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From the Chairman
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13th March, 1986 R15

The Rt. Hon. Margaret Thatcher, MP,
Prime Minister,
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Prime Minister (4)

You do not need to read all this. But it contains some interesting and helpful points, paving the case for Government funded applied R&D to be more industry oriented, and for research generally to be better assessed and managed. MCA IP/3

Dear Margaret

Following recent conversations on the Research Councils, I thought you might like to see the evidence which I shall give to the House of Lords next week. I am sure there is no need for you to read the whole of it but your office will be able to sideline appropriate paragraphs.

Yours ever

Douglas

FINAL PAPER FOR HOUSE OF LORDS SELECT COMMITTEE ON S & T (FOR MARCH 19 1986) SUBMISSION BY THE ECONOMIC AND SOCIAL RESEARCH COUNCIL

NOTES ON PUBLIC SUPPORT FOR SCIENCE AND TECHNOLOGY

1. Introduction

This paper uses the conventional distinction between basic, strategic and applied science, but it is important to recognise that basic and strategic science (and indeed applied science) cover a spectrum. At one end is that basic science which may never have any practical application; at the other is strategic work which will soon be applied. The first kind of science is to be likened to work in the arts, music, or sport: it gives interest and pleasure but has no commercial value, as the latter does. This paper will argue that the proportion of public funding should diminish as one moves from the former to the latter. The problem, of course, is that it is frequently impossible to tell in advance either what practical value a particular piece of research will have or how long it will be before any practical applications can be exploited. These are probabilities, not certainties.

Where a system is concerned with allocating resources, there are two ways in which it can be operated. One can use markets or one can plan. With research, applied or strategic work that seems likely to have early application will have commercial value and it will be both possible and desirable to rely on the market and give commercial concerns maximum influence over which work is done. Their prior judgements on commercial application will usually be more perceptive than those of researchers.

For basic science carried out in universities or research councils, it is impossible to use the market. Over much of the university and research council system we shall have to "plan", as now. It is therefore essential that those setting strategies

and making decisions in both the ABRC and the Research Councils, should use the most effective and up-to-date techniques available. Strategies need to be chosen and decisions taken in the best available ways. Perhaps the hardest task will be to persuade scientists - sadly even some of those who are also businessmen - that present methods simply will not do.

It must, of course, be borne in mind that there is a further obstacle to the efficient management of science when it is funded by Government. As I said in my Mond lecture of 1984:

"The problem is that while this might appear managerially efficient it would not appear constitutionally acceptable. There is a permanent and inevitable tension in a democracy between managerial efficiency and constitutional propriety. It may be that, too often, we take constitutional propriety too seriously and so spend more than we need. This is certainly an issue which needs debate, but such debate will almost always end by requiring a more elaborate organisation than a purely "managerial" solution would require. There is a price to be paid for Parliamentary accountability and democratic control. It is right that such a price should be paid. The important question is how much more we need to spend - to keep Parliament and the public happy - over and above what it would cost to achieve what a manager would regard as an efficient solution. For the price we pay - in money and in time "given" to public sector work - is high."

2. Extent

Governments in all market (OECD) economies give significant support to science and technology including expenditure on R and D activity. The share of GDP spent on R and D by the UK Government has remained reasonably constant since the mid-1970s, at about 1.3 per cent, roughly equally divided between civil and defence purposes. As Table 1 shows, this percentage in 1983 was high relative to that of other EEC countries and Japan, as a proportion of GDP. However, excluding defence R and D, UK

Government expenditure was proportionally well below that of France, FR Germany and the Netherlands, and at the same level as Belgium, Italy and Japan.

Table 1: Government Funded R and D as a Percentage of GDP, 1983

	Belgium	France	FR Germany	Italy	Japan (1981)	Nether-lands	UK
Civil	0.58	0.96	1.04	0.62	0.63	0.90	0.65
Defence	0.02	0.46	0.11	0.04	0.01	0.03	0.65
Total	0.60	1.40	1.15	0.66	0.64	0.93	1.30

Source: OECD Selected Science and Technology Indicators, 1979-1983 Paris, June 1984.

