rich in natural hydrocarbon resources with only limited domestic markets and needs for capital, for example Saudi Arabia, Kuwait (the "Gulf States"),

(ii) countries rich in hydrocarbons, but with substantial needs for capital to finance industrialization, and a significant actual or potential domestic market ("non-Gulf oil producers") and

(iii) other developing countries ("LDC without hydrocarbons").

6 - The industries downstream from petrochemicals which are the consumers of petrochemical final products (the "consuming industries"), for example the tyre manufacturing, textiles, plastics processing industries, etc.

7 - Other actors with more marginal role in the system, for example the engineering companies who carry out the construction of petrochemical plant (the "Engineering Companies"), banks who provide finance, etc.

The classification of the actors into the above groups does not mean to imply that within a group, such as the "Nationals", there is a complete harmony or that they act together politically or economically as a block, but merely they have a similar role, and often the same kinds of objectives, constraints, freedoms of action, commercial preoccupations and so on. Clearly within a group, a state of fierce competition may exist.

The groups of actors are considered in turn in the following section.

## B - The main actors

### 1 - The majors

This refers to the seven "truly" multinational companies whose operations are not centred in a single country or region. These are Exxon, Royal Dutch/Shell, BP, Gulf, Texaco, Standard Oil of California and Mobil. These companies have operations throughout the world, and are wholly international in outlook, i.e. they can more or less attempt to rationalize the geographical distribution of their activities according to the relative advantages in terms of costs, availability of materials and skilled labour, location of markets, tax structure, etc. without regard to national boundaries.

The traditional view of joint-stock companies is that their objective is to maximise profits. While this may be appropriate in the case of companies in which a significant degree of control is exercised by the shareholders, it is less evident in the case of the majors where there is a considerable gulf between ownership and control. It appears that an important

objective of the majors has been to maximise their retained earnings, or at least to ensure as far as possible that retained earnings were sufficient to pursue a financial strategy of self-financing of their investment projects. This considerably increases the autonomy of the management and reduces the role of the shareholders to a rather passive one. The ascendancy of management over the shareholders leads to the emergence of rather more vague and generalized objectives such as the consolidation of power and influence in the world, rather than mere profit maximisation.

The majors seek to increase their power and or profits through vertical integration, economies of scale and diversification.

They are highly integrated vertically, traditionally carrying out all the operations from exploration and extraction through transportation and refining, to marketing and distribution.

Although vertically integrated, however, their operations have not always been balanced, so that BP for example, have tended to have an excess of crude, because of their substantial interests in the Middle East, while other oil companies have been short on crude, and have had to buy it in.

Economies of scale are made possible by the very large scale of their operations.

The majors are being increasingly challenged at the upstream end of their operations by the mounting will of the developing countries to control and valorize to the maximum their own resources. In the first place the majors have in general had to relinguish control of the extraction process as host countries have taken control through nationalizations or participations.

They are coming under further pressure as the producing countries venture further downstream into areas of refining, and even the manufacture of petrochemical base products.

Because of the exhaustible nature of oil, and because of the challenge from the oil-producing countries just referred to, the oil majors have intensified their efforts towards diversification. This has been principally in the two fields, i.e. :

(i) Manufacture of petrochemical products:

All the majors have petrochemical activities, and they are at present dominant in the manufacture of aromatics, they also manufacture other base products, and are likely in the future to move further downstream.

(ii) Other energy fields:

The oil majors have kept abreast of developments in nuclear energy, have acquired concessions for the exploitation of deposits of shale and tar sands and carry out research in such areas as coal gasification while at the same time trying to prolong the "oil age" as long as possible.

The thrust of the majors into these costly new fields, coupled with the greatly increased costs of explorations in off-shore zones, have placed considerable strains on the ability of the majors to finance themselves.

The relations between the majors and the petrochemical industry result from :

(i) the fact that they are suppliers, by virtue of their refining operations of the oil-derived petrochemical feedstocks, i.e. naphtha and gas-oil, and

(ii) the fact that petrochemicals represent a natural direction of diversification for the oil industry. They are producers of petrochemical feedstocks, they are in a better position than most to meet the very heavy demands for finance placed by this very capital-intensive industry, there are considerable overlaps in technology between refining and the manufacture of base products, and there is also significant hope for realizing savings and improvements in efficiency through physical integration, on a single site, of the refining and primary petrochemical transformation processes.

Petrochemical production still accounts for a relatively modest (about 5%) part of the total output of the refining industry (although this proportion is steadily increasing), although it is important for the majors that its production of naphtha should be valorized. From the point-of-view of the petrochemical industry, on the other hand, supplies from refineries represent a vital lifeline, since, at least in Europe and Japan, the industry is based predominantly on naphtha.

The considerable financial strength of the majors is of great significance in its relations with the petrochemical industry. The recent soaring of investment costs in the industry resulting from the substantial increases in mean plant size, coupled with rising prices of capital goods, has placed financial strains on the industry, thus placing those enterprises in a position to draw on the financial strength of the majors in an advantageous position.

2 - The Private Petrochemical Industry

The word "private" here refers to their ownership by private shareholders, as distinct from State ownership.

As has already been seen above, these can be subdivided into three sub-categories, i.e. :

(i) The "Multinationals", chemical companies whose activities can genuinely be said to be spread out throughout the world, such as Dow, Union Carbide, Monsanto, ICI.

(ii) The "Subsidiaries", wholly-owned petrochemical subsidiaries of the Majors, either established from scratch or by acquisition.

(iii) The "Nationals", private chemical companies whose scope is not truly multinational in the sense of (i) above. (There is of course no strict dividing line between the Multinationals and the Nationals, but rather a continuum, with many companies who would probably be classified as National in the present sense who are nearing the threshold of multinationality).

The traditional ultimate objective of profit maximisation can be ascribed to all of these companies (subject to the reservations mentioned for the Majors).

In order to continue to exist and to make profits, an industry must naturally assure that every aspect of its operations are secure and efficient, but the petrochemical industry has certain preoccupations peculiar to it, as follows :

(i) secure supplies of feedstock. In countries not self-sufficient in oil or natural gas the industry is dependent on imports of crude oil (or naphtha obtained from refining crude). A high proportion of this crude comes from a relatively small number of countries, and the events of 1973/74 at least served to demonstrate the vulnerability of countries not self-sufficient in oil. Furthermore the fact that feedstock is obtained from the world's most important sources of energy, oil and natural gas, means

that as energy and its possible future shortage become increasingly a focus of world attention, the petrochemical industry may be incidentally affected by government regulatory measures.

(ii) ability to finance its investments. As already observed, continual increase in plant size and rising construction costs have considerably added to the problems of financing new investment.

(iii) hold costs at a competitive level. At a time when competition has been increasing in the industry, the pattern of unit costs has been in constant evolution as the possibility of realizing economies of scale has increased, as the process technology has advanced, and with the substantial increases in energy prices since 1973. Enterprises must keep abreast of these developments and ensure their strategy adapts suitably.

(iv) ensure the marketing of products. Because the petrochemical industry is characterized by rapid technological change, the pattern of demand is in a state of continuous change, as new products and processes appear. The larger enterprises are better placed to achieve the diversification desirable to reduce risks from this source.

An important characteristic of the petrochemicals market is its "opaqueness", i.e. the fact that the majority of flows of products consist either of deliveries of an enterprise to itself, or to another enterprise whith whom they have a bilateral agreement. This means that it is correspondingly more difficult for a new entrant to get established in the market.

At present the industry is characterized by substantial worldwide overcapacity, following the interruption of the growth of demand occasioned by the recent recession. Oil-producing countries, particularly in the Middle East, have announced their intention of moving downstream into the production of petrochemicals as part of their plans for industrialization. If this come about it could present further competitive challenge to established producers.

The special features of the three sub-groups earlier enumerated are now considered :

a) The Multinationals

Their advantage lies in the globality of their operations, and the resulting geographical flexibility in the siting of their activities. Locational decisions are important for the petrochemical industry, the Multinationals are able to make assesments on a global level of prospects for the industry, and to invest accordingly. This assesment will be based on the relative expected growth and proximity of markets, transport costs, relative feedstock costs and availability, relative position in relation to taxes, investment subsidies, etc., labour supply, and the many other factors of importance in determining overall costs.

Because countries are usually anxious to attract industry, they often make valuable fiscal concessions, and the Multinationals are able to take full advantage of these, and indeed to "play one country off against another" in order to secure advantageous arrangements.

