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INTERNATIONAL SYMPOSIUM ON INDUSTRIAL DEVELOPMENT
Athens, 29 November-20 December 1967
Provisional agenda, Item 3 (f)

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PRACTICE OF INDUSTRIAL RESEARCH AND DEVELOPMENT

Submitted by the Government of the Netherlands

1/ A summary of this paper appears in document ID/CONF.1/GS.1.

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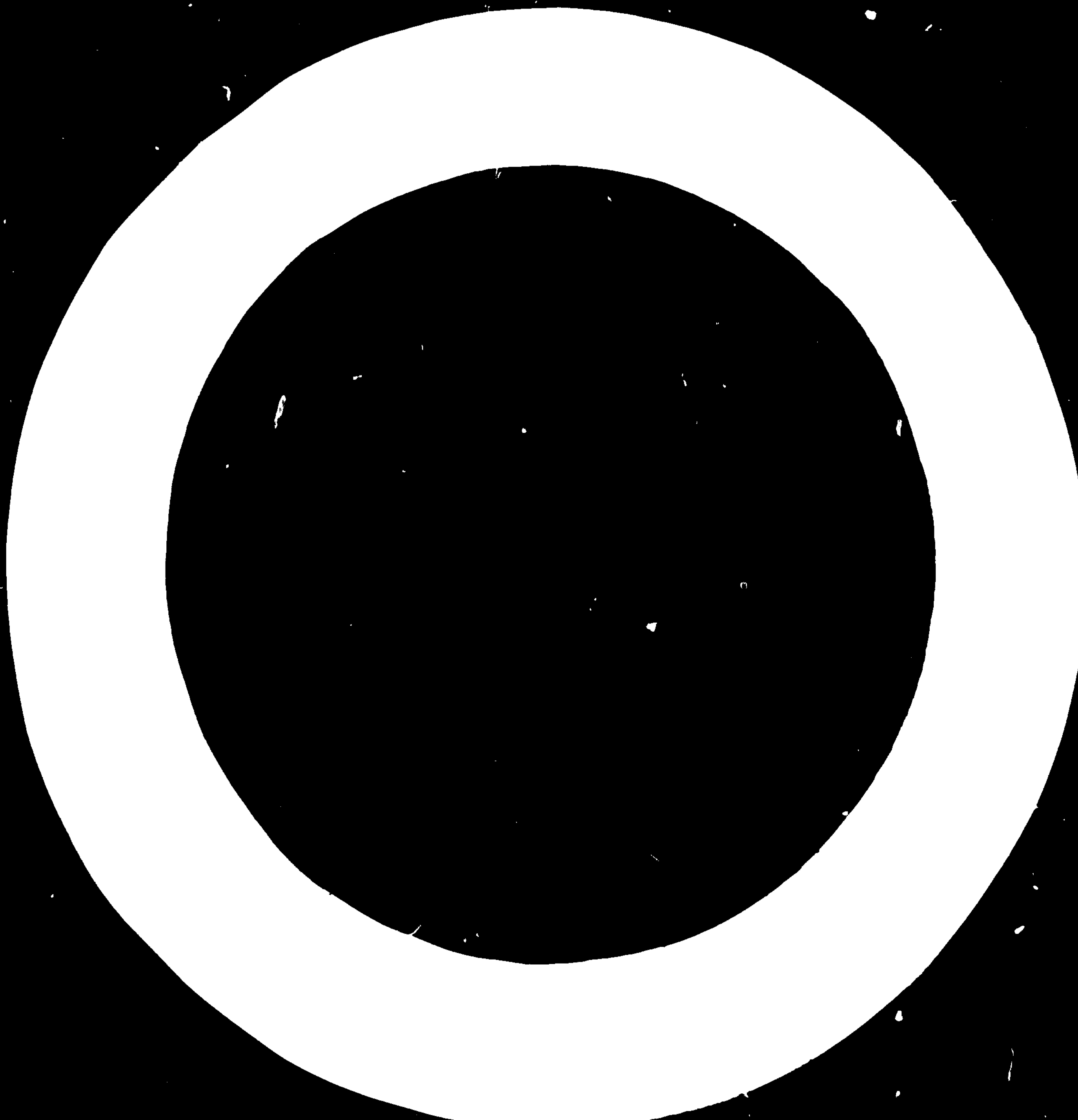

CONTENTS

RESEARCH POLICY AND RESEARCH MANAGEMENT

1. Only one decade ago, the relevance of research and development (= R&D) for the economy was not yet generally accepted. This became manifest through discussions on the subject everywhere, and through the efforts of groups of officials and others to convince responsible leaders of R&D's value for welfare.