3. Objectives

These considerable expenditures, cannot be justified as "science for science's sake". If they financed a purely cultural activity, they would be much smaller. There is a clear case for some spending of this kind in the UK, but at their present level, a substantial part of these expenditures has to be justified by the contribution that they do, or are likely to make, to the achievement of Britain's economic, social and political objectives.

Deciding the appropriate level and pattern of R and D expenditure is a matter of judgement, and first of political judgement in weighing the relative importance of various objectives. In my political judgement, the most important objective against which UK Government R and D expenditures need to be assessed at present is increasing the efficiency and competitiveness of the British economy compared to the other EEC countries, North America and Japan. This is not to deny the importance of other intellectual, social and political objectives, but their achievement depends heavily on reversing Britain's relative economic decline.

For this reason, I shall here largely ignore the essential contribution of publicly funded R and D to regulatory functions (eg pollution, food and drug safety) and to the provision of what society defines as public goods (eg defence, health, urban and transport infrastructure). I shall leave them to others to discuss, and shall concentrate on the contribution of Government-funded R and D to economic performance. This is of fundamental importance, because the competitive survival of the UK - with high wages in international markets - depends crucially on the fostering and application of science and technology.

We must, however, take careful note that we really are living in an information revolution and that information and systems to handle, manipulate and transmit it are increasingly important saleable commodities. The British preoccupation which leads many of us to imply that the production of tangible goods alone represents legitimate economic activity must not blind us either to these facts or to the corollary that much research and development activity today is concerned with software, systems and consultancy - not hardware. It may not, therefore, show up adequately in the R & D statistics.

Deciding on the appropriate size and pattern of Government-funded R and D in order to improve Britain's economic performance requires judgements of a technical, economic and organisational

nature. These judgements can be informed by experience and analysis generated by practitioners and analysts over the past fifteen to twenty years (see brief bibliography at the end of this paper).

From this, it emerges that, whilst the amount of UK public support for civil R and D is low compared to some EEC countries (France, FR Germany and the Netherlands), it compares adequately with others (Belgium and Italy) and with Japan. However, the pattern and organisational structure of such support remains largely that of an imperial world power, rather than that of a medium sized European power with economic regeneration as its prime objective. We still suffer from a British Empire syndrome.

4. Basic Research and Training

Basic research and training are essential for technical problem solving in firms, and not just because basic research generates knowledge and discoveries that firms can exploit. More important, exposure to, and experience in, basic research gives the technical problem solver access to knowledge, methodology and to a network of formal and informal professional contacts outside the firm that greatly enhance its technical productivity.

The case for public support for basic research and training rests on two sets of arguments. First, British firms appear to underinvest in basic research and training, because of relatively short time horizons, risk aversion, and (most important) the fact that the responses of competitors will make it impossible for them to obtain all the potential benefits of their investment. The results of basic research are published, and trained researchers can leave a firm and take the benefits of their training to another.

Second, while the results of basic research are published, they cannot be considered as "information" available freely to anyone who wants to apply them. The results must be understood, assimilated and interpreted in the country or the firm that intends to use them. Intramural investment in basic research is necessary for both firms and countries who want to exploit the world's basic research effectively.

Whilst a general economic case can therefore be made for public support for basic research and training, it is more difficult to decide how much support should be given, and in what institutions and fields. Table 2 shows that, by international standards, UK expenditure on "advance of knowledge" as a percentage of GDP sits in the middle of the range: at the same level as Belgium, France and Japan; below FR Germany and the Netherlands; but above Italy. OECD statistics on R and D related to the "advance of knowledge" have been criticised, given the intrinsic difficulties of comparable measurement in the academic sector. For this reason, the Advisory Board of the Research Councils has recently sponsored a more detailed comparison of basic research activities in France, FR Germany, Japan, the Netherlands,UK and USA (1). This comparison will throw further light on a number of disturbing features related to the structure and pattern of basic research in the UK, to which we now turn.

