General Report

Gaps in Technology

PARIS 1968

The Organisation for Economic Co-operation and Development was set up under a Convention signed in Paris on 14th December 1960 by the Member countries of the Organisation for European Economic Co-operation and by Canada and the United States. This Convention provides that the O.E.C.D. shall promote policies designed:

- *to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the world economy;*
- *to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development;*
- *to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.*

The legal personality possessed by the Organisation for European Economic Co-operation continues in the O.E.C.D. which came into being on 30th September 1961.

The members of O.E.C.D. are Austria, Belgium, Canada, Denmark, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

The following Report was prepared for discussion by the Participants to the

THIRD MINISTERIAL MEETING ON SCIENCE
of OECD Countries

(11th and 12th March 1968)

The GAPS IN TECHNOLOGY BETWEEN MEMBER COUNTRIES *Series*
includes the following reports:

General Report

Sector Reports:

- *Scientific Instruments*
- *Electronic Components*
- *Electronic Computers*
- *Plastics*
- *Pharmaceuticals*
- *Non-Ferrous Metals*

Analytical Report

FOREWORD

The problems posed by the growing importance of science and technology and their impact on national policy were reviewed by the Ministers responsible for science and technology in the OECD Member countries, when they met in Paris, first in 1964 and, next, in 1966. At the time of the second conference, the Ministers agreed that they should meet again and decided that a Committee of senior officials responsible for science policy should be set up, with instructions to carry out preparatory work for their future discussions. Their task included a study on "national differences in scientific and technical potential" — that is, on what has generally come to be described as "*technological gaps*".

Subsequently, a Working Group on Gaps in Technology was mandated by the Committee for Science Policy to prepare a series of studies on the basis of which a thorough diagnosis of the problem of Technological Gaps could be presented to the Ministers for Science. This included studies in a number of industrial branches, conducted by groups of experts working in close liaison with the Organisation's Secretariat, as well as an analytical report by the Secretariat which marshals all the available statistical evidence on: (*a*) differences between Member countries in research and development and educational efforts; (*b*) differences in performance in originating and diffusing technological innovations in the economy; and (*c*) on the effect of these differences on technological and economic exchanges between Member countries.

The results of the above studies have been summarized and conclusions reached by the Committee for Science Policy presented in the following General Report on Technological Gaps between Member countries, which is submitted to the Ministers for Science as the basis for their discussions. It is accompanied by a list of issues and recommandations which highlight some of the main points which Ministers may wish to discuss.

CONTENTS

I. THE GROWTH OF CONCERN ABOUT THE TECHNOLOGICAL GAP

1. At their Second Meeting, Ministers for Science in OECD countries agreed that "one of the main themes of future work should be the social and economic consequences resulting from scientific and technical research efforts, with special reference to the implications for the advanced and less developed countries of national differences in scientific and technical potential. This study should be undertaken bearing in mind the main scientific and technical trends to be foreseen in the coming decade". Since that time, an important public debate has been taking place about the nature and significance of the "technological gaps" between the Member countries of the OECD. The gap between the advanced countries and the underdeveloped countries of the world, which is certainly wider than that between OECD countries, has also been causing much concern.

2. There has been much confusion in this debate between the *nature* of the technological gaps as narrowly defined, and the economic, social and political *effects*, and the *causes*.

3. Ministers became concerned over the "technological gap" as a result of the differing speed and effectiveness with which Member countries appeared to be developing and exploiting their scientific and technological capabilities, as judged by a number of criteria, particularly performance in a number of industrial sectors. Public and inter-governmental discussion subsequently emphasized the weakness of many European countries in bringing new products and processes into the economy, that is to say, in the process of technological innovation, with the possible consequence of reliance on innovation from outside.

4. In particular, three possible effects of these deficiencies have been stressed. First, the technological superiority of certain international companies has led to a fear of domination of some industrial sectors by foreign-based firms. A second concern has been that a failure to maintain strong research-intensive industries will lead to a "brain drain" of scientists and engineers to other nations, particularly to the United States, and thereby weaken the capacity to innovate. Thirdly, some countries have emphasized the need to maintain a continued, unimpeded flow of technology among countries through licensing, foreign investment and other arrangements. The discussions in NATO were to some extent focussed on this last aspect of the problem.

5. Social attitudes reflected in management, education and the propensity to innovate have been seen by some as the fundamental cause of the technological gap. Others explain the superiority of certain Member countries in some industrial sectors by the large amount spent on research and development, not only by industry itself, but also by governments, as exemplified by American expenditures for defence, space and other goals. The increasing "price of entry" into modern technologies has also high-lighted the disadvantages arising from the market, technological, economic and political fragmentation of Europe.

II. THE RESULTS OF THE OECD STUDIES

6. For policy discussions on the above problems to be more constructive and meaningful, it has been necessary to gather more precise information on the *nature and extent* of technological gaps, and on their *causes.*

1. THE NATURE AND EXTENT OF TECHNOLOGICAL GAPS

7. Given the terms of reference of the OECD study, information has been gathered on three related aspects of the problem:

A. Differences in the development of national scientific and technological capabilities;

B. Differences in Member countries' performance in technological innovation;

C. The economic effects of A and B, including the effects of international economic and technological exchange.

8. These three aspects of performance are intimately linked in the complex *process of technological innovation,* in which there is close interaction between the development and spread of scientific and technological knowledge, its application in the form of new products and processes, and the diffusion between firms and countries of new technology and the products and processes embodying it.

9. In view of the particular conditions and problems of the *developing* Member countries, a special section giving the relevant facts about these countries has also been prepared:

D. Special problems of the developing Member countries.

A. Differences in the Scientific and Technological Capabilities of Member Countries

Scientific and Technical Information

10. The studies of specific industrial sectors have confirmed the remarkable freedom of access to non-proprietary scientific and technical information in the OECD countries. The leading scientists and technologists in all the sectors studied are continuously in close contact, and seem to have access to the same body of technical knowledge. The complex management and organisational problems of disseminating information (which will be dealt with as a separate item on the Ministers' agenda) have not yet, but may in the future, lead to difficulties in gaining access to information.

Scientific and Technical Manpower

11. A careful analysis of available data has revealed a somewhat unexpected situation. Although the *overall* educational effort of the United States is greater than that of other Member countries, this is much less evident when attention is focussed on scientific and

technical personnel and on current educational efforts in the science and technology branches. Thus the proportion of people with a higher education background in the United States labour force is much greater than in the European countries. However, the United States advance is less marked when the proportion with degrees in science and technology is examined. As regards current educational efforts, the United States appears to put relatively much more emphasis on pure science than on technology. The European effort in technology surpasses the United States effort in both relative and absolute terms.* France and the United Kingdom each produce, in relation to the number of persons in the relevant age group, as many Doctorates in pure science as the United States. The United Kingdom, in particular, appears to be putting a relatively strong emphasis on the production of scientists and technologists. It is to be noted, however, that in the United States graduates are more likely to enter management positions than in Europe, which has resulted in a better trained body of managers in private industry.

The Migration of Scientists and Engineers

12. These findings pose the question of whether European countries are devoting sufficient resources to research and development activities and to investment in the research-intensive industries to derive maximum benefit from their relatively large educational effort in science and technology. They also suggest that the United States may not be building up higher scientific, and particularly technological, education sufficiently to meet the increasing demands from industry and Government. The evidence shows that Europe has lost in recent years approximately 2,000 scientists and engineers annually. Significant rates of emigration are, however, limited to a few countries only and they are, moreover, concerned with one-way flows only.

Research and Development Effort

13. If the gap between the United States and some European countries is narrower than anticipated in terms of the stock of persons in scientific and technical occupations and the current output of highly qualified scientific and technical personnel, it is certainly very wide in overall research and development efforts both in absolute terms and when expenditure is expressed as a proportion of national product. In 1964, the United States devoted 3.4 % of GNP to R and D, the economically-advanced European OECD countries together 1.5 %, the European Economic Community 1.3 %, Canada 1.1 % and Japan 1.4 %.

14. The existence of a substantial stock of scientific and technical manpower is not in itself an adequate reason for large R and D efforts. It may be more beneficial that they are employed in producing and selling results of R and D instead of on R and D itself. It *is* the case, however, that the existence of such a stock in Europe related to the relatively low R and D expenditures *would permit* an expansion of R and D if this were thought to be justified on economic or political grounds. In fact, the combined efforts of the four Western European countries for which data are available (United Kingdom, France, Germany, Netherlands) do show some closing of the expenditure gap between 1958 and 1964, the United States index of Gross National Expenditure on Research and Development as a percentage of Gross National Product rising by a quarter and the "European" index rising well over 40 %.

*The Importance of Research-Intensive Industries**

15. The largest disparity in R and D is in industry. In the Business Enterprise sector, industrialized Western Europe spends on R and D 26 % of the United States figure, whereas in other sectors the figure is nearly 32 %. In terms of qualified manpower employed on R and D the Western European figure is 59 % for the Business Enterprise sector and nearly 83 % for other sectors.

* The principal reason for this finding which differs from many earlier studies is that previous comparisons have often ignored non-university higher education institutions, e.g. "Ingenieurschulen" in Germany, HTS in the Netherlands and Colleges of Advanced Technology and similar institutions in the United Kingdom.

* Just as certain industries are designated as "capital-intensive" in that they require relatively large inputs of capital for a given output, so — for similar reasons — can certain other industries be designated as research-intensive. The research intensity of an industry can be defined as R and D expenditures expressed as a percentage of sales or value added, or as R and D manpower as a percentage of total employment. In the industrially-advanced countries, the following industries are the most research-intensive: aerospace, electrical (including electronics and scientific instruments) and chemicals (including pharmaceutical and petroleum refined products). These are the industries considered in this section — and in Table 1 — as research-intensive.

16. A very substantial portion of this industrial R and D occurs in the so-called research-intensive industries and a substantial proportion of the R and D expenditure in these industries is financed by governments. The situation in a number of OECD countries is summarized in Table 1. In the United States as compared to European OECD countries and Japan:

i) a higher proportion of total R and D and industrial R and D is concentrated in research-intensive industries;

ii) a higher proportion of the R and D expenditure of the research intensive industries is financed by government.