2. As a matter of fact, several Governments and a large number of big firms had already integrated R&D in their activities. But it is only recently that the interest in R&D has spread over nearly all big firms and a substantial number of medium-sized firms. Moreover, it has gradually been recognized that the fast increasing demand for scientific manpower and equipment brings about the necessity of special organizational measures. The complexity of the problems to be solved, the huge sums of money to be spent and the subsequent request for methods to face priority questions with reliable guidance, caused the feeling that serious studies of R&D policy and R&D management were necessary.

3. The Soviet Union, with its centralized research management, proved to be a stimulus for other countries. This was first of all the case for the USA, where initially president and congress had no other guidance than that of some ad hoc consultants and advisory groups. In Western Europe, the same call for research management led to the more or less tentative formation of such institutions as science ministries and science offices. The awareness of R&D as a subject for state care, covering both specific governmental and private aims, has spread so rapidly that R&D policy and management are now topics in all kinds of countries, advanced or not advanced. With the help of the machineries established country-wise, international seminars became frequent features. In 1961, the Economic Commission for Africa together with UNESCO organized such a seminar in Addis Ababa, Ethiopia.

4. There long-range planning led to the promotion of self-sustaining growth in such a way that, from 1980 onwards, adequate use of native human resources in a modern technologically advanced society will be possible. Not more than three years later, the same institutions, together with forty-one African countries, stated that the development of national resources - human resources as well as natural resources - ought to be supported by the development of scientific research (Lagos, Nigeria; August, 1964).

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5. Extensive recommendations concerning this "development of scientific research" were formulated; they concerned planning per country and per continent. For the first type of planning, the recommendations were very impressive; one of these related to setting up in a country some form of a national research body for the planning, directing and co-ordinating of all scientific research. There was, in addition to such a body, also a plea for a national research budget. It was stated that, in the immediate future, 0.5 per cent of national income, or 6 per cent of total national investments, ought to be available for research as a whole. Further it was recommended to create a national register of research manpower, and to watch carefully its planned growth in order to avoid emigration. Furthermore, public relations activities were recommended for the improvement of general science consciousness.

6. The items on their continental-scale programme were not less impressive. Within the framework of the organization of African unity, a scientific and technical committee on natural resources had to be established; it was to promote policy discussions on a continental level, as well as practical research on standardization, harmonization of terminology, and maps.

7. An African convention on conservation ought to be established; it was to avoid exhaustion of mineral, animal and vegetable resources. Finally, to assure the maximum use of African scientists in the continent, some international pool of research people ought to be made. One more example of highly valuable international discussion may be referred too, viz. the International Seminar on Industrial R&D Institutes in Developing Countries (Beirut, Lebanon; December, 1964). There, the discussions no longer orbited around general points of view, but were pin-pointed on questions of the workshops of industrial R&D and the institutes required to carry out the investigations. Reading the papers of conferences like those convened at Lagos, Addis Ababa, Beirut, together with the knowledge that there are quite a few comparable manifestations that could have been mentioned, makes it clear that, for the time being, it is very difficult to add any valuable contribution to all the viewpoints and recommendations that have been brought to the front so far. I dare to say that even in countries with advanced R&D experience, most authorities dealing with matters of science policy will find it a tough job to propose a step forward beyond all that has been elaborated in those conferences.

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However, by no means must we forget that the success of all the best studies will not depend on their formulation but on their grade of realization.

THE PROCESS OF INDUSTRIAL RESEARCH AND DEVELOPMENT

8. R&D is a very difficult matter. Since science and technology are evolving from year to year, problems become more and more complex too, and so does R&D management. Thus the uncomfortable feeling arises that realizing R&D to their full contemplated effect, particularly where a gap must be filled between a low level start and a high level finish, might be too ambitious.

9. It is frequently said that research, as well as the subsequent span of time up to practical application, have substantially speeded up in the course of years. To put it in terms of industrial R&D: on the basis of steadily improving sources of fundamental knowledge, experience, available methods and equipment, educational level, etc., the technological development will be faster and faster. Studies have been made which prove this statement. A nice result has been presented by Frank Lynn; he studies twenty major innovations whose commercial development started in the 1885 - 1950 period (see table 1).

10. The "incubation period", covering the "D" from R&D together with commercial development, went down from thirty-seven years in the beginning of this century to fourteen years recently. It has to be noted, however, that Lynn's selection of innovations was ex post.