The Multinationals are able, because of their size, to take full advantage of economies of scale, and the financing of new projects represents less of a constraint for them than for the smaller enterprises.

b) Subsidiaries

Although not as large as the largest Multinationals, some of the subsidiaries of the Majors have considerable activity in the petrochemical field, particularly in the area of base product manufacture.

They are distinguished from other petrochemical enterprises by their relationship with the parent company. While they tend to have a considerable degree of autonomy as regards the management of their affairs, they are for the most part tied to the parent company for their supplies of feedstock. While the advantage in terms of security of feedstock can be expected to outweigh any disadvantage which arises from this obligation, there could be times when this constraint carries a penalty, as the relative advantages of the different feedstocks change.

As already mentioned, the financing problems of Subsidiaries are considerably eased by virtue of the substantial resources of the parent companies. The possibility of realizing economies through the integration of petrochemical and refining activities in a single site is also a valuable advantage.

c) The Nationals

Smaller, national-based enterprises are at a disadvantage with respect to the Multinationals and the Subsidiaries. As prices come under pressure due to increasing competition, they are squeezed before the bigger firms.

Firms operating principally on a national level do not have the same facility to make optimal locational decisions on a worldwide basis. They are subject to local trends and influences, and are in a weaker position in relation to the national government.

Equally smaller firms tend to be increasingly put under strain by the trend towards larger unit size of plant, which produces financing problems, and increases risks.

There is thus pressure on the smaller firms to rationalize their operations and move towards larger groupings, and for the larger firms to seek to diversify their operations geographically, that is to seek to internationalize or multinationalize their activities, either through sole or joint ventures outside their previous zone of operation.

At the same time they will seek support and assistance from their own national governments, at least where they seem threatened with extinction.

## 3 - The developed countries

The governments of the developed countries have a number of different roles in relation to the petrochemical system, some of which are conflicting.

They seek to ensure that national demands for petrochemical products are met at reasonable cost, subject to national priorities as a whole. They seek to ensure that the petrochemical industry established within their frontiers makes a maximum contribution to national wealth and well-being. Where this is judged beneficial they will seek to attract foreign investment in petrochemicals. They try to stimulate, encourage, and where necessary, protect their own national firms, particularly in the face of foreign competition, and to support and promote their activity abroad, while at the same time ensuring that they make an equitable contribution to the national exchequer, and that a state of reasonable competition in maintained.

Very few of the developed countries are self-sufficient in energy, and some are almost wholly reliant on imported energy. With the likely approach of scarce energy, governments of developed countries may become increasingly interventionist in energy matters, and this could have repercussions for the petrochemicals industry.

Finally, governments have the function of ensuring that the non-economic priorities of a society are met as well as the economic ones. As a society's wealth increases, the relative value it places on factors such as a clean environment takes on an increased importance. The conjunction of increasing wealth and a deteriorating environment which often accompanies it may lead to dramatic action being taken by governments, as has already been seen in Japan, and to a lesser extent in the USA. The petrochemical industry is an important energy user, and a significant emitter of gaseous, liquid and solid pollution. A stringent anti-pollution programme would therefore impose significant costs on the industry.

a) The USA

The USA is the most economically powerful of the industrialized countries : five of the seven major oil companies, and most of the chemical multinationals, are American. As the most powerful country she enjoys the position of de facto leader of the Western industrialized countries.

The role which the USA sees for itself in the world clearly depends on political developments in that country, but barring a radical change in direction, it can be assumed that the American strategy will continue to be based on political, economic and military leadership of the West. In so far as the USA sets the tone for East-West and North-South relations, American attitudes will be important if not decisive in determining the pattern of economic development in the world, which is itself one of the main determinants of growth of the petrochemical industry.

In relation to feedstocks, the era of advantageous feedstock prices in the USA may come to an end, partly as a result of government measures and partly as a result of natural forces. The present government is pledged to reducing American dependence on imported energy.This may mean that oil prices are forced up to world levels and also that prices of natural gas (at present the predominant feedstock for American petrochemicals) will be forced up to those of oil. In any case the process of natural exhaustion of the reserves of gas is leading new investments in base product manufacturing plant in the USA to be based on naphtha and gas-oil. In view of the chronic shortage of naphtha in the USA, this could lead to increased imports of naphtha in the future.

Until energy independence in the USA is obtained however, it can be assumed that America's foreign strategy in relation to energy will be :

(a) in general, fostering good relations with producing countries,

(b) specifically, concluding bilateral exchange agreements,

(c) encouraging the dependence of oil-producing countries on their oil revenues,

(d) promoting further exploration in more strategically secure zones.

Point (c) above is interesting. If the USA (and other consuming countries) can encourage the oil-producing countries to embark on expensive industrialization programmes, then they will become more dependent on their oil revenues, and this will redress the balance of power somewhat in favour of the consuming countries.

b) Other developed countries

Particularly envisaged in this group are the EEC countries and Japan ; Canada, for example, falls more within the sphere of influence of the United States.

These countries are generally characterized by a high degree of energy dependence (with the exception of the U.K. and at present the Netherlands). The industry of Japan, for example, is largely based on imported crude, and large quantities of naphtha are imported for the petrochemical industry. Because of the vital importance of imported oil in the eonomies of these countries, governments will be increasingly forced to take an active role in energy management.

Several of these countries have established national oil companies, whose purpose is to promote national oil interests, to negotiate on behalf of governments, and so on. If such companies increase in importance, they could reduce the power of the majors in the world scene, establishing a tendency towards government-to-government negotiations and transactions.

The desire of European governments to reverse the trend towards concentration of economic activity has had an important impact on the petrochemical industry and may continue to do so. The promotion of national regional development policies has led to attractive incentives being offered - thus the heavy petrochemical investment in the Mezzogiorno area of Italy.

## 4 - Socialist countries

The interplay between the petrochemical systems of Socialist countries and other countries has been relatively modest until now. The Eastern block is self-sufficient in oil, the USSR being one of the largest producers of crude in the world. There is at present a certain flow of, in particular, aromatics from Eastern Europe into Western Europe, and of final products in the other direction, and Eastern Europe also imports significant quantities of final products from the rest of the world.

It can be assumed that the strategy of the Socialist countries is to provide themselves with a modern petrochemical industry capable of at least satisfying their own increasing needs for final products, and in suitable areas, of consolidating exports in order to earn "hard" currencies. Since demand in Socialist countries is itself likely to grow fairly fast, particularly if their economies are permitted to move in a somewhat more consumerist direction, a high level of investments in petrochemicals could be involved.

In relation to investment in petrochemical plant, there has been a recent tendency for Eastern block countries to commission the construction of petrochemical plants with Western engineering firms, for which payment is made not in currency but in petrochemical products from these plants after they begin to produce.

Since engineering firms have no distribution and marketing network for selling petrochemicals, they dispose of them to brokers, who offer them on the open market. Since the quantities involved can be quite large, the arrival of these products on the market can have a considerably disruptive, if temporary effect on the market. A generalization of this trend would be a matter of concern to the industry.

On a more strategic level, while the Eastern block has been self-sufficient in oil in the past, this situation may not continue indefinitely. The production potential of existing wells is limited, and while the Soviet Union has considerable untapped resources, these may prove difficult and expensive to exploit. It is thus conceivable that these countries could begin to compete for oil in the Middle East. As well as placing further pressure on world supplies, this would inevitably make the struggle for dominance in the Middle East between the two super-powers more acute.

5 - LDC with hydrocarbons

Under this heading a distinction has been made between the Gulf State type, as exemplified by Saudi Arabia, with enormous resources in relation to her level of economic activity, the size of her domestic market, and her needs for capital, and other developing countries with hydrocarbon resources, such as Iran, Algeria, Venezuela, etc.

Developing countries seek to broaden and diversify their economic structure, in particular through industrialization. The economic basis of their development programmes is their oil (and gas) resources, but it also represents a potential starting point for a policy of industrialization. Thus their strategy in relation to their hydrocarbon resources is :

- to obtain maximum control over their own resources,

- to commercialize to the maximum the raw materials to which they have access.

As regards the second point, the objective is to convert an activity which is a source of foreign currency, but which is marginal in terms of industrial activity directly generated, into national industries relying on domestic factors, increasing employment activities and skills.

The logical consequence of such a strategy is to move downstream into refining and then into manufacture of, in the first place, the more upstream petrochemical products. Many producing countries have announced their intentions of embarking upon, or increasing, programmes of construction of petrochemical plant, particularly in the Middle East,where the possibility of installing considerable new ethylene cracking capacity is being discussed.