17. Table 1 has indicated the relatively greater concentration in the United States of R and D efforts in research-intensive industries. Table 2 shows the relatively greater concentration in terms of average size of R and D programmes. Sixty-three per cent of industrial R and D in the United States is on programmes whose total R and D expenditure is more than $100 million per annum. No firm in any European country has an R and D programme of this magnitude. Conversely, less than 5% of the United States R and D efforts goes to programmes costing less than $1 million, whereas the French figure is 17%. The Belgian and Swedish figures are between 20 and 30% and in all other countries for which figures are available, the bulk of R and D expenditures is on these small programmes.

18. The United States concentration of efforts on large-scale R and D programmes appears to be even greater in the research-intensive industries. Eighty-eight per cent of R and D in the aeronautics industry is in programmes of $100 million or more and 70% of electronics R and D is in such programmes.

19. If, as the sector studies in the research-intensive industries suggest, there are certain minimum threshold levels below which innovative efforts are likely to be largely unproductive, then the dispersion of Europe's relatively small efforts deserves attention.

Fundamental Research

20. In addition to its intrinsic importance, fundamental research is one of the keys to innovation in the research-intensive industries and is also necessary for defence, nuclear and space activities. A short-sighted view of the significance of fundamental research may endanger the future development of a host of other activities of a more applied nature.

21. In the United States, between 1958 and 1965, fundamental research increased at an annual growth rate of 17% which is twice the annual growth rate of all R and D activity in the same period. For European countries, despite the scarcity of data, it is probable that the annual growth rate of fundamental research is of only the same magnitude as for R and D in general.

22. In terms of resources, the United States has a strong position in most fields of fundamental research, but above all in fields where heavy capital and maintenance expenditure, and a large number of highly qualified scientists (above Ph.D. level) are necessary. This is the case for atomic, molecular and solid state physics. Solid state physics, for example, influences progress in a number of applied research fields, for instance electronics and communications. There seems to be a sharing-out of work between government, industry and universities, but in these three sectors research is mostly done in very big units with intense cross-fertilization between sectors.

23. European fundamental research units are generally much smaller. It is significant that the only European research institute (CERN) capable of matching the work of its American counterpart (Brookhaven) is financed and manned on a plurinational basis.

Public Goals and Research and Development

24. The evidence shows quite clearly that although the largest disparities in R and D performance are in the Business Enterprise sector, the greatest divergence as far as *provision of finance* is concerned is in the Government sector. Measured at current official exchange rates, the United States devoted four and a half times as much public money to R and D as industrialized Western Europe, 8 times as much as the European Economic Community. For privately financed R and D these differences are cut by about 50% in the case of Western Europe and Canada.

25. The United States Government expenditure on R and D is, however, highly concentrated in defence, space and nuclear energy programmes in which industry is the principal performer. For example, 56% of total R and D expenditure in the United States in 1963–64 was concentrated in these three areas. The corresponding figure for the United Kingdom was 40%, France 43% and Sweden 31%. This being the case, it is clear that civilian economic benefits of R and D have depended to a large extent on

Table 1. The R and D effort in science-based industries

In percentages

	United States *c*	United Kingdom	Germany	France *c,d*	Japan	Italy	Canada	Netherlands *e*	Sweden	Belgium	Norway	Austria
R and D performed in science-based industries as a percentage of gross national expenditure on R and D	46.4	41.3	39.7	33.7	33.7	28.7	24.6	35.7	33.6	40.9	16.8	23.2
Individual science-based industries as a percentage of total industrial R and D expenditures												
Aircraft	38.3	29.0	..	24.6	..	..	16.9	..	19.8	1.5	..	..
Electrical *a*	24.8	24.5	31.2	28.6	30.3	25.7	29.1	..	24.3	20.3	22.0	18.6
Chemicals *b*	13.0	14.4	34.7	19.4	27.3	28.1	23.6	..	9.9	43.8	21.3	24.0
Total	76.1	67.9	65.9	72.6	57.6	53.8	69.6	64.4	54.0	65.6	43.3	42.6
Percentage of each industry's activity financed by Government												
Aircraft	90.4	84.3	..	78.3	..	..	46.1	..	69.7	..	..	..
Electrical *a*	61.8	36.0	4.0	29.9	0.5	..	22.6	..	36.6	2.8	9.7	..
Chemicals *b*	15.9	..	..	2.8	0.1	0.3	1.9	..	2.4	3.4	4.7	..

a. Including electronics.

b. Including petroleum refining and drugs.

c Includes depreciation, excludes capital expenditure.

d. 1964.

e. Five large companies including food and drink industry.

"fall out" and "spin off" effects. The evidence of the sector studies suggests that whilst it has not been the aim of United States policy to support industries or products directly for commercial purposes, the indirect commercial effects have been considerable.

B. Differences in Member Countries' Performance in Technological Innovation

26. The performance of a country in technological innovation has been defined as the rate at which new and better products and production processes have been introduced and diffused throughout its economy.* The OECD studies have attempted to compare two aspects of Member countries' performance:

- performance in terms of being first to commercialize new products and production processes successfully (i.e. performance in *originating* innovations);
- performance in terms of the level and rate of increase in the use of new products and production processes, wherever they might have first been commercialized (i.e. performance in *diffusing* innovations).

27. There are — as one would expect — differences between Member countries in their performance in technological innovation. Furthermore, the pattern and extent of these differences is very different in the *diffusion* of innovations from that in *originating* innovations. And the pattern of performance in *originating* innovations varies considerably from sector to sector.

* It should be noted that, thus defined, *technological innovation* is different from *invention*. Invention can be defined as the establishment or the postulation of the technical feasibility of a new or better product or process. The translation of an invention into an innovation normally requires development work, together with manufacturing and market activities.

Table 2. **Concentration of R and D expenditure in the business enterprise sector by size of R and D Programmes**

	Size of R and D Programme in United States dollars (at official exchange rates)				
	100,000 to 999,999 I	1,000,000 to 9,999,999 II	10,000,000 to 99,999,999 III	100,000,000 and over IV	Total
United States (1964) *a*					
Number of firms	1,500	500	102	28	2,130
% of all industrial R and D done in the group	3.7	11.7	20.8	62.7	98.9*
France (1963) *a*					
Number of firms	327	97	16	—	440
% of all industrial R and D done in the group	15.7	34.9	43.4	—	98.5*
Sweden (1964)					
Number of firms	113	26		—	139
% of all industrial R and D done in the group	28.9	63.6		—	92.5*
Belgium (1963)					
Number of firms	48	12	—	—	60
% of all industrial R and D done in the group	21.8	66.4	—	—	82.8*
Norway (1963)					
Number of firms	29	2	—	—	31
% of all industrial R and D done in the group	44.3	20.9	—	—	65.2*
Austria (1963)					
Number of firms	18	2	—	—	20
% of all industrial R and D done in the group	47.3	26.1	—	—	73.4*
Spain (1964)					
Number of firms	23	1	—	—	24
% of all industrial R and D done in the group	67.5	13.6	—	—	81.1*

* The balance is made up by firms with R and D programmes of less than $ 100,000.

a Figures established on the basis of current expenditures including depreciation.

Source: Additional data received for ISY.

Performance in Originating Innovations

An Overall View

28. Three sets of indicators have been used in order to have an overall view of Member countries' performance in originating innovations: first, data on the location of some 140 significant original innovations since 1945;* second, receipts for patents, manufacturing licences and technological know-how; third, trade performance in research-intensive product groups.

* The sample of innovations is drawn mainly from the basic metals, electrical, and chemicals industries.

29. All these indicators suggest that, in absolute terms, firms based in the United States have had the highest rate of original innovation over the past 15 to 20 years. Of the 140 innovations, they have originated approximately 60%. United States firms also have the largest share of world exports in research-intensive product groups (about 30%), and the largest monetary receipts for patents, licensing agreements, and technological know-how (between 50 and 60% of total OECD receipts).

30. There are also significant differences amongst other Member countries in performance in originating innovations. After United States firms, those of Germany and the United Kingdom appear to have

the strongest positions. The United Kingdom originated about 15% and Germany about 10% of the 140 innovations considered; but Germany has had a higher share of world exports in research-intensive product groups (22% as against 14% for the United Kingdom). French-based firms follow immediately after those of Germany and the United Kingdom, in terms of shares of world exports in research-intensive product groups.

31. When account is taken of population differences, the United States still has the strongest performance in originating innovations, but the performance of the Netherlands, Sweden and Switzerland is at about the same level as that of Germany and the United Kingdom.

The Varying Pattern amongst Industrial Sectors

32. The conclusions of the Groups of Experts, which undertook the sector studies on technological gaps for the OECD, illustrate the considerable variation amongst sectors in patterns of performance in originating innovations.

Electronic Computers

In the early stages of the development of the computer industry a number of European Member countries, together with the USA, made important contributions to the development of basic computer technology. In the 1960's, however, a major gap has developed between the USA and other Member countries in originating innovations, and this is reflected in the very strong position of USA-based firms on both the USA and world markets.

Semi-conductors

From the outset, USA firms have had a very strong lead in invention and originating innovations, which is reflected by the position of USA based firms on world markets.

Pharmaceutical Products

There are no general and deep-rooted differences amongst Member countries in inventive capacities. Furthermore, no country has an overwhelming lead in originating innovations. Nonetheless, USA firms have had the strongest performance, followed by Swiss and by German firms. This position is reflected in shares of world markets.

Plastics

No important gap exists amongst Member countries in invention, originating innovations or the production of *bulk plastics.* USA based firms have had a clear lead over the past ten years in originating innovations in *specialized plastics* used for defence and space purposes.

Iron and Steel

There are no fundamental disparities between countries with regard to the availability of technological know-how in the iron and steel sector. Differences exist, for economic, technical and other reasons, in the rate of application of a new technology. Eventual convergence towards a standard appears to be the rule.

Machine Tools

There exists no major technological gap between Member countries' machine-tool industries in general, despite marked differences between firms or countries in the technical performance of specific machine-tools. A gap which has existed for numerically controlled machine-tools — due to their earlier development and industrial use in the USA — is now shrinking. It may, however, widen again if numerically controlled machining is only hesitantly accepted in Europe and Japan.