11. Industrial "R" and even "D" may lead to commercial results, but may also lead to impractical results or to unintended side-effects.

12. What does this mean in reality: What ranks higher: the profitability of a company, or the benefit of the consumer? Does a commercially developed innovation indeed increase national income; does it befome an impetus for other economic activities? And, finally, does it contribute to the welfare of foreign countries and, in the end, to that of the world as a whole?

13. Reports showing the rapid evolution in technological R&D, and its impact on society, make people nervous. Especially those people who have responsibilities concerning the improvement of the economy of countries in poor condition, are bound to suffer from their awareness of the widening gaps between the rapid progress elsewhere and what they themselves can afford to do.

14. As a consequence of this feeling of uncertainty, there is a real danger for exaggeration and consequently this may mean a danger for the attention to be drawn away from possible inperfectness in the essential follow-up of necessary successive actions, thus frustrating the targets. The meaning of this point can best be demonstrated with the help of a case-study, namely the story of the electric bulb.

15. As schoolboys we have learned that the electric bulb was invented in 1879, by Thomas A. Edison. We all accepted this as a fact, not only because schoolboys are quite willing to accept what the teacher says, but also because it suits their minds: being fascinated by spectacular things.

16. History, however, reveals that Edison's electric bulb was not at all a true invention. In 1650 it was already known that light could be produced by electricity; that was the discovery of Otto von Guericke. In the early years of the 19th century, Sir Humphry Davy succeeded in making sheets of metal glow with the help of a battery.

17. In 1841 Frederic de Moleyns applied for a patent regarding a vacuum glass bulb containing powdered charcoal bridging the gap between two platinum wires. From 1841 to 1879 several other people had contributed to the development of a usable bulb; for example: Heinrich Goebel, Sir Joseph Swan, Sawyer and Man.

18. The significance of Edison's work was essentially to check all the phenomena then known, as well as the details of the bulbs that had already been developed. The main "headache" was the filament. Edison used a vacuum technique too. This technique itself had had already a past of an even more dramatic character than that of the very conversion of electricity to light. This too went back to the 17th century, when Keppler, Toricelli and Pascal made termendous efforts to prove that vacuum existed. These scientists had not only to face the technical problems; they had to convince! In fact, they had to fight the ecclesiastics; for them the very assumption of a vacuum was an insult to God.

19. All in all, Edison had the basic knowledge readily accessible: on the one hand the principle of vacuum, and on the other hand the principle of converting electricity into light. He could thus concentrate on a proper design of the bulb. Essentially, this required a tremendous lot of "development" work.

20. Edison did his job very systematically. First he hired a glass blower, next he built a special laboratory for the project. When, in the end, success was evident he appreciated its importance: the darkness of the earth could be removed.

Centuries of light and welfare could begin! Edison kept his laboratory as a statue of technological revolution; today it can be seen by anyone who visits Ford's collection in Greenfield Village, Michigan.

21. In a way, Edison had reasons to be optimistic. He had the means to transfer products of laboratories to private industry. He was an entrepreneur, and, indeed, a progressive entrepreneur. He designed, and built, electric energy plants and their distribution system. He brought the energy and the bulbs to the people. What he did was in fact more development than research. This was a story of 1880.

ECONOMIC RESULTS OF INDUSTRIAL RESEARCH AND DEVELOPMENT

22. We are now living nearly 90 years later. Electrical light is accepted in everybody's mind as so simple and highly useful a device for material comfort that it is hardly believable that not all or nearly all people in this world have it at hand.

23. Hardly believable indeed! But how about the fact that only a small part of the world's population can have this "daily blessing"?

24. Basing myself on rather scarce data, I can make the rough estimate that nowadays no more than 30 per cent of the world population use electric light. So, out of the present 3.3 billion people, 2.3 billion have no electric light at all. This last figure exceeds by 800 million the world population of 1880, estimated at 1.5 billion inhabitants. Accordingly, there are nowadays more people without electric light than there were before its introduction!

25. I hope not to be blamed for sticking so long to the example of the bulb. Several facts have been illustrated by it, and each of these is pertinent to the subject of this paper. These facts are:

(a) The total effort of getting a technical product, evan a rather simple device, may have involved a long-lasting process of fundamental research, applied research and development.

(b) This process does not only require the bridging of gaps in technical knowledge and know-how, but also the surmounting of barriers of human factors; think of religion, bias, inertness, etcetera.