Such developments could have an important impact on the world petrochemical scene. It is not yet clear what role the established chemical companies would play in such developments, i.e. whether they will participate in the form of joint ventures, and modify their investment behaviour in the traditional geographical areas accordingly, or whether they will adopt a more confrontationist attitude.

On a more general level, actions taken by these countries will influence the price and availability of crude oil, which in turn are of considerable importance to the petrochemical industry, because they influence both the price and availability of feedstock, and of energy itself, of which the petrochemical industry is no mean user. This will depend on the extent to which the interests of the oil-producing countries converge or diverge. It is therefore worth looking at the special considerations which apply to the two types distinguished.

a) Gulf States

At present, these states do not spend all their oil revenues on imported goods and services, and therefore have a large balance-of-payments surplus on current account, which is mainly deposited in Western banks.

The important factor which distinguishes these states from other oil-producing countries is that they have a much greater degree of flexibility in their production strategy. Since the present level of income is not required to finance current expenditure, they could, for economic or political reasons, reduce their production well below present levels. Indeed if their criteria were the purely economic ones of maximising the discounted value of long-term income, then they should almost certainly cut back production now, since oil under the ground is likely to appreciate faster than its current money value will appreciate in the bank.

This element clearly introduces an element of instability into the world oil supply situation.

Evidently the prosperity of these countries depends on reasonable world stability being maintained. The existing rulers govern on feudal lines, and profit enormously at present, and therefore do not want to see the status quo disturbed. This state of affairs need not, however, necessarily persist.

The existence of sizeable Arab funds invested in the West gives them another power beyond that of being suppliers of oil, i.e. the movement of funds could be deployed as a policy to create chaos on international monetary markets.

Recent events make it clear that a sine qua non for the continuance of OPEC as a significant force in determining oil prices and production is Saudi Arabian solidarity, and the strategy of Saudi Arabia in relation to OPEC will therefore be determinant.

As a force to be reckoned with on the international petrochemical scene, their wealth makes their challenge stronger, in that, at least in the short term while establishing their industries, they need not be subject to the normal commercial imperatives of making a reasonable return on their investments. A further important point in this connection is the price at which feedstock is transferred to the petrochemical industry in these countries. At present large quantities of natural gas are flared in the Middle East. This means that a very low price could be justified for ethane/methane feedstocks, helping to enhance competitivity.

On the other hand the absence of domestic markets means that production must be for export, which will produce certain problems for countries unfamiliar with marketing and commercialization problems.

b) Non-Gulf Oil Producers

The degrees of freedom of these countries are much more limited as oil revenues are required to go towards financing investment, and the consumption of a population with growing expectations.

An advantage presented by these countries, however, is the existence of significant actual or potential domestic markets, which could add momentum to the establishment of a national petrochemicals industry going as far as the manufacture of certain lines of final products.

In the development of such industry, regional cooperation and agreements are likely to play an important role in enhancing its prospects of success. Such cooperation might include economic and technological aid, as well as harmonization of investment plans and complementarity of production, as in the Andean Pact countries.

6 - LDC without hydrocarbon resources

In common with the LDC with hydrocarbon resources, their concern is to lay the foundations for a more industrialized society in their countries. In contrast, however, the move into petrochemical production, and in particular the manufacture of base products, is not a natural direction for industrialization as it is for countries rich in hydrocarbons.

As development in these countries proceeds, however, certain of the industries downstream from petrochemicals, for example textile manufacture, tyre factories, will establish themselves locally, increasing the demand for petrochemical final products. When such demand reaches a certain point within a geographical area, then it will become feasible to establish certain types of downstream petrochemical operation locally. In the first instance foreign firms will normally be involved, possibly in partnership with local enterprises. Developing countries will be faced with the dilemma of making the conditions for foreign investment sufficiently attractive to attract industry, while at the same time trying to ensure that a base is laid for a genuine national industry.

Because the establishment of a viable petrochemical industry is usually dependent on the proximity of a substantial and accessible market, a climate of economic cooperation between developing countries in a given region will greatly increase the prospects of establishing local petrochemical activity successfully.

7 - Consuming industries

These include agriculture (for nitrogenous fertilizers), the plastics processing industry, the textiles industry, the rubber processing industry, the process industries generally (for solvents), and so on. They obviously form an extremely heterogenous group of actors.

Generally their behaviour in relation to the petrochemical system is passive rather than active. Their influence on the other actors is exercised through their market place behaviour, that is through buying or not buying petrochemical products.

An exception to this occurs in the rubber industry, where tyre manufacturers and international rubber processing corporations such as Goodrich have become involved in the manufacture of synthetic rubbers. These cases, are, however, exceptional.

8 - Other actors

Amongst more marginal actors already mentioned are engineering contractors who erect petrochemical plant, and banks and other financial institutions, who provide finance for the industry.

These actors can be regarded as having a fundamentally passive role in relation to the petrochemical industry, as channels through which necessary goods and services flow, rather than as entities whose strategies influence the system.

However, a phenomenon relating to engineering contractors which is noteworthy is the current tendency for them to negotiate plant installation contracts with Eastern block countries in which, because of currency problems, payment is not made in cash, but in product itself, for example ammonia. These so-called "buy-back" deals can have an extremely disruptive influence on the markets. Since these engineering firms have no expertise in marketing petrochemical products, they pass them to brokers who drop them onto the markets, which are often undermined as a result.

Similarly, while banks exercise only a very fringe influence on the petrochemical system in normal circumstances, when an enterprise becomes very indebted to a bank because of liquidity problems, then the latter will take an increasing interest in, or control in, the affairs of the former.

The main contribution from a bank in this situation, however, will be sound financial and management principles, rather than any strong sense of strategy relating to the petrochemical industry.

## C - Strategy of the actors table

On the page overleaf appears the table of "Strategy of the Actors" This table summarises in schematic form the principal objectives of the actors and their means of action upon one another. A row and a column are allocated to each group of actors. The diagonal squares contain the "objectives" of each group of actors (particularly in relation to petrochemicals), and the main constraints to which they are subject. The problem of defining the objectives of the actors is not a simple one, and one on which a given group of experts may not be able to reach absolute agreement. This is particularly true of a country, whose often mutually inconsistent policies are the resultant of many different internal pressures, tendencies and shades of opinion in which the outcome will depend on the balance of power prevailing at a given time, the interplay of democratic forces, and so on. It may therefore be somewhat of an oversimplification to regard an actor as being a coherent entity with fixed criteria which determine his behaviour. In spite of these strictures, however, the hypothesis of the actor as a homogeneous entity with given consistent objectives is sufficiently accurate to be a useful and applicable concept.

In fact an actor will have a whole hierarchy of objectives, some of them mutually contradictory. It is useful, however, to think in terms of a single main objective which finds expression in a number of sub-objectives, and this convention has been adopted in the table.

Again the choice of which should be regarded as the ultimate or main objective is open to some disagreement, but this choice is not of critical importance for the present purposes, which are essentially to confront the objectives of the different actors with one another in order to identify the conflicts and communities of interests between actors.

The term "constraints" refers to matters outside the control of the given actor, which could in some important way restrict his freedom of action, constitute a threat to his existence, and so on.

The off-diagonal squares in the table represent the means of action, actual or potential, which actors have on one another by virtue of the balance of force between them. Thus the square in the i'th row and the j'th column displays the means of action which actor i has with regard to actor j.

The purpose of completing the table of actors' strategy is twofold, i.e.

(i) to determine to what extent the objectives and projects of the different actors are compatible with, or in conflict with, one another, and thus to identify communities of interest and actual or potential alliances, and

(ii) to appreciate the balance of force between the actors, and to determine the means which they possess to bring about their objectives, and the constraints to which they are subject.

A consideration of the dynamics of these relationships leads to the formulation of certain fundamental hypotheses, the realization or non-realization of which condition the evolution ot the system.

It should be noted that gathering the work carried out into the form of a table, apart from its presentational advantages, ensures that the relations between each pair of actors is considered systematically ; in other words, it results in certain questions being asked which might not otherwise have been asked.