Non-ferrous Metals

No gap exists in aluminium, copper and nickel production, where a number of Member countries have originated significant innovations. Amongst the newer metals, no gap exists in invention, nor in originating innovations related to germanium. However, USA-based firms have a clear lead in originating innovations related to tantalum and — to a lesser extent — titanium.

Scientific Instruments

Within this highly diversified sector, no overall gaps have been identified. Firms based in countries such as Germany, Japan, the Netherlands, the UK and the USA all have a strong performance in originating innovations in specific instrument groups. USA firms have a clear lead in electronic test and measuring instruments, but firms based in Europe and Japan also have originated significant innovations in such groups as nuclear, bio-medical, and process control instruments.

Man-made Fibres

The scientific and technological potentials of Member countries are being effectively utilized at the present time and are likely to be effectively utilized in the foreseeable future. It is not possible to say whether there are at present any technological gaps that need to be bridged or closed, but it is important that in the future no barriers should be raised to impede the free operation of patents and licensing systems. Differences between national industries mainly result from the size of the market and the greater or lesser degree of integration of firms.

33. Thus, the OECD sector studies, together with other information which has been collected, show that gaps in performance in originating innovations do exist, but that the pattern varies considerably from sector to sector. The leadership of USA-based firms appears to be concentrated in the research-intensive sectors of industry, but also extends into the advanced products of more traditional industries. In product areas that did not exist 15 years ago, such as electronic computers, transistorized components, the manufacture and fabrication of titanium and satellite communications, the USA firms have the lead. In the pharmaceuticals and "bulk" plastics sectors, however, where important innovations were made in the 1920's and 1930's, the performance of certain other Member countries has been strong, as it has been in conventional methods of generating and distributing electrical power and in consumer electronics. In older established industries, such as iron and steel, copper, aluminium and metal-working processes, several Member countries have made important original innovations.

European Weakness in turning Invention into Innovation

34. There is, however, one conclusion that appears irrefutable. United States firms have turned into commercially successful products the results of fundamental research and inventions originating in Europe. Few cases have been found of the reverse process. The basic technique for titanium was developed in Luxembourg; much of the fundamental work on digital computers was done in Europe, and European countries even made technically successful computers which were then commercial failures; fundamental work on the tunnel diode was done in Japan but first exploited commercially in the United States; and fundamental work on instruments in Germany and the United Kingdom was turned into commercially successful products in the United States. It should be noted that, in consumer electronic goods, and in electron microscopes, Japan, too, has made significant original innovation on the basis of fundamental work done in other countries, including the United States.

35. In the chemical industry, however, fundamental research undertaken in Europe has been better exploited commercially by European firms. The important discoveries of Zeigler and Natta were exploited by German and Italian industry. Only one case has been found where the United States has been the first to commercialize a new plastic, based on fundamental work undertaken in Europe.

Performance in Diffusing Technological Innovations

36. Two sets of indicators have been used to measure Member countries' performance in the diffusion of technological innovations: first, the level and the rate of increase in the use of significant new products and production processes; second, rates of increase in total factor productivity.* These indicators show that the USA has the highest *level* of diffusion of new products and processes, but that many other Member countries have had higher *rates of increase* in the diffusion of new products and processes over the past 10 to 15 years. However, rates of increase in diffusion have been much higher in Japan than in European Member countries, whose rates of increase have been closer to that of the USA than to that of Japan.

37. It is therefore safe to conclude that, as a corollary of high rates of economic growth and

* Total factor productivity is generally defined as total output per unit input, where input is an appropriately weighted average of capital and labour inputs. Growth in total factor productivity is then the difference between the growth rate of output and the weighted average of input growth rates. Thus, input growth + total factor productivity growth = output growth.

Thus defined, the growth of total factor productivity results not only from the greater diffusion of new products and production processes, but also from increases in capacity utilization, better education of management and the labour force, and the shift of resources to more productive sectors. It should be noted that both the OECD and other studies have shown a positive relationship between increases in the diffusion of new products and processes, and increases in productivity.

investment in Japan and Europe, new products and processes (including those originating in the USA) have been effectively diffused throughout most of the economies of the industrially advanced Member countries.

38. On the other hand, differences between Member countries in performance in originating innovations do not appear to have had any effects on Member countries' overall economic growth performance. The current slowing down of economic growth rates in some European countries, as compared with the United States, is to be noted, but it is of recent origin and there is no evidence that it is related to the problem of the technological gap.

39. What is quite clear is that the main effects of differences in performance in originating innovations are felt in competitive positions in specific product areas, and in particular those which are research-intensive.

C. Relationships to International Exchange of Goods, Capital and Technology

40. It is pertinent to ask whether the differences in scientific and technological capabilities of the OECD Member countries and in their performance in original innovation have an influence on international economic relationships, i.e. on trade in goods, movements of capital, flows of technology and movement of professional manpower.

Technology and Trade in Goods

41. In general, international trade and investment relationships within the OECD area show up the increasing inter-dependence between the various national economies. This inter-dependence is demonstrated by trading relations — for example within the European trading blocs — and by significant international investment activity, predominantly by companies based in the United States.

42. Within the pattern of intra-OECD trade in manufacturing goods, it appears that the United States tends to have a trading advantage over other Member countries in newer, more sophisticated products, and that United States companies have to rely upon their capacity to innovate in competition on foreign markets. The same is true to a lesser extent of the United Kingdom and Germany. This suggests that European countries enter trade in the research-intensive industries and products once the technology is well established and the innovative element in competition is replaced by more traditional elements of advantage (labour costs, etc.). The pattern of United States-European trade supports this thesis.

43. At the same time, the European countries, Japan and Canada, (and in particular Italy and Japan), *have been able to compete successfully* from this position. All of these countries, with the exception of the United Kingdom, have had increases in their share of the export market for research-intensive products and for the more sophisticated products of all manufacturing trade groups.

44. In short, from the point of view of trading relationships *per se* there is no indication that the USA advantage in those goods where scientific capability and innovation skills are important has had deleterious consequences for other countries.

45. As the experience of Japan indicates, and as the above analysis of the role of the European countries, Japan and Canada in OECD trade would logically suggest, the increasing share of these countries in trade in the research-intensive products is very likely to be related to the inflow of technology from abroad. For this reason, the following section will examine briefly some data on the flow of technology between OECD Member countries.

The Flow of Technology between OECD Member Countries and its Relationships to Trade Performance*

46. This part of the analysis is based upon the data on receipts and payments for technology collected as part of the OECD Statistical Year on Research and Development. These data need to be treated with some caution. Nevertheless, they may be used to give a general guide to technology flows between Member countries. The data do not allow a detailed sectoral analysis. The general features characterizing the flows of technology between Member countries are:

* The "flow of technology" as conceived of here includes transfer of technology between independent firms (e.g. by licensing) as well as transfer between parent firms and subsidiaries.

i) United States receipts for patents, licences, etc. account for 57 % of total receipts in OECD countries and the United Kingdom some 12 %.

ii) The European countries account for about 65 % of the total payments for technology, Japan for about 13 %.

iii) The proportion of United States receipts coming from Europe, Japan and Canada in relation to total United States receipts has increased rapidly in the past five years.

iv) Weighting payments for technology inflow by the contribution of industry to GNP (in absolute terms), it appears that Japan (0.67 %) and Italy (0.49 %) have proportionately much heavier inflows than the larger European countries (about 0.3 %).

47. The data are general, but they do tend to support the conclusion that the trade performance of European OECD countries, Japan and Canada (particularly in relation to the increase in share of trade in research-intensive products) is associated in varying degrees with net payment for licences, patents and know-how, predominantly to the United States, as well as with an indigenous scientific capability. The case is perhaps clearest for Italy and Japan. Both countries have increased their share of trade in the research-intensive products appreciably; neither has made a particularly large research and development effort in the research-intensive industries and both have had a particularly high import of technology in relation to the total size of their industrial activities.

48. These observations or arguments are consistent with the views that the OECD European countries, Japan and Canada have traded successfully in the research-intensive products at least to some extent on the basis of imported technology, and that these technology imports have been derived largely from the United States. Again these observations are in accordance with the conclusions of the trade analysis that, to varying degrees, countries other than the United States enter trade in the products of the research-intensive industries and in more sophisticated products in general at a stage where *original innovation as a factor in competition* is, relatively speaking, less important. In short, the trade performance can apparently be explained by the flow of technologies, a large proportion of which was originated in the United States.

49. The following evidence suggests that *this flow of technology has been based less on imitation than on direct investment by United States companies.* The proportion of United States receipts for technology which was associated with exchanges between parent companies and subsidiaries as opposed to that between independent companies grew from 63 % to 75 % over the period 1956–66; these figures are subject to a number of *caveats*, but they seem to indicate a long-term trend. It is worth noting, however, that while United States direct investment plays a big role in the transfer of technology to Europe, it is relatively less significant in the case of Japan.

Movements of Private Capital: International Companies

50. The analysis of capital flows between Member countries is unfortunately bedevilled by the extremely poor statistical material available. The United States is the only country with reasonably comprehensive data on outflows of capital. The following analysis is therefore based quite extensively on United States material. At the same time, the United States accounts for about three-quarters of the total capital outflow from OECD countries. The broad conclusions which can be drawn from an analysis of investment flows are:

i) Since the formation of the European Common Market the pattern of United States investment outflow has changed proportionately in favour of Europe. The rate of growth of United States *capital stock* in Europe has been particularly high; it has multiplied by 4.5 between 1957 and 1966 in the EEC, and by 3.5 in the rest of Europe. About three-quarters of United States direct investments abroad are now in the OECD area, mainly in manufacturing industry.

ii) All United States manufacturing sectors tend to have a high proportion of their total investments outside the United States. The ratio of foreign to total investment for the principal manufacturing industries is between 15 and 30 % and has been increasing. The data available do not indicate that research-intensive industries are more prone to invest abroad than others, but it is hard to reach a firm conclusion on this point.

iii) These investments do not represent a particularly large share of *total* capital investments in Europe (between 4 and 5 % in all European countries, except Benelux, about 13 % in the United

Kingdom), but the proportion is much larger in Canada (about 40 %).

iv) There is a strong general tendency for production by United States subsidiaries abroad to exceed United States exports, and to develop faster in similar product groups, but there is no indication that this tendency is more marked in the research-intensive products than in others. In general, sales of United States subsidiaries in Europe in paper production, chemicals, rubber machinery and transport equipment were more than three times greater than United States exports in these product groups.