(c) As soon as adequate knowledge to make a new product has been obtained, a new process of assimilation in the economic systems has started. This process may be as time-devouring as the preceding work. In the case of the electric bulb it has been clear that even with the help of well-managed routine production and distribution techniques, the problem of assimilation by the ultimate consumers market, the world, is far from being solved.

26. The third point (c) represents the crucial problem of the developing countries. How to change this picture? Concerning industrial R&D there is only one answer: a continuous effort to get the most out of the time, money and manpower available. This, to a large extent, can be done by the mere transfer of the existing technological knowledge, know-how and experience of the advanced countries. Many existing sources are in fact placed at the general disposal of everyone, and these should be used much more widely for the benefit of the whole world.

27. But next, to be able to draw benefit from the reservoir of scientific knowledge from abroad, developing countries too must stimulate their own R&D activities. As a matter of fact, here the same necessity of an efficient use of the available potentialities is urgent. Apart from the organizational aspects, apart from topics that concern programming and selecting projects, it seems essential to consider realistically the question of the amount to be spent for industrial R&D and that of how to distribute this amount among the various types of R&D. As will become clear in the next paragraphs, the answers to these two questions will basically influence the profitability of industrial R&D. The said questions bear on the whole sequence from basic research to applied research, to development, to pilot production, to investment and finally to the effect on the whole economy as measured in terms of national income.

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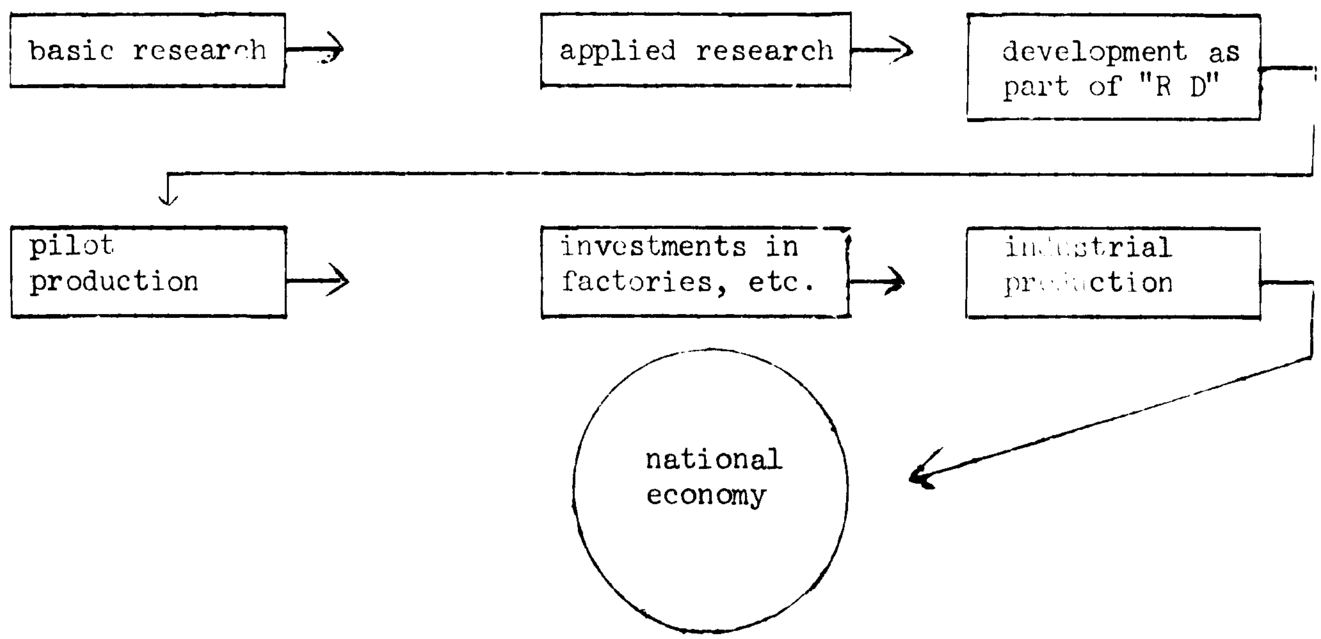
28. This sequence can be visualized as follows:



A proper understanding of this sequence may be of paramount importance in developing and guiding a country's research effort.

29. The first three components: fundamental research, applied research and development, although they are easily seen as separate activities, are rather arbitrary in their distinction. In many respects, however, their differences are real.