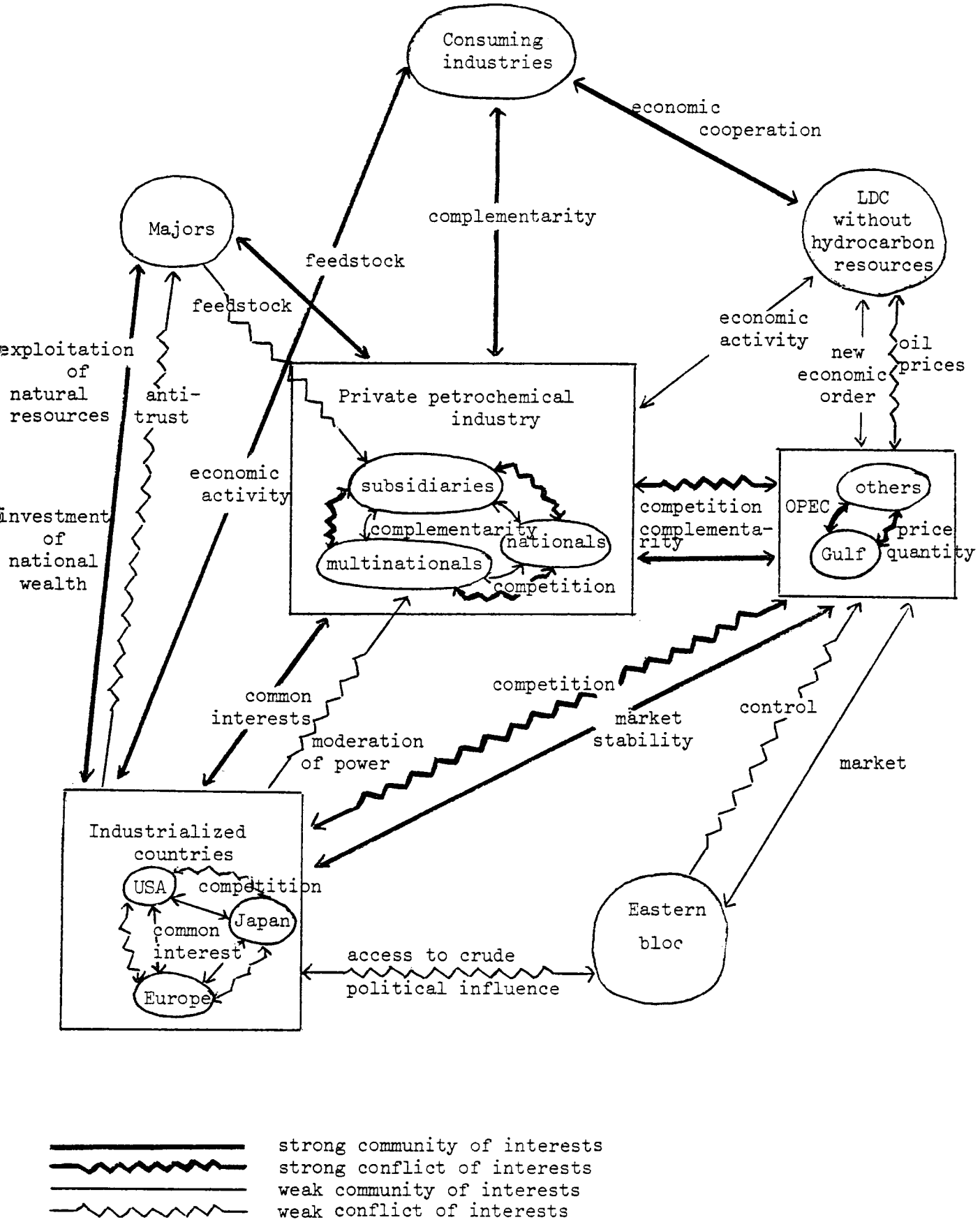
The information contained in this table was gathered together partly by extensive reading of technical and economic publications. In order to complete this information, it was supplemented by carrying out interviews with a number of senior personnel within the organizations in various parts of the world in which issues of strategy were tackled. Finally, further material is gained by considering the conflicts and communities of interest inherent in the objectives and roles of each of the actors.

Finally, it should be borne in mind that, with many of the means of action mentioned in the table, there is a second means, represented by the antithesis of the first. For example, if one means of action is the formation of joint ventures, then a second is the refusal of joint ventures, and so on.

D - Relations and balance of force between actors

The diagram below represents the principal antagonistic and protagonistic relationships between the actors. Straight lines represent a community or convergence of interests, whereas zig-zag lines represent conflicts or divergence of interest.

Diagram 4.1 - Potential communities and conflicts of interest between actors



The relations of the actors are characterized by a great deal of ambivalence, which reflects the complexity and inter-relatedness of the petrochemical system. Thus petrochemical firms are, at the same time, competitors and mutual customers, since they sell and buy base and intermediate products amongst themselves. The oil-producing countries and petrochemical firms have a supplier/customer relationship which gives them a common interest in the maintenance of an orderly market, but as the former venture increasingly into petrochemicals themselves, conflictual situations could arise. The ambivalence can also be found in relations between the OPEC countries, where the solidarity and obvious coincidence of interests of members is offset by the distinct differences in objectives and constraints between the Gulf and the non-Gulf type of members.

Thus, while the system in typified by a substantial number of actual or potential conflicts, few of these are unmitigated by any conjunction of interests or mutual dependencies, and these latter have a stabilizing effect on the system as a whole.

In analyzing the relationships between actors, the major conflicts, both actual and potential, are of particular interest, since these naturally introduce instability into the system, and could be instrumental in changing the system or creating ruptures with the past, an awareness of which is essential in carrying out a forecasting exercise.

The picture given by these conflicts, however, needs to be complemented by information as to the relative strength of the actors in conflict. It is by considering the balance of force between them that conclusions can be drawn as to the likely outcome of these conflicts.

In table 4.1 overleaf, the five major conflicts which appear to arise in the petrochemical system are identified, and compared in each case with the major means of action which the actors have on each other.

In the first case there is the struggle between the oil-producing countries (particularly the oil-exporting countries) and the Majors concerning, essentially, the control of the oil produced. This conflict is of importance to the petrochemical industry because an important part of the world's petrochemical industry uses oil derivatives as feedstocks. Some of the battles relating to this conflict have already been fought ; most exploitation of oil in exporting countries is now carried out by a nationalized company, which is at least nominally under the control of the national government. The strength of the producing countries lies with their legal omnipotence within their own national boundaries. They are free to take almost any action in their country to assure the control, exploitation and disposal of their own natural resources, and of all investments located on their territory. On the other hand, the initiative does not by any means lie entirely with the producing countries.

The trump cards of the oil majors are their technological, commercial and managerial skill and expertise. Until this superiority is removed, which is unlikely to occur in the shorter term, the majors will continue to play an important, albeit diminished in comparison with some years ago, role in the oil industry.

Table 4.1 - Main conflicts, petrochemical system

| Protagonists | | Reason for conflict | Means of action of (1) on (2) | Means of action of (2) on (1) |
|---|---|---|---|---|
| (1) Majors | (2) Oil-exporting countries | Struggle for control of oil | - Obstruction of technological transfer<br>- Abstaining from joint ventures, etc.<br>- De facto control of national companies, joint ventures<br>- Increased exploration and exploitational activity in more docile countries, within sphere of influence | - Takeovers, nationalizations, participation in equity or management<br>- Interruption or reduction of production<br>- Venturing themselves into downstream activities<br>- Dealing directly with national oil companies in developed countries, etc. |
| Private petrochemical industry | Oil-exporting countries | Competition in petrochemical industry | - Maintain technological supremacy<br>- Abstaining from joint ventures, etc.<br>- De facto control of national companies, joint ventures<br>- Intensifying of competition, pricecutting, etc.<br>- Discrimination against products coming from oil-exporting countries | - Price competition<br>- Agreements with Third World countries<br>- Protection of national markets |
| Developed countries | Oil-exporting countries | Oil prices<br>Competition in petrochemical products | - Protectionism<br>- Playing on role of dollar, permitting depreciation, etc.<br>- Diplomatic, military pressure<br>- Preferential purchasing policy<br>- Freezing of petrodollars<br>- Agreements between developed countries to form more powerful negotiating block | - OPEC decisions : price, volumes of production<br>- Movement of cash deposits<br>- Selective embargos<br>- Diplomatic pressure<br>- Protectionism |
| Gulf-oil exporters | Other exporting countries | Differences of objectives and constraints | - Unilateral action with regard to oil prices<br>- Undermining OPEC policy (Saudi Arabia) | - Diplomatic pressure<br>- Appeals to arab solidarity, public opinion<br>- Aid to subversive movements |
| Petrochemical companies amongst themselves | | Competition | - Pricecutting<br>- Price agreements | |