51. The research-intensive industries are in fact amongst the United States industry groups which invest most heavily abroad (though certain groups not normally considered as research-intensive are also major sources of international investment). There are reasonable grounds for maintaining that investment by United States companies is generally associated with technological sophistication and that United States companies in Europe in particular tend to specialize in the production of more sophisticated products in all groups (with the possible exception of some consumer goods sectors, such as motor cars). It is increasingly argued that an important reason for "dynamism" of United States companies in Europe is that they tend to market products which are "new" in Europe and which have a high income-elasticity of demand, though often these products have been marketed and proved for some time in the United States.

52. Correspondingly, the concentration of United States investments in the research-intensive industries in Europe in relation to total sectoral investments in Europe is relatively high, and the concentration of United States investments within nearly all sectors appears to be highest in the more advanced products of the sector. It appears quite reasonable to attach a particular qualitative importance to investments in the research-intensive industries because they are a major source of innovation for the rest of the economy.

Concluding Remarks

53. The following general points may be made on the basis of the foregoing analysis:

i) The OECD countries in general have had no particular problems as far as their trading positions are concerned which can be ascribed to disparities in scientific and technological capabilities. In fact, countries other than the United States have an increasing share in trade in research-intensive products.

ii) The main reasons for this would seem to be that there has been diffusion of technology across national frontiers as well as the development of trading blocs in Europe. As a result of diffusion, countries with relatively lower scientific and technological capabilities have been able to enter successfully the export trade in the products of research-intensive industry and more generally trade in advanced products.

iii) Direct Investment flows from the United States to Europe have played an increasingly important role in the flow of technologies between these countries. While there is no particular evidence that United States companies in the research-intensive industries invest abroad more readily than others, it is reasonable to relate United States foreign investments to generally higher technological levels in the United States. It is very probable that United States production in Europe is proportionately more concentrated in more advanced products than European production proper. In this sense, the trade analysis alone does not cover all the effects of technological disparities within the OECD economies. The relative and growing importance of investment flows, rather than exports is almost certainly related directly to the development of European trading blocs.

D. Special Problems of the Developing Member Countries*

54. The scientific and technological problems of the developing Member countries have been studied in detail in the course of the OECD Pilot Teams Project.** This Project was not a part of the study

* The developing Member countries, as referred to here, are Greece, Portugal, Spain, Turkey and Yugoslavia.

** The developing Member countries listed above have participated in the Pilot Teams Project. In addition, the project has been carried out in Ireland and Italy. The objective of the project is:

"to examine how scientific research and technology can best be related to national problems of production and social welfare, within the framework of plans and of technological gaps, but it throws light on the conditions under which science and technology can be effectively related to economic and social development in the developing Member countries. A summary of the findings of the Project, which are relevant to the analysis of technological gaps, is therefore included in this Report.

Scientific and Technological Capabilities

55. The developing Member countries all possess a considerable educational infrastructure, including a number of Universities. At the same time (as the Mediterranean Regional Project on educational planning indicated), the *stocks of scientific and technical personnel* are relatively much smaller than in the more industrialized countries.

56. These limitations in the supply of scientific and technical personnel to the economy, and to the society in general, are reflected in the relatively limited growth of research and development and related scientific activities in the developing Member countries. The Pilot Teams studies showed that, in general, expenditure on R and D was a relatively small proportion of GNP (usually about 0.2 to 0.3 %), and that the proportion of the population engaged in such activities was particularly small (averaging about 2.07 R and D personnel per 10,000 of the population). These measures indicate that the industrialized countries devote proportionately between 4 and 10 times as much of their national resources to R and D activities as the developing Member countries.

57. The orientation of these scientific and technical activities is markedly different in the developing Member countries. The main difference is reflected in the relatively high concentration of effort in the agricultural sector, in the Universities and, in some countries, in a very few large research institutes (the best example being the nuclear energy research establishments).

58. Governments finance a greater proportion of R and D expenditures than in the industrialized countries (the Government share is usually about 80–90 %), and private industry, in general, neither finances nor executes research.

policies for the promotion and maintenance of an adequate rate of economic growth".

The reports on Greece, Spain and Turkey will be published shortly and the Irish report has been published by the Irish Ministry for Industry and Commerce, Dublin. The other reports will become available during 1968.

59. The Pilot Teams' studies indicate that there are inadequacies in the organisation of scientific and technical resources in R and D and related activities. Typically, R and D activities, both in and outside the Universities, are dispersed amongst a large number of small research units, and the co-ordination between these units is limited. At the same time, these research groups are undersupplied with equipment and ancillary resources. There are, of course, exceptions. In particular, the few large research institutes referred to above are generally well equipped. (But generally, in other sectors and particularly in the Higher Education Sector and in Agricultural Research, scientific activities suffer from inadequate resources.)

60. The impact which these scientific activities have had on the economies in the developing Member countries has been limited. There have been some successes (for example, some considerable agricultural yield improvements have been achieved on the basis of local adaptive research activities; also some mineral exploitation possibilities have been opened up), but though valuable and interesting from the point of view of what they may teach, they do not represent the general case. In particular, local manufacturing industry has had little benefit from R and D and related scientific activities.

61. To some extent this situation reflects the inadequacy of resources and the difficulties in getting research results applied. But a second and important aspect of the problem is the fact that a good deal of the R and D activity under way is not particularly closely related to the conditions of the countries in question.

62. Finally, while some considerable re-orientation of scientific effort is possible in these countries, and while it should be possible to increase the availability of scientific and technical personnel, success in these areas will depend upon extensive administrative and organisational changes.

Access to Production Technologies

63. In principle, the developing Member countries have available to them a considerable "store" of technologies developed in the industrialized countries. In practice, the availability and use of such technologies has been limited. The data available on receipts and payments for patents, licences and know-how indicate the small extent to which the developing Member countries have purchased technology

from the industrialized countries. They account for about 2 to 3 % of total purchases in the OECD area.

64. It is true that a good deal of technological knowledge is transferred to these countries after patents have expired, i.e. there is probably a relatively high proportion of "non-propriety" technology which is imported in the form of capital equipment. But, even if allowance is made for this, the role of the developing Member countries as purchasers of technology has been relatively small. In general, changes in the technology of production in these countries have been limited in comparison with the considerable changes in production technology in the industrialized countries. Furthermore, these changes have often been associated with foreign subsidiaries, whereas local manufacturing industries have been slow to change production methods.

The Economic Framework

65. It would be misleading to disregard the economic and social circumstances which underlie these observations.

66. These circumstances cannot be identified simply with "underdevelopment" as it is normally conceived. For one thing, the rate of growth of GNP in certain of the developing Member countries (and notably in Spain and Greece) has been particularly rapid in the recent past.

67. Where such growth has occurred it has frequently been associated with a large inflow of resources from the industrialized countries. Tourist receipts and workers' remittances have played an important part and so has direct foreign investment.

68. While this access to resources on external account has sustained a high rate of growth of GNP, the developing Member countries still have to deal with some major problems of economic organisation. For example, land yields and labour productivity in agriculture have increased (in the wake of the rural exodus), but the agricultural sectors are not yet organised for rapid technological change. An important consequence has been the rise in food prices and imports to meet urban demand. Similarly, the local manufacturing sectors, while they have experienced some growth of demand, are often characterized by the traditional small firm, and investible resources are still very limited. This limited adaptation of local production is also reflected in the external economic relations of the developing Member countries. There has been some growth of manufacturing exports, but as a general rule this growth has been limited and the traditional predominance of agricultural exports is still characteristic.

69. Thus, in spite of GNP growth, the economies in question still show a number of traditional features. The persistence of these features accounts, to a considerable extent, for the relatively limited *demand for new technologies and for scientific activities*, from the industrial sectors in particular. In this respect the developing Member countries are in a situation which is distinct from that in the industrialized countries, where increasingly the demand for science and technology in production has been strengthened by the necessities for internal and external competitiveness.

70. Thus, in order to apply science and technology to production on a meaningful scale, it will be necessary to implement some major development measures, and at the same time an explicit and conscious development of scientific and technological capabilities will be needed.

71. The Pilot Teams' studies indicate that the reorientation and development of scientific activities in the developing Member countries could contribute significantly to growth and development; and the development of such an infrastructure would help also in making better use of the technologies already available in advanced industrialized countries of the OECD. Such a programme will take some time to implement because a considerable measure of reorganisation is a pre-requisite.

2. THE RESULTING DEFINITION OF TECHNOLOGICAL GAPS

72. The above findings make it possible to arrive at a definition of the problem and this is a significant step towards a correct diagnosis and, in consequence, towards relevant policies. The evidence gathered in Sector Studies of nine industrial sectors and a General Analysis shows that:

i) there are major differences among the Member countries in the level of resources devoted to R and D, and in objectives of government-supported R and D, as well as in the organisational and structural arrangements which enable these resources to be brought to productive use;

ii) there are equally big differences between the United States and other Member countries in terms of production and stock of high-level manpower and current efforts in higher education, as well as in the general educational level of the labour force. However, the differences between the United States and European countries are much less marked *in scientific and technical personnel, and in current efforts in scientific, and particularly technological, higher education*. In this respect, the United Kingdom, Germany and France appear to have relatively strong positions;

iii) the United States leads in the *introduction of new products and processes* in industry (" original innovation "), followed by Germany and the United Kingdom — with high performance by the Netherlands, Sweden and Switzerland, when population is taken into account. The leadership of United States-based firms is concentrated in the science-intensive sectors of industry, but also extends into the advanced products of more traditional industries;

iv) up to the present, these differences have had no demonstrable effect on the rate of economic growth of Member countries. Although in the last few years growth rates have been slower in some countries, most European countries and, especially, Japan have experienced a higher rate of growth per capita in the last 15 years than the United States. This growth has accompanied, to an appreciable extent, the importation of technology through licensing, and foreign investment, and a wider diffusion of advanced technology within national boundaries. The evidence suggests that the results of technology have, in general, been effectively transferred to European Member countries through licensing and subsidiaries, whereas Japan has, in the main, bought licenses.