30. After a long period of discussions, it has become possible for the secretariat of the Organization for Economic Co-operation and Development, in close co-operation with the twenty-two member-countries, to make workable definitions for these activities. They have been published in the so-called Frascati Manual "proposed standard practice for surveys of research and development", OECD (1962):

"a. fundamental research

Work undertaken primarily for the advancement of scientific knowledge, without a specific practical application in view.

b. applied research

The same, but with a specific practical aim in view.

c. development

The use of the results of fundamental and applied research directed to the introduction of useful materials, devices, products, systems and processes, or the improvement of existing ones."

31. The practical establishment of the frontiers between basic and applied research and development still provides many difficulties, but there is now sufficient experience in making reliable statistics on R&D efforts in many countries.

32. There is a 20-years old philosophy that R&D expenditure should be compared with national income. This philosophy is based on the assumption that national income will be influenced by R D, while R D costs seem to represent R&D efforts. The more is spent for R&D, the higher will be the contribution to the national economy.

33. Indeed, series of studies are published in which graphs illustrate the relationship between R&D expenditure and national income. Any doubt about the relevance of this correlation that might rise in the mind of someone watching this way of jumping to conclusions, is easily kept down by the attractiveness of this simple, clear-cut relationship. However, it is my personal opinion that we ought to be much more cautious in this matter.

34. Not all national R&D efforts are oriented towards the national economy (e.g., defence and space research).

35. From the remainder, there is a part that has only a remote relation to it (much fundamental research, educational research, while in some special cases the effect of medical research can even have an opposite effect and lower the <u>per capita</u> national income).

36. But the most important point is that even as far as R&D is directly oriented towards the national economy (civil industrial R&D), their results can contribute to welfare only if adequate investments for their exploitation are made. This means that between the R&D effort and the national income, at least <u>the strategic step to investment</u> must be considered first.

37. The product of research is new knowledge. This may concern new products (including better products), new processes (including cheaper processes), new and better services and methods. When using this knowledge, it becomes clear that new or revised investments have to be effected in order to start the making of new products, to continue the manufacturing of existing products with the help of the new processes. If nothing is done in this respect there can be no improvement, and there will be no relationship at all between the R&D effort and the national income.

38. To speak of "no relationship at all" may seem somewhat theoretical, but if the investment is not more than 10 per cent of what might be an optimum, then it is also quite understandable that only very little result from R&D will be achieved, compared with investments of up to [illegible] or 100 per cent of the optimum. Here we can go back for a moment to the example of the electric bulb. In a given country, external economics can be so frustrating that there is no reason for any production; for example when people cannot pay for electricity, energy plants are not available, the money for power transmission networks is missing, etcetera.

39. Under such conditions there is no need for investments to produce bulbs. Only a well-balanced sequence of the components as indicated in the figure above, can be successful. If in this sequence one or more links are missing, or if on the other hand one or more components are over-saddled, serious disappointments cannot be avoided. Waste of money will be the result. This means: waste of time, waste of scantily available qualified manpower. Thus wrong conclusions may easily be drawn in evaluating the components separately, particularly with respect to industrial R&D.

DOSING AS A PROBLEM

40. For long, problems of dosing investment have had the attention of economists. The influence of "over" and "under" investment on business cycles has been analysed. So far, however, there is no analogous theory concerning R&D efforts. For the time being, the relation between R&D and investments is considered to be very close, for net investments are more and more considered to result from the introduction of new technological elements. It will therefore be of much interest to see if interrelationships of R&D efforts and investments could be quantified in the same way as has been done with investments and national income. If this could be done in a clear way, it would be possible to point out whether too much or too little money is spent for R&D. Subsequently, the same could be evaluated concerning a breakdown of R&D into its three main components: development, applied research and fundamental research.

Dosing within research and development

41. Because only little is known about the relations controlling the whole sequence, we are forced to restrict outselves to statistical data that are available at this moment. For this purpose we can make reference to the USA. From the statistical

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point of view, the American data are highly valuable. They are in fact available in time series over a sufficiently long period.

42. Table 2 comprises a time series from 1957 on to 1965 of money spent in industry on basic research, applied research and development. The ratio proves to be 4 per cent for basic research, 20 per cent for applied research and 76 per cent for development (- 1 : 5 : 19).

43. Roughly speaking, for one dollar spent on basic research, five dollars were spent on applied research, and nineteen dollars on development. Of course, one has to be cautious in interpreting these figures. R&D activities in industry are normally supported by R&D in other sectors, namely universities, public and private non-profit-making institutions.

44. If all national R&D activities are included, then the USA figures (1961) give 9 per cent basic research, 21 per cent applied research and 70 per cent development, hence a ratio of 1 : 2 : 7.

