

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 recommendations which highlight some of the main points which Ministers may wish to discuss.

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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 highlighted 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 tech-

* 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.

nical 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.

* 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 plural-national 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

* 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.

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.

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)				Total
	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	
<i>United States (1964) a</i>					
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*
<i>France (1963) a</i>					
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*
<i>Sweden (1964)</i>					
Number of firms	113	26	—	—	139
% of all industrial R and D done in the group	28.9	63.6	—	—	92.5*
<i>Belgium (1963)</i>					
Number of firms	48	12	—	—	60
% of all industrial R and D done in the group	21.8	66.4	—	—	82.8*
<i>Norway (1963)</i>					
Number of firms	29	2	—	—	31
% of all industrial R and D done in the group	44.3	20.9	—	—	65.2*
<i>Austria (1963)</i>					
Number of firms	18	2	—	—	20
% of all industrial R and D done in the group	47.3	26.1	—	—	73.4*
<i>Spain (1964)</i>					
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 re-orientation 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 re-organisation 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 re-

lating 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 exploitation 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 consensus 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 acceler-

ated 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 re-allocation 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 businessmen 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 economies 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 inter-

national 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.