3. THE CAUSES OF TECHNOLOGICAL GAPS

73. The results of the Sector Studies make it clear that the term " technological gap " symbolizes a complex of differences in contemporary social, economic and industrial development, in a world where new knowledge is increasingly the product of *organized* scientific and technological effort. There is no single or simple cause.

74. *Scientific and technological capability* is clearly a prerequisite, but it is not a sufficient basis for success in original innovation and in science-intensive industry. Although scientific and technical information (as the sector studies have shown) is readily available, commercially successful innovation depends on relating R and D efforts and organisation to the market.

75. *The market* is in fact a very important factor conditioning the realization of scientific and technological potential, if success is defined as the commercial explotation of a given innovation. The market should be big enough to enable producers to achieve the *necessary* economies of scale, without unduly limiting the number of firms and thereby the scope of competition, which is essential to continuing expansion.

76. *The size and homogeneity of the United States market*, including that portion made possible by

Government procurement, helps American firms to commercialize discoveries because it facilitates the prediction of market requirements. The European market, considered as a total, has a greater potential size for many products than that of the United States because of the greater population, and the greater density and more even distribution of industrial development. However, its present *per capita* production and income, and government budgets, are smaller than those of the United States and national divisions, with diverse political and contrasting social structures, result in fragmentation in the European market, thus making the realization of this potential very difficult.

77. Nevertheless, the successful performance of some American firms in the existing European market indicates that *a broader European market would, in and of itself, not solve the problem.* Many American firms, which have already adapted to the competition of a wide domestic market, appear to be better able to compete in world markets than their counterparts in other Member countries which do not have the advantage of a big domestic market. Nevertheless, there are some instances of penetration of the American market by firms without the advantage of big domestic sales, and such success is in general linked with the establishment of subsidiaries and an adequate sales organisation in close touch with the United States outlets.

78. One reason advanced for the difficulties experienced by European companies in entering or maintaining a position in the market for some products in science-intensive industries is the *inadequate size of firm.* The number of sectors where there are important economies of scale in R and D in consequent production and marketing activities may be relatively small, but it is growing and includes important categories within the " advanced technology " group, such as aircraft, large computers, satellite communications, etc.

79. There is, nevertheless, a wide range of areas where *small firms can be competitive* by exploiting technological opportunities. This often depends on the availability of " risk " capital, which appears to be deficient in some Member countries, and particularly in Europe.

80. These differences in the performance of Member countries' firms raise the question of the role of Government support. Science-intensive industries in some Member countries have been the recipients of large amounts of government finance for R and D, and of substantial government orders for products required for defence and space programmes. A trend is beginning towards similar action in relation to other national social and economic goals. The precise effect of these government expenditures is still a matter of debate and conjecture, but there is now a concensus that there have been substantial *indirect* effects. For example, markets have been substantially influenced, especially in America, by defence and space goals. Massive programmes of research, development and pilot production to achieve clearly-defined goals constitute a stimulus and an aid to industry which may be of crucial importance in forcing new technologies through the initial stages of development at a faster rate than would otherwise be possible.

81. In this connection, it should be noted that the *conditions under which Government support is given* are fully as important as the scale of such support. For example, United States' support is concentrated in industry, and this facilitates the transfer of the results of Government-supported R and D into the economy. In many Member countries, on the other hand, there is a marked tendency to put the money into government laboratories, from which the feedback into the economy is less direct.

82. The general quality of the economic, educational and social environment, together with traditional cultural attitudes to change and competition, also influence the performance of the firms, and can be a significant factor in differences among countries. In this connection, *the educational system of a country is considered to be of vital importance,* since the general level of education of the labour force is an important factor in adjustment to rapid change and in the development of consumer attitudes.

83. But while the social and economic environment, and government policies to make it conducive to innovation, can facilitate decisions to innovate, *they cannot take the place of the decisions of management.* Risk can be diminished but not removed. In the last analysis, there is a decision to invest resources, based on an assessment of a future market and the likelihood of success, through R and D, of developing a new product or process to meet the need. Thus, management is the indispensable link in the whole chain of events leading to the successful commercial exploitation of new knowledge, and increasingly in determining the directions of research which will lead to successful new products and pro-

cesses. In this sense, it appears somewhat questionable to oppose the two concepts of a "technological gap" and a "managerial gap". The essence of the problem is the need to integrate technological capability with management decision-taking, in relation to competition in the market.

84. In the techniques of *management*, including the management of research, and of combined technological and market forecasting, the United States appears to have a significant lead. This is undoubtedly linked with the greater commitment to long-term planning, to the clear formulation of goals, both in business and government (as far as national goals are concerned), and to the more rapid development and adopting of management technologies in general.

III. POSSIBLE INTERPRETATIONS OF THE RESULTS

85. Developments as complex as those outlined above cannot be easily explained in terms of an integrated analysis or a general philosophy of the total process. The inter-relationships between science and technology, economic and social change, and industrial progress are clearly changing in significant ways, the understanding of which is advanced but by no means completed by the present study. It is, however, possible to ask more meaningful questions than at the beginning of the study, and to bring forward some tentative interpretations.

1. SCIENCE IN RELATION TO SOCIAL AND ECONOMIC CHANGE

86. The first question to be asked is whether science and technology are now so influential in social and economic change that countries with a capability in this area are able to sustain a significantly faster rate of change than others, and thereby to reap the economic rewards which seem to go with flexibility in the use of human and physical resources.

87. Differences in the level of technology between countries are, of course, a commonplace of history, but they may have a fresh significance in modern industrial societies in which economic well-being and political strength are more dependent on an ability to maintain a higher rate of technical, economic and social change than in the past. The importance of research and development may reside in the fact that it is to a growing extent both the source of innovation and the means of adjusting to it. This is probably reflected in the growth of resources devoted to R and D by all Member countries, and the growing range of national objectives for which R and D is supported by governments.

88. It must be recalled, however, that this rapid growth is relatively recent. To a considerable extent it goes back only to World War II, and to an accelerated period of growth in the 1950's and 1960's. Only in the past 5–10 years has there been a concerted attempt to formulate the principles of national science policies. A backward look brings out three key features of these recent events. The first is the revolutionary change which has taken place in the concept of fundamental research. It is no longer feasible to consider fundamental research as completely isolated from the goals and purposes of a society or industry. Second is the important role played in the United States by major technological adventures related to political goals in scientific development and in forging closer links between industry, the universities and government. The third is the dominant role of defence, space and nuclear goals in the allocation of resources to science and technology.

89. These changes imply that the manner of bringing new knowledge into practical use may well be altering. If defence and space goals have been useful stimuli to change in the United States, it is pertinent to ask what would have been the effect if these United States resources had been directly applied in promoting civilian technology for the economy. The

question is not wholly hypothetical because there is in fact a trend (even if slight) towards expenditure on R and D for social and economic objectives in Member countries as a whole.

90. If, as would not seem unreasonable, the economic effects of R and D spending in relation to social and economic purposes will be greater than the "fall-out" from defence and space R and D, then it clearly becomes important to try to look at science and technology in the context of economic growth, even if the impact is difficult to "seize" in terms of economic analysis.

2. THE DIFFUSION OF INNOVATION AND ECONOMIC GROWTH

91. The OECD study suggests that there exists an association between economic and productivity growth and Member countries' performance in the diffusion of technological innovations.

92. On the supply side, the rapid and widespread adoption and diffusion of new techniques and products will continue to be an important element in the growth possibilities in the Member countries operating at full capacity, together with the reallocation of resources from less to more productive sectors and more skilled management and a better educated labour force. Past performance suggests that Japan has been most successful in adopting and diffusing new techniques and products. Many European Member countries have done so more rapidly than the USA, but — unlike Japan — not at a pace that has markedly reduced differences in the *level* of use of advanced techniques, or in the level of income.

93. Several factors will influence the rapidity with which Member countries will adopt and diffuse new techniques and products in future.

94. First, the degree to which new technology is diffused internationally. The experience of the past 15 years suggests that the system of international diffusion of technology has functioned satisfactorily. It should be noted, however, that technology appears to be increasingly diffused through direct foreign investment.

95. Secondly, the social and economic climate existing within each country. A high rate of investment will encourage innovation in the form of equipment embodying more productive techniques, thus reducing the gap between average and best practice techniques in the economy. A high rate of growth will increase the expected return from any innovation. A competitive climate will put pressure on business men to adopt the most efficient techniques. Management and labour with high levels of education will be better able to absorb, improve and adapt to innovations. And the experience of Japan suggests that the efficient absorption and improvement of foreign technology may require quite sizeable R and D activities.

3. THE ROLE OF ORIGINAL INNOVATION

96. Although there have been no apparent effects on overall growth or on trade performance, it is the demonstrated difference in performances in *originating* innovations which has been the greatest cause of concern in certain Member countries. There is, however, no body of theory — whether economic, social or political — which readily enables the significance of these differences to be assessed. It is possible at this stage only to explore meaningful problems.

97. The first obvious economic reason why a country needs some capacity for originating innovation is to be able to develop new products and processes which

will answer a national requirement, and which cannot be obtained elsewhere. This is the case when a country has a relatively high level of *per capita* income and therefore is the first to experience the need for labour saving techniques and new consumer products. It may also be the case in such areas as agriculture, where techniques must be adapted to local resource conditions.

98. Secondly, a country may need firms with capacity for originating innovation in order to maintain vigorous scientific and technological development. A healthy and useful scientific community might be difficult to maintain unless its research and its contribution to world knowledge are applied to meet practical needs. This is because success in the application and commercialization of new knowledge will generally create more demand for new skills and knowledge, and thereby lead to more funds for fundamental research and education. Failure in application may well have the opposite effect.

99. Thirdly, aggressive industrial policies for R and D and original innovation in a country are likely to provide the strongest external economics or spread effects throughout the economy by generating a continuing demand for new and better input products produced in large quantity and therefore cheaper; by providing a continuing stream of new production methods and skills; by creating an atmosphere of progress, competition and forward movement needed to attract the best minds into industry; and by ensuring a more rapid and efficient absorption of imported technology.