45. Another point is that in the comparison of amounts of money for the various R&D activities not one period, but successive periods ought to be taken in mind. Perhaps we ought to compare expenditure for basic research in the period, e.g., 1957/59 with expenditure for applied research in 1960/62 and for development respectively in 1963/65. Then the relation is no longer 1 : 5 : 19, the average of 1957/65, but 1 : 7 : 33.

46. Elimination of the decreasing money value diminishes these figures slightly, but does not change the pattern. A third correction could be relevant to the problem, namely, the expenditure for government-sponsored R&D carried out by industry. If this is excluded and one looks only at the distribution of the own funds of companies, then the figures become: 7 per cent basic research, 29 per cent applied research and 64 per cent development; hence a ratio of 1 : 4 : 9 (figures of 1962).

47. Whether one considers one figure or the other, some conclusions are evident:

(a) Bearing in mind that basic research is the mother of applied research, the one dollar for basic research seems to be sufficient to spend several dollars on applied research.

(b) Next, development activities meant to bring the research results to the factory, are carried out at a cost level a few times higher than the cost level of the research on which it is based.

It seems important for every country and every industry to bear these ratios in mind, because deviations in both directions may cause waste of money.

Dosing research and development in relation to investment and national income

48. As far as the research efforts have been made for industry, success in gaining new knowledge and know-how will be materialized through investments.

49. Here the multiplier effect, which is evident in the follow-up from basic research to applied research and development, is also present. However, the determination of the value of this multiplier is less clear. The problem is the choice between gross and net investments. The difference between these two parameters is the effort to substitute existing investments. There is no clear relation of new technological elements to net or tare investment. In both cases, technological progress can be, or will be, introduced. The element of new technology is an essential condition for really new investments, but substitution of existing capital goods is also stimulated by the possibility of applying new techniques. Net investments are not always as new as they seem to be.

50. Anyhow, it seems to be useful to relate the yearly R&D effort in industry to gross investments as well as to net investments.

51. Table 3 gives some data. Here the R&D multiplier M_r has been introduced. M_{r_g} is equal to gross investment I_g, divided by the amount of money spent for civil R&D (= gross expenditure on R&D minus military-, space- and nuclear research). M_{r_n} is equal to net investment I_n divided by civil R&D.

52. From table 3 it appears that in the countries concerned the research multiplier varies substantially. The multiplier in relation to net investments varies from 5.7 in USA to 15.3 in Western Germany, the multiplier in relation to gross investments from 13.0 in UK to 24.7 in Western Germany. These differences are striking, and confusing too. The same is true for the share of national income that has been used for investments. Extensive studies will be needed to come to a good understanding, eventually a reappraisal of the statistical data.

53. For the purpose of this paper, the observation will do that investments in relation to research efforts are a multiple of R&D expenditure.

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54. In the examples given, generally speaking, gross investments are, as a sequence of R&D efforts, a 15-fold and net investments a 10-fold of the expenditure of R&D! For the USA the whole sequence is as follows (taking the figures of the gross national R&D expenditure):

1 dollar basic research)
2 dollars applied research) 10 dollars R&D
7 dollars development)
60 dollars net investment
140 dollars gross investment
700 dollars national income.

55. This is not more than a statistical pattern for one year. Applied to the follow-up in subsequent years, the figures diverge. In other countries, the research multiplier is higher and the multiplier indicating the ratio between national income and investments is lower.

Synthesis

56. For policy-makers, who are bound to guide the R&D efforts in a country, budgeting is the most direct way of influencing the activity. Essentially, budgeting R&D means decision-making on national resources of scientific manpower and additional personnel. This includes distribution over fields of basic research, applied research and development. If the distribution is not adequate, there will be a serious waste of scientists and money for equipment. Therefore, much attention has to be paid to a proper balance between the fields of R&D concerned.

57. Having a large number of professors engaged on basic research, without having possibilities for follow-up in applied research and further on in development, is uneconomic. Too high expenditure for all R&D facilities together, without good prospects for concerting "new knowledge" into adequate investments for industrial use, is no less a mistake. Normally, it will be possible to calculate with the help of macro-economic data, the percentage of national income to be used for investments. If a level of 10 per cent of national income is available for net investments, then it is evident that approximately 1 per cent of national income can be used for R&D.

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58. The word approximately is used not only because there are differences from country to country, but also because it is undesirable that ups and downs in the investment level as a consequence of business cycles are followed by the same ups and downs in R&D personnel. In the recommendations of the international congress at Lagos in 1964, it is stated that for R&D a 1/2 per cent of national income (= 6 per cent of total investments) ought to be made available as a target for the immediate future.