Secondly, there is the conflict, briefly alluded to earlier, between the hydrocarbon-producing countries and the so-called private petrochemical industry. This conflict is essentially one of potential competition, but it could be of a different order from that between private petrochemical firms. Investment criteria of developing countries may be different from those of traditional petrochemical firms, containing a "political" element, or at least economic criteria other than those of an accepteble return on capital. Developing countries will not be able to increase their share of the world market unless they increase their capacity at a rate faster than the growth in world demand. A further consideration is that a new base product industry situated for example in the Middle East might benefit from low cost feedstock, particularly natural gas in view of present lack of alternative markets, and might also draw significant benefits from the greater security of supply. Finally there is a fear among traditional producers that new petrochemical complexes in the wealthy Gulf states might not be subject to the normal economic constraints of profitability, paying off investments, and so on, which would make their competition more formidable. While there are many counter-arguments, the extent to which such a movement could be resisted by the established petrochemical industry is limited. While the firms in industrialized countries hold advantages in terms of technological and commercial expertise, there is virtually a free market in technology, and although some firms might decline to cooperate with or participate in new ventures in the Middle East, a general boycott in unthinkable. Thus given that the new ventures were successful, defensive strategies on the part of established firms such as moving downstream into more specialized areas would be more likely. Such developments would be important since they would imply a significant shift in the pattern of world porduction.

The third major conflict is that between the developed (or OECD) countries and the developing, oil producing countries.

Apart from a possible emergence of competition referred to above, which has an aspect on a national level, there is the vital issue of the price (and quantities supplied) of oil. While price is a potential source of conflict in any relationship between suppliers and customers, it has unique significance in the case of oil, in view of the control exercised over world exports by a small number of countries, and the indispensable nature of energy, and oil in particular, in industrialized economies. The price of oil directly affects the price of oil-derived feedstocks such as naphtha, and gas-oil, and indirectly those of other feedstocks such as methane and ethane. Substantial shifts in oil prices could therefore affect the competitiveness of petrochemicals where non-petrochemical competitors with different energy inputs exist.

Apart from the direct consequences for petrochemicals of changes in oil prices (and quantities supplied), such changes, and relations between OPEC and developed countries in general, will have important implications for general economic development in the world. Few people can doubt the relationship between the OPEC price increases of crude in 1973 and the world economic recession of 1975/76. Since the growth in demand for petrochemicals will be partly determined by general world economic growth, this factor is of interest for another reason.

A comparison of the means of the developing oil-producing countries and the developed countries appears to show a balance of power favouring the former over the next two decades, but the key role of Saudi-Arabia should not be ignored. Her level of oil exports, productive capacity and reserves are such that the solidarity of OPEC depends on the goodwill of Saudi Arabia, a very non-typical oil producer.

This leads to the fourth major conflict listed in table 4.1, i.e. between the "Gulf" type of oil-producing country and the others.

Some evidence of such a conflict becoming actual rather than potential has appeared in the last year, with Saudi Arabia effectively vetoing OPEC price increases. Conflicts arise out of differences in economic situation, political system and philosophy, and political allegiance. So far as the balance of power is concerned, Saudi Arabia has the economic strength to pursue its chosen policies independent of the policies of other OPEC governments, so that the cohesiveness of OPEC appears somewhat delicate. Increasing geographical diversification of petrochemicals could give new impetus to cooperation between oil-producing countries, as harmonization of investment programmes within zones, technical cooperation and complementarity of production will be important to the success of new projects in these countries

Competition within the "private" petrochemical industry itself constitutes the fifth major conflict, and this factor has been of particular importance in recent years, when a conjunction of high competition and extensive surplus capacity has led to a downwards pressure on prices in the petrochemical industry. As competition becomes more intense, the greatest pressure always falls on the weakest units, and in the field of petrochemicals these have been the smaller national companies, not large enough to diversify commercially or geographically, and put under strain by the trend towards ever larger units.

This conflict therefore has implications for the "orderliness" of the market, particularly in relation to pricing policy, and the structure of the market, in particular the member size distribution of producers.

It is to be noted that, of the five major conflicts described above, four involve the oil-exporting countries. It does not follow, however, that this poses an undue threat to them, since each of these conflicts is mitigated by some parallel convergence of interests, as mentioned earlier. Furthermore their natural resource is a major asset which gives them the necessary robustness to withstand the challenge presented.

# V - THE FUNDAMENTAL HYPOTHESES

## A - Use of hypotheses

Scenarios describing the development of the world petrochemical industry and its environment will be constructed. In the first instance these will be described in terms of a number of hypotheses about the future. These can either be binary hypotheses, i.e. which are or are not realized, or continuous in the sense that they place a specific value on a variable in the future.

Scenarios are schematic representations of the future, economically expressed, which confine themselves to describing those aspects of the future which are important for the system under study. The number of hypotheses which characterize a scenario should be sufficiently large to provide an outline working description of the system. Taking these as a basis, scenario descriptions can then be elaborated in greater detail.

It is obviously desirable that the hypotheses which go to make up a scenario be mutually consistent, and also that the scenarios developed be, in some sense, "plausible". This is the objective of the SMIC method. The knowledge and experience of experts in the petrochemical industry, in particular those who concern themselves with problems of strategic planning, is drawn upon, their opinions being gathered together by means of a questionnaire. Questions are put to these experts not only on the simple probabilities of given hypotheses being realized, but also on conditional probabilities, i.e. that hypothesis i will be realized given that hypothesis j is (or is not) realized. The SMIC method then provides the two above-mentioned criteria, i.e. consistency, and reasonable degree of likelihood, are met by the scenarios.

## B - Choice of hypotheses

The basic hypotheses for the formulation of the scenarios had to be selected. The various stages of the prospective analysis already described provide insight into the system and serve as a basis for choosing these hypotheses, but there is of course no mechanistic method by which this can be done. The choice must also be made in function of the need for parsimony and completeness mentioned above, and also with a view to the information which the scenarios need to provide.

The scenarios must contribute to the provision of detailed numerical information required by the model. This information includes forecasts of demand for the various final products, forecasts of total capacity in respect of the different processes, and forecasts of the development of the different cost factors.

The structural analysis of the system comprising the world petrochemical industry and its environment demonstrated the sensitivity of the industry to the international politico-economic situation. Variables of economic cooperation between the major blocks, international monetary stability, and the solidarity of oil-producing countries are all highly motor on the system. These variables exercise their effect both on the supply and demand side as far as the petrochemical industry is concerned. They affect both the magnitude and the geographical emphasis of world economic growth, which is an important factor in determining the growth of demand for petrochemicals in the different zones. On the supply side, the location of capacity will depend on the development of international relationships, the willingness of the richer countries to provide loans and credits, and also of course on the local development of demand. Finally the various aspects of international relations have an important bearing on the question of availability and cost of feedstocks, since, outside the United States, much petrochemical

feedstock derives ultimately from imported oil, which recent events have shown are very much in the arena of international political developments.

Among the internal variables, those dealing with the role of developing countries in the petrochemical industry in the future proved to have a high motricity. These included the rate of transfer of technology, and the variables representing the share of developing countries in world production in the future.

The retrospective study showed a picture of an industry which, because of its high technology, capital intensiveness and large scale, and its functional integration into the existing industrial fabric, has hitherto been dominated by the industrialized countries, but which domination is just beginning to be challenged by those developing countries with oil resources, who see in petrochemicals an appropriate area into which to channel their drive towards industrialization. It showed how competition in the industry has become more strong, and the downward pressure this has exercised on prices. It also demonstrated the vital importance of the question of feedstocks for the industry, and how developments in the area of energy, and in particular oil prices, can alter the relative advantages between zones.

The "Strategy of the actors" analysis showed a number of actual or potential conflicts of interest between the actors in the system, in particular between the established industry in the developed countries, and the hydrocarbon rich developing countries, the latter partly in their role as oil exporters, and partly as potential competitors in petrochemical production. However the analysis also brought out that there were important symbiotic relationships between the protagonists. Thus while the countries with resources can guarantee the supply of feedstock, the established oil and petrochemical countries possess the technological knowhow, commercial and marketing power,and indeed themselves represent potential markets for petrochemical and oil products.

Competition and marketing power emerge as the basis of another of the main conflicts identified, i.e. that between the firms which make up the private petrochemicals industry. Finally the future cohesiveness or otherwise of OPEC, and in particular the policies of Saudi-Arabia, could have an effect on the system, most directly through price and availability of oil, and thus of petrochemical feedstock.