100. Fourthly, when countries are committed to improving the scientific and engineering branches of higher education, both in quantity and in quality, some capacity for originating innovation may be necessary in order to ensure the effective use of the scientists and engineers thereby provided. Without dynamic and aggressive programmes for R and D and innovation, and given the increasingly international nature of the labour market for scientists and engineers, many scientists and engineers may emigrate. From the point of view of the OECD area as a whole, such emigration could in fact increase overall economic benefits, if scientists and engineers are better utilized in the countries to which they emigrate. It may, therefore, be wiser policy for a country to let some of its scientists and engineers emigrate than to attempt to sustain original innovation artificially in uneconomic sectors of the economy. On the other hand, it is clearly more advantageous in the long run for a country to keep its scientists and engineers, if there exist R and D and innovative activities which are economically viable, and where the scientists and engineers are needed.

101. Furthermore, in certain new product groups, a strong capacity for original innovation is already, and — to an increasing extent in future — will be a necessary characteristic of industrial firms capable of taking an effective place in international competition. Moreover, an aggressive R and D strategy, combined with a strong position in original innovation leads to high returns based on rapid growth of output and monopoly profits. It also leads firms to keep at the frontier of growth by penetrating world markets.

102. Finally, there are two wider reasons why some capacity for originating innovations should exist in a large number of Member countries. First, the greater the amount and the geographic spread of original innovations, compatible with the requirements of scale and efficiency in the use of resources, the greater the amount of new technology from which all countries can benefit. Second, a strong capacity for original innovation in a number of Member countries will help to allay political fears about the concentration of economic and technological decisions in any one country.

4. THE ROLE OF THE RESEARCH INTENSIVE INDUSTRIES

103. The research-intensive industries are very important in relation to the above discussion of technological innovation. Industries such as chemicals, electrical machinery (including electronics), scientific instruments, and certain branches of machinery, play an important role in the diffusion of new products and processes throughout the economy, and therefore an important role in productivity growth.

104. This is because, first, these industries have relatively high rates of growth and, therefore, investment, so that there are relatively good possibilities for incorporating the latest techniques into their production processes. Second, and perhaps more important, these industries manufacture mainly producers' goods, and they have relatively high rates of product innovation. They are, therefore, a continuous source of new and better production techniques, equipment, components and materials for the industries which they supply. In this context, it is relevant to quote the following conclusion from a report on patterns and problems of technological innovation in United States industry:

> "... we can speculate that the total process of of technical innovation in American industry in recent years has consisted in the emergence of certain technologically advanced industrial areas – chemistry ..., the broad area of electronics, and aerospace — which have exerted pressures for change on traditional industry either by serving as technological models, by making new demands on traditional industries as suppliers, or by exploiting market opportunities represented by traditional areas. Pressures for growth and expansion, as well as the interdependence of industries as sources of supply and as market, have caused these advanced waves of technology to spread out over all industry."*

105. It is clear, therefore, that for growth and productivity reasons, all industrially advanced countries must have access to the new products of the research-intensive industries. The economic benefits will be all the greater if some of these products are manufactured locally, not only because of the employment opportunities thereby created, but also because of more rapid local access to them and because the user can co-operate more easily with the manufacturer to ensure their effective utilization.

106. The previous analysis shows that the above conditions are, in fact, being fulfilled to an increasing extent. Although there have been some examples of time lags in access to new and better producers' goods, the evidence points to a reduction in these time lags. One obvious reason for this trend is that the production and marketing strategies of industrial firms producing these innovative producers' goods are being increasingly placed on a world wide rather than on a national basis.

107. Some countries consider that the research-intensive industries are also important because they offer more scientific and technological opportunities for originating innovations; because they employ relatively large numbers of scientists and engineers, not only in R and D, but also in other employment functions; because they interact with, and transform, the previously traditional technologies of certain industries; and because they form the basis of knowledge, skills, materials and equipment which new technologies will develop in future.

108. For all these reasons, the industrially advanced countries cannot realistically discuss the place of original innovation in their economies, without at the same time considering the role of original innovation in these research-intensive industries, as well as in more traditional sectors of the economy. The analysis in previous chapters has shown that a number of Member countries have had a strong performance in original innovation in sectors based on chemistry, the basic metals, consumer electronics and conventional electrical machinery. However, in the more recently developed branches of the electronics and aerospace sectors, the United States has a very strong lead. Few will contest the tremendous importance of the former sector for future economic and technological development, although many will contest the value of the latter. However, the above analysis shows that this United States lead has not had any adverse effects on other countries' growth and trade performance.

* A.D. Little "Patterns and Problems of Technical Innovation in American Industry". Report to the NSF, published by the United States Department of Commerce, September 1963.

5. TENTATIVE CONCLUSIONS

109. On the basis of present evidence, therefore, the main problem is *not* so far the impact of any technological gap on Member countries' growth and trade performance. The real concern appears to be about *how* the European and Japanese scientific, technological and related industrial capabilities will be exploited in future.

110. The analysis in previous chapters of this report shows that by comparison with the USA, the scientific and technological resources of Europe and Japan are substantial, and that they will increase rapidly in the future. At the same time, by comparison with the United States, these European and Japanese resources have not produced many significant original innovations in certain new technological areas. This difference can be explained partly by the better utilization of scientific and technological capabilities in the United States than in certain other Member countries.

111. Basically, there are two mechanisms through which these other countries' scientific and technological resources will be better utilized: first, industry and government within these countries can take the necessary action to improve utilization; second, the resources can be better used by United States firms either in the countries concerned, or in the United States. Both these mechanisms are in fact in operation. Evidence on past performance, and economic theory, both suggest that, from the point of view of economic growth and trade performance, it is immaterial which of the two mechanisms predominate. Nevertheless, it is the apparent predominance of the latter mechanism in certain sectors which is a cause for concern in certain Member countries, who feel that they may thereby have little influence in future on the pace and direction of technological advance, and will not be able to relate such technological advance to the fulfilment of certain economic, social and other national objectives.

IV. POLICY IMPLICATIONS

1. DEFINITION OF THE POLICY PROBLEM AND AREAS OF POSSIBLE ACTION

112. The differences in levels of scientific and technological capability and in innovation in industry that have been brought to light are not entirely new, but represent trends of long standing. What, then, are the factors that account for the present concerns? The evidence of the OECD studies suggests the following:

i) Products of industrial sectors which require much R and D and innovation are growing in number and in importance. Although their weight in the total output of the Member countries is still relatively small, as compared, for example, with agriculture and construction, their role in the total industrial economy of advanced countries is generally conceded to be of growing importance. This is partly because it is believed their impact on more traditional industrial sectors may be important, and partly because of their growing importance in world trade.

ii) Together with the above trend, there is some feeling that in certain science-intensive industries the point may be reached after which it will become increasingly difficult for new firms to enter the market successfully.

iii) Although technology is being effectively transferred among Member countries, the relative importance of foreign investment as a vehicle for transfer appears to be increasing. This fact has raised the issue of the effect of location of industrial decision-making on national economic, employment and research policy. This matter is linked with the important role now played by international companies which operate on a world-wide basis, and in some cases have a strong leadership position in the total market.

113. Thus, the growing importance of science-intensive industries, the increasing "price of entry" to the market, and the growing role of direct investment and international companies in the process of technological transfer appear to be the new factors which explain the *political* importance of the issues with which this report is concerned.

114. The findings of the OECD study would suggest that three main lines of action are required. *First of all,* individual countries will need to take measures to enable their industries to strengthen their performance in original innovation, and their abilities to exploit these innovations in the market. This can only be achieved by deliberate efforts on the part of the countries themselves. *Secondly,* groups of Member countries, including the European members, will need to develop more effective forms of co-operation in order to overcome the existing fragmentation of markets, industries and technological efforts. Success in this direction is necessary if co-operation and exchange between the United States and other Member countries is to be effective. *Thirdly,* co-operation between all the Member countries will be needed to avoid the development of obstacles to technological exchanges, thereby increasing the benefits to all. Each of these three aspects of policy will now be discussed.

2. POLICIES AT THE NATIONAL LEVEL TO STRENGTHEN PERFORMANCE IN INNOVATION

115. There is a wide range of measures at national level which would contribute to building up national and scientific and technological capabilities and success in original innovation. These measures would imply a *new stage in science and technological policy in coming years,* including close integration with economic, industrial and commercial policies. The principal objectives of this new stage would be:

i) to relate government science policy more explicitly to clearly-defined economic, social, defence and other objectives, in order to provide clearer orientation of effort, leading to better utilization of and more economic output from scientific and technological resources;

ii) to define the possible contribution of science and technology to a wider range of government objectives;

iii) to strengthen communication and co-operation among industry, the universities and government agencies, in order to overcome the "isolation" of science and technology from those who may apply their results;

iv) to consult industry much more comprehensively in the formulation and execution of policy, in particular in Europe, in order to overcome the weaknesses in the innovation process in some Member countries as revealed by the present study.

116. There is no unique prescription for policies in these directions. Economic, industrial and social policies are clearly just as much involved as, and inter-related with, those in science and technology. Some of the following would, however, provide the basis for a new partnership between industry and government and thereby help to strengthen Member countries' performance in original technological innovation.

A. Widening the Market

117. The sector studies have shown that a large and stable market is often a necessary condition for success in original innovation in sectors with high development, tooling and marketing costs, since it enables firms to write off the fixed costs of innovation over a large number of units produced. Several measures can be taken within national boundaries to increase the size of the market for technologically sophisticated goods. High and steady rates of growth and investment are likely to increase the expected return and reduce the risk of any original innovation. However, the sector studies have shown the existence in some countries of a certain conservatism in using equipment embodying the latest techniques. Such conservatism exists not only in industrial firms, but also in government departments, and mainly in those outside the field of defence.

118. In partnership with industry, governments can help overcome such conservatism in two ways: firstly, by giving financial or other encouragement to firms, installing technologically advanced equipment which, although economically viable, may entail heavy costs and risks; secondly, by making government departments look methodically and imaginatively at the way in which science and technology can contribute to their objectives, and formulating thereafter performance specifications for technologically advanced products, which they will purchase, and to which industry can respond. Inter-governmental co-operation in such procurement may be desirable, when the volume of national procurement is inadequate, in relation to the developing and launching costs of the new product. The problems this poses will be discussed later in this chapter.