59. It was estimated that this percentage would represent 200 million dollars in 1970 for this group of forty-one African countries. From this amount, 40 million dollars were recommended to be spent on fundamental research. This is 20 per cent of the total R&D budget: a rather high figure in comparison with the figures of the USA, varying from 4 per cent (8 million dollars) to 7 per cent (14 million dollars).

60. Forty million dollars for fundamental research would lead to a fund of knowledge for which an R&D programme of 1 billion dollars could be elaborated in the future. This is in contrast with the estimation that by 1980 some 320 million dollars for R&D might be available. In comparing the poor countries with the USA, as we have done here, it is unlikely that these countries could do relatively more fundamental research in an effective way. On the contrary; experience in industry leads to the following general and important conclusion:

> The smaller the amount of money available for industrial R&D, the more it is true that development must dominate over research. Fundamental and applied research have even to be neglected, as soon as estimates make clear that money available for these activities are below the size where any serious effort can be made.

61. Of course, nobody can say what is right or wrong in any specific situation. However, I sincerely hope that my statements may have thrown some light on the necessity to focus the R&D policy of developing countries on budgeting and timing, in close connexion with the national capacity for investment and production. As in many countries only small amounts of money can be made available for R&D activities, it will be useful to look for knowledge abroad that can save time, manpower and money.

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62. Contracts for licenses can be made, arrangements for joint ventures are possible, technical assistance on a multilateral or bilateral basis can be accepted. Much development work can be done in this way with little research.

63. This trend of thought is of the utmost importance in all situations where funds for R&D are very limited, or where the appropriate facilities with respect to needed experts and equipment are too scarce. Here is a broad field for transfer of technical knowledge and know-how, in itself an attractive item for another paper. The potential profitability can be extremely high, as soon as this transfer can be made effective by establishing good personal relations between R&D people in the developed and in the developing countries.

ANNEX 1

Table 1: Average rate of development of selected technological innovations[a/]

Factors influencing the rate of technological development	mean lapsed time (years)		
	incubation period (b)	commercial development (c)	total development
TIME PERIOD			
Early twentieth century (1885-1919)	30	7	37
Post World War I (1920-1944)	16	8	24
Post World War II (1945-1964)	9	5	14

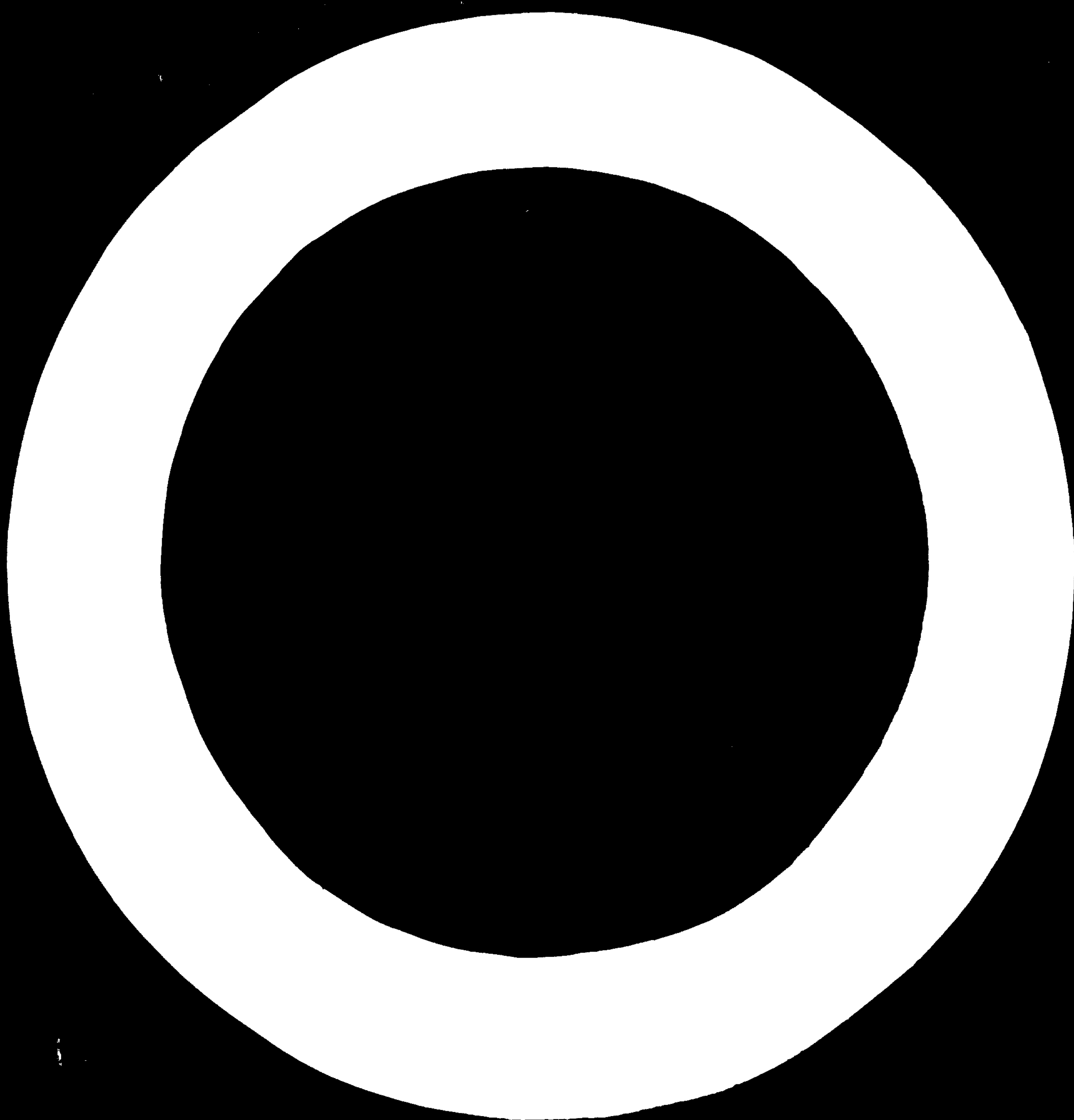
a/ based on study of 20 major innovations whose commercial development started in the period 1885-1950;