Following the synthesis of the various stages of analysis, a set of hypotheses was chosen, which fall into four groups as follows :

1 - Politico-economic hypotheses

(i) Increasing economic cooperation between industrialized and developing countries,

(ii) Mean rates of economic growth (GNP) in the different groups of countries,

(iii) Increasing degree of protectionism in international trade,

(iv) Increasing importance of Eastern block countries in international trade,

In choosing the politico-economic hypotheses, it is not only a matter of which variables to base them on, but also at what level. They can either be at a higher level, which discuss the general economic, etc. climate, for example North-South cooperation, or at the lower, more concrete level of rates of economic growth, increase in trade, and so on.

In view of the need for scenarios to provide detailed numerical data on rates of growth of demand, hypotheses concerning these lower level variables will be made. In so far as rates of economic growth by region respond to the general economic and political climate, then certain wider hypotheses are subsumed in the growth hypotheses.

However these estimates need to be placed in a wider economic context, and three higher level hypotheses have been chosen. The question of economic cooperation between industrialized and developing countries is clearly important ; in the MICMAC ranking it is the variable with the highest motricity, both overall and of the external variables on the internal variables only. The tendency of international trade towards protectionism or not is an interesting variable. In the MICMAC analysis it proved to have both a high motricity reflecting the depressing influence of protectionism on world trade in general and trade in petrochemicals in particular, and also a fairly high dependence, reflecting the fact that, in certain difficult circumstances, governments come under increasing pressure to take protectionist measures.

Finally a hypothesis will be made regarding the share of Eastern block countries in world trade. An increase in this share could have important implications for the petrochemical industry, leading, for example, to the proliferation of "buy-back" arrangements (see section "Strategy of the Actors).

2 - Feedstock/energy

(v) The price of oil in real terms,

(vi) The price of oil in the USA relative to world price,

(vii) The price of natural gas relative to oil,

(viii) The general coutinuous availability (at reasonable prices) of feedstock to petrochemical companies.

It is clearly essential to incorporate hypotheses relating to the question of feedstocks, in terms of price and availability.

The "Strategy of the Actors" stage of the analysis emphasized that the drive towards assuring feedstock supplies was likely to play an important role in influencing the behaviour of the actors.

Over the next ten to fifteen years, at least, the world price of crude oil is likely to be a crucial factor, because of its influence both on feedstock prices and on energy prices. MICMAC showed this variable to have a high motricity, and it was seen that the increased price of oil led directly to greatly increased naphtha prices, and also shifted the balance of competitivity in petrochemicals in favour of the United States. The influence of oil prices on energy prices is also of importance to the petrochemical industry in so far as it is also a major energy consumer, quite apart from its feedstock needs.

Hypotheses about feedstock prices are particularly important in this study, since the model will require estimates of these prices in the future. Estimates of other costs incurred by the petrochemical industry will also be required, but feedstock prices are probably the most interesting, since they are likely to be the most volatile. If there is a serious disequilibrium between supply and demand for oil in the mid 1980s, as many forecast, then the price of oil could rise sharply with similar consequences for feedstock prices.

It was seen that oil prices in the USA are somewhat insulated from world (or OPEC) prices. In view of the importance of the American market, therefore, a hypothesis about the (relative) price of oil in the USA has been retained.

Finally, a hypothesis about whether gas prices will continue to lag behind oil prices has been adopted. It has been seen

that the problem of gas prices has been important in the past, for example, giving a cost advantage to those producers who use natural gas products, rather than oil-based products, as their feedstock. It was seen that this factor could be even more important in the future, as the petrochemical industry could, in countries such as Saudi Arabia, be a means of valorizing natural gas which might not otherwise be valorizable at all, i.e. thus justifying a low price.

3 - Market organization

(ix) Orderly, free market, with prices related to economic costs,

(x) Decrease in captivity of markets,

These hypotheses, which relate to general pricing strategy and the openness of the markets to all comers, emerge as having potential importance in the "Strategy of the Actors" analysis. In particular, the policy which is followed in terms of pricing is of great importance in the model, and the scenarios will be required to provide assumptions in this respect.

4 - Location of new investment and role of developing countries

(xi) Significant increase in the share of oil-exporting countries in total world petrochemical capacity,

(xii) Free access to process technology and knowhow in the future.

These hypotheses corresponding to the variables "Share of oil-rich developing countries in total production of base products", "Share of oil-rich developing countries in total production of final products", and "Rate of technological transfer", which were amongst the most motor internal variables emerging from the MICMAC analysis.

Furthermore, issues related to the possible emergence of developing countries with oil resources as important producers of petrochemicals were shown to be of considerable importance in the "Strategy of the Actors", and could give rise to a shifting orientation of new investment in the petrochemical industry in developed countries also. Finally, assumptions concerning the location strategies for new petrochemical investment are required for the model, which gives an added importance to these hypotheses.

The above hypotheses were those on which the opinions of experts were sought.The SMIC questionnaire is contained in the next section. The hypotheses postulated are defined more fully there.

## C - The SMIC questionnaire

The SMIC questionnaire comprises 4 sections, containing the questions and statement of the hypotheses brought out earlier.

- The section "General economic hypotheses" allows the expert to specifiy the world economic context which he envisages during the period 1980 to 2000 ; in addition to describing the background against which the petrochemical industry will develop over the period, it also helps the respondent to answer the questions which follow subsequently.

- The section "Major hypotheses", in which the five basic hypotheses directly concerning the evolution of the world petrochemical industry are presented. These hypotheses are those on which the role of the main actors is determinant, and it is therefore these that are processed by the SMIC method.

- The section "Related questions" which explores some of the links between the major hypotheses and the more general questions, in order to complete the description of the scenarios.

- The section "Additional questions", which concerns trade in petrochemicals, investment and demand, whose purpose is to serve as a frame for forecasting the data required by the model.

The questionnaire is presented below. It was distributed, in February 1978, to 300 selected experts throughout the world, from different geographical areas and backgrounds : oil and petrochemical companies, governments (as represented, usually, by State oil or chemical companies), engineering firms, OPEC, research institutes, the specialist press etc.. and chosen on the basis of their involvement with long term development.

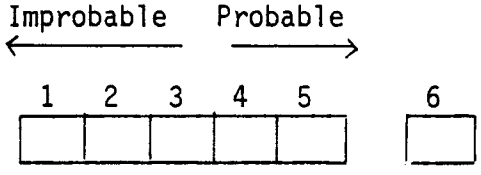
# A P P E N D I X

## THE SMIC QUESTIONNAIRE

## Codification of answers

With the exception of open questions, you need only mark with a cross (X) the box corresponding to what appears the most accurate answer.

Many questions are asked in terms of probability. Indicate your reply by marking an X in the appropriate box according to the following code :




1 = very improbable
2 = improbable
3 = rather probable
4 = quite probable
5 = very probable

(possibly) 6 = unrelated, where two hypotheses are considered to cross

# GENERAL ECONOMIC HYPOTHESES

A - The Gross National Product for the period 1980-1990 (according to country groups) will increase at a constant price rate of an average annual (*) :

| Industrialized countries | | Developing countries | |
|---|---|---|---|
| | less than 2 % ☐ | | less than 2 % ☐ |
| | between 2 % and 3 % ☐ | | between 2 and 4 % ☐ |
| | between 3 % and 4 % ☐ | | between 4 and 5 % ☐ |
| | between 4 % and 5 % ☐ | | between 5 and 6 % ☐ |
| | over 5 % ☐ | | over 6 % ☐ |

B - The cost of OPEC oil will increase in constant money during the period 1978-1985 :

by less than 50 % ☐
at between 50 % and 75 % ☐
at between 75 % and 100 % ☐
by over 100 % ☐

Improbable ← → Probable

C - The average price of oil in the USA will meet the world price during the period 1980-1990

1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

D - Protectionism will develop between the different regions of the world during the 1980-1990 period

1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

E - The price of natural gas in the consuming regions will, in 1990, be equivalent to its energy value (price of BTU - oil)

1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

F - Communist countries will considerably develop industrial and commercial exchanges with western countries (their share in world commerce will increase from 5 % in 1977 to over 10 % in 1990)

1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

G - Economic cooperation (in terms of the North-South dialogue) will actually develop between industrialized and developing countries during the period 1980-1990

1 2 3 4 5 ☐ ☐ ☐ ☐ ☐

(*) The average annual growth rate of the Gross National Product at constant price between 1960 and 1970 was at 4,9 % in industrialized countries and at 5,3 % in developing countries (UNO source).