119. Although such action within national boundaries is useful, most national markets for new products are not big enough to amortize the costs of original innovation. The sector studies have shown that fragmentation of the European market has been an important hindrance to success in original innovation. Further action in a number of areas, by both industry and governments, is necessary to overcome this fragmentation.

120. However, the sector studies have shown that the market in product areas with a high rate of technological innovation is essentially a *world* market, exploited by international firms. They have also shown that by far the largest market for such products is in the United States, and that – where countries other than the United States have been successful in original innovation – they have generally penetrated the United States market.* Although efforts will be necessary to widen both national and regional markets, it is unlikely that countries can be successful in original innovation unless they succeed in penetrating the United States market. And in fact moving areas of technology, where close and frequent contact is required between producer and customer, penetration of the United States market will often require production activities – and even R and D activities – in the United States, in addition to sales activities. The implantation of production activities in the United States will also facilitate penetration of the large government market for technologically sophisticated products.

B. Creating a European Capability for Technological Innovation

121. One striking feature of the factual analysis in this report is that scientific – and more particularly – technological manpower resources in Europe are not markedly smaller in quantitative terms than those in the United States, but that they have been far less productive of successful original innovations, especially in the science-intensive industries. One contributing factor has been the size of markets for technologically sophisticated products discussed in A above. But there is also reason to believe that scientists and engineers have not been deployed and utilized as efficiently as in the United States.

* For example, Europe in pharmaceutical products and chemicals; Japan in consumer electronics.

The Size Structure of Industrial R and D

122. The above analysis shows that, by comparison with the United States, industrial R and D in Europe is fragmented. The advantages of more concentration of the industrial R and D efforts into larger firms have been too often repeated to require extensive treatment here. They include the avoidance of duplication, the spreading of risks, the support of more long-term or expensive projects, the existence of a variety of technological skills, the compression of "lead times", and existence of strong capabilities in production engineering and marketing.

123. There has been a movement towards greater concentration of scientific and technological resources in European industry, both through mergers and through government finance of specific development projects in specific firms. However, this movement is taking place on a *national* rather than on a *European* basis. Concentration on a European basis would be more efficient; firstly, because the range of possibilities would be very much wider; and secondly, because it would facilitate the marketing of new products on a European rather than on a national basis.

124. Furthermore, the award of governmental development contracts poses problems because there may be considerable duplication amongst the projects being financed in the various Member countries in Europe.

The Deployment of Scientific and Technological Resources

125. In the United States there is a greater concentration of scientists and engineers, and of R and D activities, in manufacturing industry than in Europe. The United States pattern may well be more efficient for original innovation: first, because industrial firms can be more flexible in their use of scientists and engineers than can government laboratories; secondly, because the presence of scientists and engineers, and of R and D activities *within* industrial firms is more likely to ensure the necessary links and feed-back between R and D, production and marketing. The redeployment of scientists and engineers is, however, a difficult task, above all because, as we have seen, the labour market for them is becoming increasingly international.

The Quality of the Environment

126. Although many of the sector studies show that large firms are necessary for successful innovation,

that on electronic components shows that new — and sometimes small — firms can make a significant contribution to original innovation. This is particularly so when large firms, because of the slowness or complexity of their decision-making processes, or because of their commitment to other product lines, are slow to perceive an opportunity to exploit a technological advance, or do not devote sufficient managerial energy or resources to it. In such cases, small firms may enter the field — or break off from large firms, and succeed where large firms fail.

127. Very few cases have been found of this phenomenon in Europe, some have been found in Japan, and a great many in certain regions of the United States. One of the reasons for this may be the larger market for sophisticated products in the United States. Another may be the greater propensity for scientists and engineers to start up their own businesses in the United States. But there is little doubt that the supporting environment plays an important role. This means not only the availability of risk capital, but also readily available managerial, marketing, and forecasting services; a readily available supply of high quality components, materials and machinery; and a supply of well-trained and flexible production workers.

128. Thus, part of this problem will be overcome only with a general increase in the technological sophistication of industry in Europe and Japan. But special efforts may be required to encourage the necessary financial and managerial services, and to increase the flexibility and general education of the work force, particularly in Europe, where it is markedly lower than in the United States.

The Management of Technological Innovation

129. Although the sector studies have shown conderable differences in performance in managing technological innovation *within* each Member country, most of them conclude that United States firms are, on the whole, better at managing original innovation than their European and Japanese counterparts. Considerable importance was attached to the greater attention paid in the United States to a continuous feed-back between customer needs and technological opportunities. The greater attention paid to marketing is probably true of all United States industry, not only in science-based industries, but in older industries too. Thus, it is not altogether surprising that United States firms were first to see the necessity of coupling technological forecasting with market forecasting in products areas with repiad rates of technological change.

130. The development of long-term plans and strategies, together with financial control techniques and decentralized management, should become more widespread in European and Japanese firms, thereby enabling a more effective deployment of scientific and technological resources. Management techniques can also be diffused by training programmes of overseas subsidiaries of United States firms.

131. However, it has been noted that the proportion of managers with a university degree is higher in the United States and that specific education in business management is also more general. In the long run, the ability of European management to adopt and use modern techniques may depend on the development of university education more compatible with, and attuned to, the needs of industry.

The Problem of Choice

132. The sector studies have show that, at the firm level, success in original innovation requires a continuous assessment of the product areas in which it should have an aggressive strategy of vigorously developing and exploiting new technology, and the product areas where it should not. Such assessments must be based on the firms' technological capability in various fields; its financial production and marketing capability; the position of its competitors, and the future significance of various markets and technologies. The sector studies also suggest that firms which make such assessments and *concentrate* their resources are more successful than those which do not make assessments and *spread* their resources.

133. At national level, an analogous problem of assessment and choice is now facing a number of Member countries, whose technological resources and markets do not allow them to be in the forefront of original innovation over a wide number of sectors. An acute problem is faced by a number of Member countries who were able to remain at the forefront over a wide number of fields in the past, but who now find it increasingly difficult to choose.

134. This is not the place for a detailed discussion of the elements that should enter into decisions about choice at the national level. Suffice to say that

there are two requirements: firstly, a strategy for industrial development which — like the strategy of a firm — is based on future technological and market trends, secondly, a science policy which is in part oriented in relation to such an industrial strategy. Such an approach can succeed only through a close partnership between industry, government and the universities in the creative task of developing and exploiting new technologies in relation to national economic and social objectives.

3. INTERNATIONAL CO-OPERATION IN SCIENCE AND TECHNOLOGY BETWEEN MEMBER COUNTRIES AND GROUPS OF MEMBER COUNTRIES

135. Although the actions reviewed above are important, more needs to be done if the pace of technological innovation is to be accelerated. For this to be achieved, other Member countries and groups of Member countries, for example, in Europe, are considering programmes for science and technology which, even if not of the same size as the space programme of the United States, nevertheless have the same power to catch the imagination of the industrial, scientific and educational communities, and the means to overcome institutional barriers and traditional attitudes. If the United States' experience is a pointer it seems beyond doubt that the political will to undertake such programmes will depend on their being the *instruments* for attaining important and stimulating objectives. Moreover, since programmes in advanced areas of technology, such as space, aviation and nuclear energy, and an increasing number of areas of civil technology, are in many cases beyond the resources of individual countries, they will depend on the identification of objectives which can be agreed between groups of countries.

The Emergence of Major Social and Economic Goals related to Technology

136. There is, in consequence, likely to be an increasing pressure or need for many Member countries to participate in international technological projects, many of which will entail not only co-operation in R and D, but also in production and government procurement.

137. In the first place, there is growing discussion of long-term goals which could be the basis for *major technological adventures*. Examples are space exploration, future communications requirements, world food requirements, the explosion of education, the exploitation of the marine resources, urban and regional development, and future health goals.

138. *In addition, there are many medium-term public needs calling for co-operation in technology and production* of a kind that has so far only been widespread in relation to defence technology. Examples are: computer grids for commercial, government and educational needs; wired telephone systems; international satellite communications; postal systems for classifying, sorting and automatic delivery; domestic house-building by systems; surface transportation between and within cities; power grids for electricity and gas; teaching machines, etc.

139. Finally, there is a growing need for the evaluation of *existing large-scale programmes* of scientific and technological effort with the purpose of more effectively relating them to the needs of the economy (space research, nuclear research, etc.).

The Requirements for Effective International Co-operation

140. Whilst the need for major programmes of co-operation in science and technology related to social and economic objectives is clear, there are a number of fundamental difficulties which call for examination:

- the need for more clarity or agreement concerning the objectives for which the projects are undertaken and the policies for achieving them;
- lack of means for the systematic examination of the alternatives for achieving a desired policy objective, or the alternative methods of managing a given project or programme;
- the seemingly inevitable competition between national and international projects;
- the difficulties of reconciling the need for efficiency and managing such projects, with the desire for each participating country to achieve a fair return in every specific area of co-operation;
- intergovernmental co-operation in applied R and D projects must often go hand in hand with inter-country co-operation in industry and in government procurement.

141. Quite apart from the above difficulties, there remains the problem of choosing objectively the most appropriate framework for international co-operation, and of working out effective and realistic arrangements for political and managerial control. Whilst there have been some past successes, there has also been a sufficient number of difficulties to make it clear that, although it is urgently necessary to give a new impulse to international scientific and technological co-operation, it is equally important to establish an effective mechanism or forum for evaluating possible projects, so that governments may have a clear picture of the objectives to be served, and alternative methods for achieving these objectives.

142. In addition to this need for *evaluation*, decisions should be related to future needs and emerging technological opportunities. Otherwise, the priorities for effort will run the risk of not reflecting the real options, which must of necessity be formulated having regard to possible technological and market trends.

143. These considerations suggest that the efforts of individual countries to evaluate possibilities and develop an effective rôle in international co-operation in science and technology could be significantly assisted by arrangements to carry out the following functions:

i) assessment of social and economic objectives in Member countries, in relation to which there are potential contributions from technology which call for international co-operation;

ii) evaluation of proposed international projects in relation to these objectives, including the formulation of criteria which would assist Member countries in such evaluations;

iii) examination and evaluation of management requirements for large-scale co-operative programmes.