b/ incubation period: begins with basic discovery and establishment of technical feasibility, and ends when commercial development begins;

c/ commercial development: begins with recognition of commercial potential and the commitment of development funds to reach a reasonably well-defined commercial objective, and ends when the innovation is introduced as a commercial product or process.

Source: Frank Lynn:

"an investigation of the rate of development and diffusion of technology in our modern industrial society".



ANNEX 2

Table 2: Expenditure for research and development carried out by industry in the USA 1957-1965 (a)

year	basic research	applied research	development	total R&D
	in millions US dollars			
1957	271	1,670	5,790	7,731
1958	305	1,911	6,173	8,389
1959	332	1,991	7,295	9,618
1960	388	2,029	8,092	10,509
1961	407	1,977	8,525	10,908
1962	500	2,449	8,515	11,464
1963	535	2,457	9,638	12,630
1964	582	2,608	10,163	13,353
1965	607	2,673	10,918	14,197
average expenditure	436	2,196	8,345	10,977
distribution of funds in %	4 %	20 %	76 %	100 %

(a) Source: "basic research, applied research and development in industry" yearly reports edited by the National Science Foundation, Washington, D.C., USA (Surveys of science resources series).

ANNEX 3

Table 3: 'Relations between civil R&D (a) investments and national income in USA and some European countries

1964	symbol	in millions US dollars					
		USA	Western Germany	UK	France (b)	Nether-lands	Belgium (b)
civil R&D (a)	R	7,750	1,101	1,249	672	291	109
net investments	I_n	44,400	16,800	9,370	8,820	2,695	1,350
gross investments	I_g	107,300	27,200	16,250	16,000	4,220	2,710
national income	Y	513,800	79,300	72,900	60,500	13,530	10,960
R&D miltiplier on I_n	M_{r_n}	5.7	15.3	7.5	13.1	9.3	12.4
R&D multiplier on I_g	M_{r_g}	13.8	24.7	13.0	23.8	14.5	24.9
ratio of net investment to national income	$\frac{I_n}{Y}$	8.7%	21.2%	12.9%	14.6%	19.9%	12.3%
ratio of gross investment to national income	$\frac{I_g}{Y}$	20.8%	34.3%	22.3%	26.4%	31.2%	24.6%

(a) gross expenditure on R&D (GERD) minus military-, space- and nuclear research;
(b) 1963.

Source: basic data compiled from OECD and other official statistical publications in the countries concerned.

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Athens, 29 November-20 December 1967
Provisional agenda, Item 3(f)

PRACTICE OF INDUSTRIAL RESEARCH AND DEVELOPMENT

SUMMARY

Submitted by the Government of The Netherlands

* This document is a summary of a paper of the same title presented as ID/CONF.1/G.1.

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