## MAJOR HYPOTHESES

The five hypotheses given here form the basis for the constructing of scenarios for the worldwide petrochemical industry. They are explicited below. Please indicate first of all what degree of probability you accord them.

$H_1$ - Supply guarantee.

For the period 1980-1990, petrochemical firms in general will be supplied in raw materials (basic hydrocarbons) in quantities sufficient and at prices which will permit them to conduct their activities in satisfactory economic conditions (for example, by making supply agreements with western oil firms, or by participating in joint ventures with producing countries).

Improbable ← → Probable

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| | | | | |

$H_2$ - Emergence of new petrochemical producers.

The major OPEC countries will be endowed with a petrochemical industry representing, by 1990, more than 10 % of world capacity (Communist countries excepted).

Improbable ← → Probable

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| | | | | |

$H_3$ - Organisation of the worldwide petrochemical market.

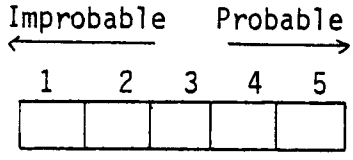
The world market for petrochemical products (*) will progressively organize itself during the 1980-90 period: the companies will in general observe professional discipline, the exchange value of major products will integrate capital returns, and one can consider that there will exist a world price for the major products (* *). The

---

(*) base products, intermediate products, final products.

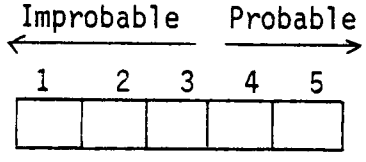
(* *) as, for example, crude oil today.

non-realization of this hypothesis (disorganization of the world market) will indicate that the market is disorganized by significant and regular sales at marginal cost (or below economic cost), or that there exist local markets which are artificially protected.



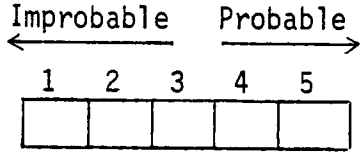

$H_4$ - Sharing of technological power.

During the 1980-90 period, countries or firms needing it will have access without restriction to the most advanced technologies concerning production processes, methods of transformation, know-how, equipment, etc.




$H_5$ - Sharing of marketing power.

The commercialization of petrochemical products (base products, intermediary products, final products) will be shared in significant measure (by more than 20 %) by the various producers through the stock markets, or by direct sale. In other words, the captivity of the petrochemical market (that is, international exchanges taking place between affiliates of a same group) will decrease during the 1980-1990 period.



Now please indicate to what degree the realization, or the non-realization, of the other hypotheses in turn would change your estimation concerning each of the preceeding hypotheses.

Conditional probabilities of $H_1$

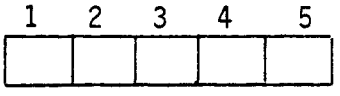
In your opinion, what would be the probability of realization of hypothesis $H_2$ :

supposing.that, on the other hand,

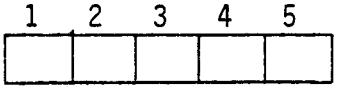
Supply guarantee

improbable ← → probable

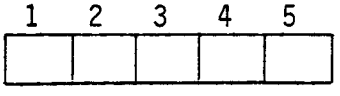
$H_2$ occurred (Emergence of new petrochemical producers)



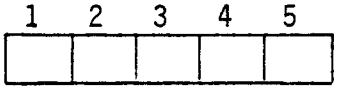

$H_2$ did not occur (no emergence of new petrochemical producers)



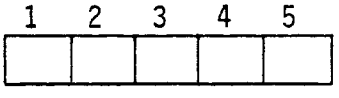

$H_3$ occurred (Organization of the worldwide petrochemical market)



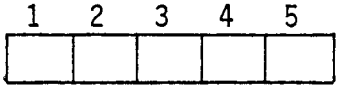

$H_3$ did not occur (no organization of a worldwide petrochemical market)



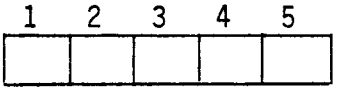

$H_4$ occurred (Sharing of technological power)



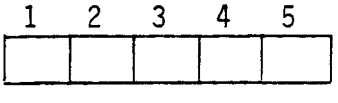

$H_4$ did not occur (no sharing of technological power)




$H_5$ occurred (Sharing of marketing power)




$H_5$ did not occur (no sharing of marketing power)



## Conditional probabilities of $H_2$

In your opinion, what would be the probability of realization of hypothesis $H_2$ :

Emergence of new petrochemical producers

supposing that, on the other hand,

improbable ← → probable

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $H_1$ occurred (Supply guarantee) | | | | | |
| $H_1$ did not occur (no supply guarantee) | | | | | |
| $H_3$ occurred (Organization of the worldwide petrochemical market) | | | | | |
| $H_3$ did not occur (no organization of a worldwide petrochemical market) | | | | | |
| $H_4$ occurred (Sharing of technological power) | | | | | |
| $H_4$ did not occur (no sharing of technological power) | | | | | |
| $H_5$ occurred (Sharing of marketing power) | | | | | |
| $H_5$ did not occur (no sharing of marketing power) | | | | | |

## Conditional probabilities of $H_3$

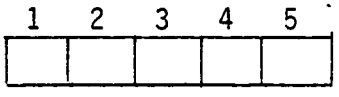
In your opinion, what would be the probability of realization of hypothesis $H_3$ :

Organization of the worldwide petrochemical market

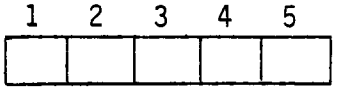
supposing that, on the other hand,

Improbable ← → Probable

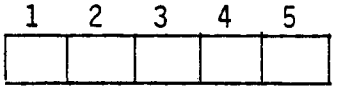
$H_1$ occurred (Supply guarantee)



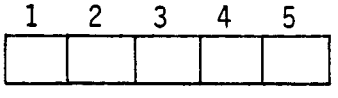

$H_1$ did not occur (no supply guarantee)



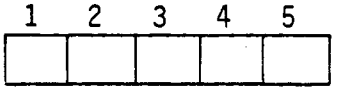

$H_2$ occurred (Emergence of new petrochemical producers)



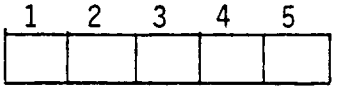

$H_2$ did not occur (no emergence of new petrochemical producers)



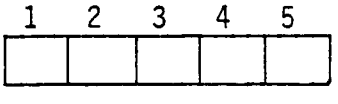

$H_4$ occurred (Sharing of technological power)



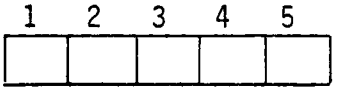

H4 did not occur (no sharing of technological power)




$H_5$ occurred (Sharing of marketing power)




$H_5$ did not occur (no sharing of marketing power)



## Conditional probabilities of $H_4$

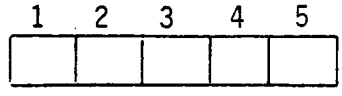
In your opinion, what would be the probability of realization of hypothesis $H_4$ :

Sharing of technological power

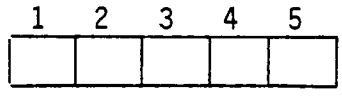
supposing that, on the other hand,

Improbable ← → Probable

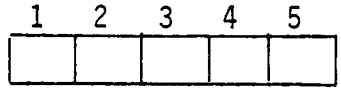
$H_1$ occurred (Supply guarantee)



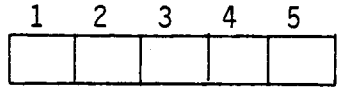

$H_1$ did not occur (no supply guarantee)



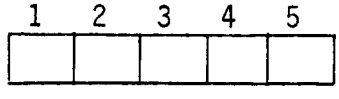

$H_2$ occurred (Emergence of new petrochemical producers)



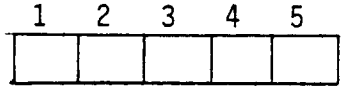

$H_2$ did not occur (no emergence of new petrochemical producers)



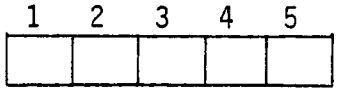

$H_3$ occurred (Organization of the worldwide petrochemical market)