New Developments in Technological Co-operation

144. Co-operation between countries is now called for in the technological and industrial aspects of development as well as the strictly scientific. Such co-operation is necessary especially if, as the OECD study shows, the root of disparities is more in the field of industrial capability in developing and using advanced technologies, than in scientific knowledge as such.

145. Technological co-operation between countries inevitably brings into the picture industrial and political interests which were not so important in the *scientific* co-operation which has been widespread in the past. There are in particular two aspects of co-operation which will become important:

i) a trend toward co-operation in the procurement by governments of technologically-sophisticated products (in fields such as transportation, health, communications, defence, and public utilities in general);

ii) using co-operation in government procurement as a means of stimulating industry to develop advanced technologies, and to achieve (by inter-company and inter-country integration of efforts) R and D production and marketing units on a scale and of a degree of efficiency required to compete internationally.

146. Such a trend is already visible for example in the European Member countries and Japan, where government procurement and co-operation with industry in meeting public requirements for advanced technological products have not been so widely or effectively developed as in the United States. In Europe, the trend appears to be most marked because of a growing realization that, as the OECD study of the technological gap indicates, the European Members show the greatest contrast between the existence of a scientific and technological potential and its realization in industrial and economic progress. The strengthening of Europe's technological capability and research-intensive industries would, in

fact, appear to call for action on four levels: widening of the market; co-operation in government procurement for technologically-sophisticated products; the creation of industrial units of sufficient dimension to compete effectively in the advanced technological areas; and co-ordinated choice of areas in which to make an effort. The recent decisions of the CEE Ministers of Science constitute a step in this direction and the proposal of the Prime Minister of the United Kingdom concerning the establishment of a European Technological Community, supported by a European Technological Institute, concerns one possible overall framework in which such policies could be pursued at the European level.

147. The vital first question which arises from these developments is the institutional arrangements through which European co-operation can be best achieved.

148. Secondly, whatever institutional solutions are developed for co-operation in Europe, and in particular within the EEC, it will be important to consider how scientific and technological co-operation on this basis can be effectively linked with co-operation between the OECD Member countries as a whole, and how this broader co-operation can itself be promoted.

149. A third important consideration is the need for vigilance so as to maintain the widest possible framework of co-operation for projects of essentially scientific and long-term interest to all Member countries.

The Rôle of the OECD in Scientific and Technological Co-operation

150. The trends outlined above suggest that the OECD will continue to have an important rôle in scientific and technological co-operation

i) as a forum for assisting Member countries to arrive at decisions related to international co-operation;

ii) in continuing to assist, on request by Member countries, in the evaluation of potential projects and relating them to technological trends;

iii) in establishing necessary contacts, and facilitating co-ordination related to programmes on similar topics organised by Member countries or groups of Member countries.

151. The latter function would be of special importance in major areas of governmental interest in technology, related to social and economic goals which the OECD Members share. Examples of fields in which the Organisation is already active, or might in the future be so are:

1) *Computer Utilization*

All Member countries have a vital interest in accelerating the use of computers in all segments of society and the economy. Whilst the development of a production capacity is likely to remain within the realm of bi-lateral co-operation, the interest in utilization is shared by all. The OECD Group of Experts on Electronic Computers has recommended a number of specific fields as calling for international co-operation; intergovernmental co-operation in planning network systems; exchange of information on advanced applications, for example, in the areas of health, education, transportation, urban planning and government services; promotion of educational facilities and development of curricula; international library for systems descriptions through which government and industry could exchange and use information about systems; and co-operation in software development.

2) *Educational Technology*

The only long-term answer to the explosive growth of education is likely to be in the direction of a more capital intensive system. The possibility that educational technology could improve the quality of instruction and contribute to cost-effectiveness needs to be carefully evaluated. In the coming decade enormous public resources will be poured into education, and into equipping the educational sector, and it therefore seems timely and urgent to assess the contribution of new technologies, and to promote co-operation in their development. Given the established OECD interest in this field, and the recent creation of the Centre for Educational Innovation and Research, this task would seem appropriate for action by the OECD.

3) *Environmental Technology*

The deteriorating quality of the natural environment is an inevitable by-product of industrial society. With continued growth in population and economic activity, the problems of water scarcity, air pollution, waste disposal and pollution of lakes, rivers and streams may soon become critical unless strong preventive measures are taken by the governments. Modern technology combined with a fuller understanding of the forces at work that are modifying the biosphere can hold the key to arresting the downward trend and restoring the quality of the natural environment. Various techniques of desalination (*e.g.* electrodialysis, reverse osmosis) and artificial atmospheric precipitation hold promise of providing plentiful water supply in even the most arid regions; modern techniques of waste treatment can assure progressive purification of lakes and rivers; control of stack emissions and development of pollution-free automobile engines can do much to restore purity to our atmosphere.

4) Urban Development Technology

Short of drastic measures, the trend toward continued, and perhaps accelerated, growth of the urban centres appears irreversible. Technology can provide many of the answers required to cope with the problems of the contemporary city. The computer can be used as a powerful tool for prediction of the functioning of the urban system, and thus provide valuable assistance in the planning, design and management of cities. Modern building technology can give us the means to construct housing more economically and might also protect the urban dweller from the undesirable aspects of the urban environment, such as pollution, noise and vibration. Advanced tunneling techniques could reduce the cost of underground thoroughfares so that they would become competitive with surface highways and thus lead to the elimination of much of the undesirable traffic and its adverse side effects from city streets. One of the first and most urgent tasks is to provide a continuous assessment of the contribution which technology could bring to improving the urban environment.

5) Marine Resources

Using the oceans to advance national goals is a relatively new but highly promising concept. Within the last decade there has developed a new awareness of the potential of the marine environment for the development and exploitation of new food and fishery resources, for mineral and energy resources and for improved accuracy of prediction of environmental conditions. To achieve these goals ambitious programmes must be directed at research in biology and physical sciences, at studies of the air-sea interactions, at the exploration of the continental shelf and deep ocean and, particularly, at the development of ocean engineering systems and deep submergence techniques and instrumentation. Much of the success in exploiting the marine environment depends upon the development of sound capability in ocean technology and marine sciences.

4. POLICIES TO INCREASE THE BENEFITS OF INTERNATIONAL TECHNOLOGICAL EXCHANGES

152. While scientific and technological projects undertaken in common provide one example of the way in which the benefits of technological advance can be shared, a great deal of technological flows between countries takes place through the processes of trade in goods, capital movements, purchases of technological know-how and the migration of professional manpower. It is important that, where necessary, action should be taken to facilitate these flows.

153. The structure of trade in manufactured goods does in itself seem to reflect a certain pattern of relationships in terms of technology. The United States seem to lead in the production and exportation of new products. Western European countries, once in the position occupied today by the United States, retain a capacity for innovating new products in some sectors, but in many cases they are brilliant followers based on the early adoption of innovations made in the United States and elsewhere. Japan, formerly competing in products based on "traditional" technology, has moved up to a position similar to that of some European countries, and in some key sectors is an original innovator.

154. Thus, trade in goods has enabled countries to acquire technologies as a result of liberal trading policies. However, the above pattern of relationships in technology will continue to evolve if Member countries succeed in developing their innovative capabilities.

155. In this connection the reduction of *non-tariff barriers to trade* would undoubtedly be beneficial to flows of technology. Industry is sometimes hampered by the need to diversify its products for export in order to fit in with varying standards, certification procedures, safety requirements, etc.; by varied patent procedures in different countries, and by regulations and restrictions in the field of government procurement. There is in consequence a definite need to harmonize standards, to consider patent legislation on an international basis, and to liberalize and harmonize government procurement.

156. In addition, countries are bound to ask themselves how they can to some extent produce their own advanced technological products and thereby benefit from the rapidly growing markets for such products. There are a number of ways in which they may develop their production facilities, either through licences, foreign investment, or by generating the technology domestically.

157. As far as licensing is concerned, the system of patent monopoly has contributed much toward avoiding wasteful duplication of research and development, ensuring the effective building-up of scientific and technical knowledge, and acting as an incentive to invention and especially to innovation. However, some patents are now so basic to the development of important sectors of industry, and the pace of technological change has become so fast, that fears have been expressed about the possibility that access to some important inventions and the related licences may be restricted. It may be desirable to give some attention to aspects of this question.

158. Foreign investment may be considered an alternative to licensing, depending on the particular circumstances of competition between firms in different countries, and on national policies. In Europe, for example, foreign investment, principally from the United States, has undoubtedly contributed to the effective transfer of technologies. However, foreign investment on a large scale raises the question of control of decision-making over important sectors of national economies, and calls for developments in national and company policy whereby the contribution to the national economy can be most effective, while allowing for a fair return for the investor. Foreign subsidiaries and joint ventures also contribute to the level of technological development in the host country, especially if the strategy of the firms concerned is to conduct R and D in their subsidiaries and joint ventures and diffuse the technology in question in the recipient economy.

159. An important additional process in the transfer of technology is the mobility of scientific and technical manpower. Whereas the provision of education is mainly a national concern, the labour market for qualified persons emerging from any educational system is becoming increasingly *international.* If a country produces more persons with certain qualifications than its economy can absorb, these persons may be expected to seek lucrative employment in countries with a higher standard of living, and the country losing manpower will experience a "brain drain". A country producing fewer qualified people than required by the private and public sectors of the economy will tend to attract them.

160. Licensing, foreign investment and the "brain-drain", should be seen in the broad context of technological development and exchange under modern conditions. The efficient exploitation of advanced technologies calls for both technological resources beyond national boundaries and access to markets that are international in scope. This, added to the mobility of the factors of production (essentially knowledge, qualified manpower and capital), leads to a new emphasis in international exchange. Flows of manpower, investment and knowledge are undoubtedly beneficial to all countries but in this new situation some countries are experiencing problems which affect the development of their own technological capabilities.

161. It is also important to bear in mind the special plight of the under-developed countries. For, whereas the evidence suggests that technology has been effectively transferred between the Member countries, the same is not true for the under-developed countries. The absence of scientific and technological capability in these countries may be an important factor in limiting the transfer of technology to them, and the aid to them in developing indigenous R and D capability may be an increasingly important task for the Member countries.

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