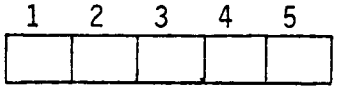

$H_3$ did not occur (no organization of a worldwide petrochemical market)




$H_5$ occurred (Sharing of marketing power)




$H_5$ did not occur (no sharing of marketing power)



## Conditional probabilities of $H_5$

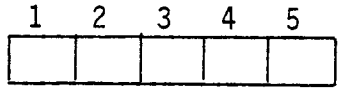
In your opinion, what would be the probability of realization of hypothesis $H_5$ :

Sharing of marketing power

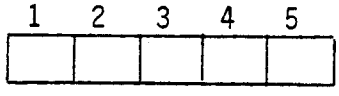
supposing that, on the other hand,

Improbable ← → Probable

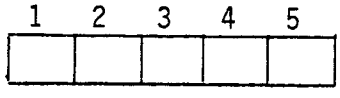
$H_1$ occurred (Supply guarantee)



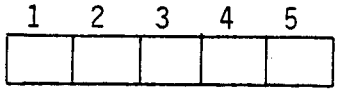

$H_1$ did not occur (no supply guarantee)



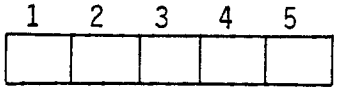

$H_2$ occurred (Emergence of new petrochemical producers)



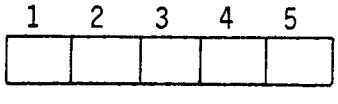

$H_2$ did not occur (no emergence of new petrochemical producers)



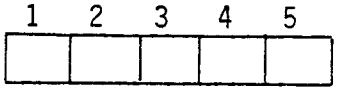

$H_3$ occurred (Organization of the worldwide petrochemical market)



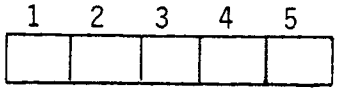

$H_3$ did not occur (no organisation of a worldwide petrochemical market)




$H_4$ occured (Sharing of technological power)




$H_4$ did not occur (no sharing of technological power)



## RELATED QUESTIONS

$Q_1$ Estimate the probability of $H_1$ (Supply guarantee) if, in addition:

| | 1 | 2 | 3 | 4 | 5 | 6(*) |
|---|---|---|---|---|---|---|
| the constant price of oil exceeded $ 20/barrel in constant money during the period 80-85: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| an energy shortage occurred before 1990: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| the price of natural gas met its energy value: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

$Q_2$ Estimate the probability of $H_2$ (Emergence of new petrochemical producers) if:

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| the constant price of oil ~~exceeded~~ $ 20/bbl in constant money during the period 80-85 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| the price of USA oil met the price of OPEC oil: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| the price of natural gas met its energy value: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

$Q_3$ Estimate the probability of $H_3$ (Organization of the world market) if, moreover:

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| protectionism throughout the world develops: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| protectionism does not develop: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Eastern countries interfere in the petrochemical market: | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

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(*) After attributing a probability, check box 6 if you consider that the questions are not related.

Q4 Estimate the probability of $H_4$ (Sharing of technological power) in the event that:

protectionism were to increase in the world: 1 2 3 4 5 6

economic cooperation were to develop between industrialized and developing countries: 1 2 3 4 5 6

economic cooperation were not to develop: 1 2 3 4 5 6

Q5 Estimate the probability of $H_5$ (Sharing of marketing power) in the event that:

economic cooperation were to develop between industrialized and developing countries: 1 2 3 4 5 6

economic cooperation were not to develop: 1 2 3 4 5 6

Q6 Estimate the probability that producing countries effect regular sales of petrochemical products at prices below economic cost:

if $H_2$ (Emergence of new producers) occurs: 1 2 3 4 5 6(*)

if $H_2$ does not occur: 1 2 3 4 5 6

if $H_3$ (Organization of the world market) occurs: 1 2 3 4 5 6

if $H_3$ does not occur: 1 2 3 4 5 6

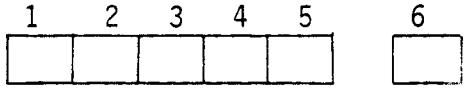
(*) Mark box 6 if you consider H and Q unrelated, and evaluate the probability of Q.

$Q_7$ Estimate the mean capital return for the petrochemical industry in 1990 (including depreciation) :

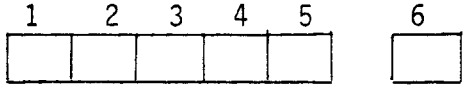
| | Less than 5 % | at between 5% and 10% | at between 10% and 15% | Over 15 % |
|---|---|---|---|---|
| in North America | | | | |
| in developing America | | | | |
| in Eastern Europe | | | | |
| in the Middle East | | | | |
| in Africa | | | | |
| in Asie/Oceania | | | | |

$Q_8$ Estimate the probability that the stream factor of plants in developing countries be comparable, by 1990, with that of industrialized countries :

if $H_4$ (sharing of technological power) occurs :




if $H_4$ does not occur :

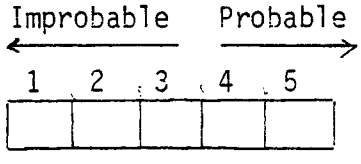


## ADDITIONAL QUESTIONS

$Q_9$ For each of the following products, what is the annual figure for intercontinental exchanges which appears the most probable for 1990 :

| | Less than 50.000 tons | between 50 000 and 100.000 tons | between 100.00 and 150.000 tons | Over 150 000 tons |
|---|---|---|---|---|
| Methanol | ☐ | ☐ | ☐ | ☐ |
| Ammonia | ☐ | ☐ | ☐ | ☐ |
| Propylène | ☐ | ☐ | ☐ | ☐ |
| Benzène | ☐ | ☐ | ☐ | ☐ |
| Toluene | ☐ | ☐ | ☐ | ☐ |
| Xylene | ☐ | ☐ | ☐ | ☐ |

$Q_{10}$ Estimate the probability that Eastern countries effect massive sales of petrochemical products at a cost below the market cost during the 1980-1990 period ?




Name the products ?

$Q_{11}$ In what degree (*) will investments be made for new capacities in the 6 zones below, and for which category of the following final products, during the period 80-90.

| | Fertilizers | Synthetic textiles | Plastics | Synthetic rubber |
|---|---|---|---|---|
| North America | | | | |
| Developing America | | | | |
| Eastern Europe | | | | |
| Middle East and North Africa | | | | |
| Remaining Africa | | | | |
| Asia - Oceania excluding Communist countries | | | | |

$Q_{12}$ To what degree (*) will investments be made in the 6 zones below for following products during the period 1980-1990:

| | Base petrochemical products | Intermediate petrochemical products | Final petrochemical products |
|---|---|---|---|
| North America | | | |
| Developing America | | | |
| Eastern Europe | | | |
| Middle East and North Africa | | | |
| Remaining Africa | | | |
| Asia - Oceania (excluding Communist countries) | | | |

(*) Please code your answers as follows :

0 = decrease in investments (reduction of capacity)
1 = weak investments (below the average investments for all industries)
2 = average investments (identical with average investments)
3 = significant investments (superior to average investments)
4 = very significant investments (much superior to average investments)

$Q_{13}$ Estimate the probability of a technical evolution in the field of plastics susceptible of creating a strong increase in worldwide demand (automobile development, for example)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| | | | | |

$Q_{14}$ What would be the exporting zones in 1990, and what would be the principal petrochemical products exported (or imported) for each zone ?

$Q_{15}$ What is the average annual growth rate (*) of the following products in the country groups below :

| | Fertilizers | Synthetic textiles | Plastics | Synthetic rubber |
|---|---|---|---|---|
| Industrialized countries | | | | |
| Developing countries | | | | |

$Q_{16}$ Comment on the major problems concerning the evolution of the worlwide petrochemical industry (in order of decreasing importance) :

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(*) Please code your answers as follows :

| | |
|---|---|
| Rate of growth inferior or equivalent to the average GNP growth rate - 4 % | = 1 |
| Rate of growth between GNP - 4 % and GNP - 2 % | = 2 |
| Rate of growth between GNP - 2 % and GNP | = 3 |
| Rate of growth between GNP and GNP + 2 % | = 4 |
| Rate of growth between GNP + 2 % and GNP + 4 % | = 5 |
| Rate of growth exceeding GNP + 4 % | = 6 |