Table 2: Government Funding of R and D as a proportion of GDP, 1982

(% x 100)

	Belgium	France	FR Germany	Italy	Japan (1980)	Nether-lands	UK
Industry	10.8	17.9	14.1	7.2	3.1	10.5	9.2
Agri-culture	2.9	5.6	2.3	1.6	6.4	7.6	5.2
Energy	6.1	10.2	19.0	11.6	6.6	4.6	8.1
Civil Space	3.1	6.1	4.9	3.1	3.0	3.1	2.2
Advance of Know-ledge	32.1	33.7	47.9	21.5	28.1	53.3	31.1
Defence	2.0	50.3	10.5	3.6	1.2	3.1	68.2
Public Goods Reg-ulation and other	8.5	19.3	18.9	4.8	5.0	18.8	6.8
	65.5	143.4	117.6	53.4	53.4	101.0	130.8

Source: OECD, The Objectives of Government R and D, 1974-1985 Paris, May 1983.

(a) The Structure of Basic Research

Whatever the level of public support for basic research, it should have three properties; first, an adequate part of the resultant knowledge should be relevant to industry's needs; second, it should be of high quality, if only to be able to be part of, and to monitor, international developments; third, it should be linked with higher education, because of the advantages accruing to firms through the training of post-graduates and through the stimulus which links with researchers in universities and the networks to which they belong can provide. Given these requirements, the sub-committee may wish to consider the following characteristics of present British government funding of basic research:

(1) The heavy commitment of resources to big science, and in particular to high energy physics and to space research and astronomy. I would not wish to argue that these items should receive no resources, and I am well aware that high quality research in them is exciting, fundamental and inevitably expensive. However, four specifically British factors may have combined to cause excessive concentration of resources in them:

(i) a constant or declining science budget, where interests and lobbies can be more effectively mobilised in defence of large and lumpy projects than of small and dispersed ones;

(ii) the prestige and influence of scientific communities related to these disciplines, growing out of their contributions to nuclear and defence policies, especially in the 1940s and 1950s;

(iii) the procedures for funding basic research, where the same agencies (principally SERC) are responsible both for funding their own laboratories, and for providing peer-review grants in Universities;

(iv) the high cost of research in these areas, which has led to international ventures, with subscriptions over whose size the UK has little control.

(b) In relation to (iii), there is the heavy concentration of government-funded basic research in publicly-funded laboratories rather than universities, with consequent disadvantages for education and training, and for links with application and with international research. The extent of the concentration is reflected in the fact that, aggregated for all the Research Councils, the intramural expenditures of their own laboratories are greater than those in universities. (For AFRC, MRC, NERC and SERC together they were, in total, £279.1m compared to £124.3m, in 1983/84). Government expenditure intramurally on basic research in 1983/84 was £216.6m, against total earmarked government expenditures in the universities on R and D of £152.1m. Some of this intramural research is, of course, performed in units and laboratories physically situated on, or close to, university campuses, with involvement with both post-graduate training and the relevant international scientific community (in particular, the laboratories of the AFRC and MRC). As such, they meet the requirements as defined above. Closeness does, however, need to be defined in a social, not a geographical, sense.

But other intramural research grew out of the earlier activities of the Atomic Energy Authority, with consequently few natural links with teaching and the international scientific community, but with a well developed consensus among researchers in the field about what should be done next and an ability to fight for their own corner and so obtain resources through the bureaucratic

processes of government.

(c) Evidence of relative decline in the quality of British basic science appears from trends in Britain's share of world scientific papers and citations. Table 3 shows that Britain's shares of both papers and citations declined over the whole period from 1973 to 1982. To some extent, this is a consequence of the growth of other scientific powers, and of their ability to publish in English language journals. But it has been suggested that the decline has been particularly rapid in fields relevant to economic application and reflects inadequate investment in, amongst other things, up to date instruments and laboratory equipment (see Irvine, Martin, Peacock and Turner, 1985). The decline which took place over the complete period 1973-82 seems to have been halted from 1980 to 1982: when figures for 1983 and 1984 become available later this year, they will show whether or not it has been reversed. The fact that the UK has performed worse than Japan and the USA is understandable. What is worrying is the extent to which our performance has been worse than that of France and Germany.

Table 3 See attached

5. Applied Research and Development

I shall not discuss at length the role of government in funding applied research and development, since it is a subject that the Select Committee treated at some length in its 1983 Report on Engineering R and D. Suffice it to make four points.

First, Table 2 shows that the British government's expenditures on civilian, industry-related R and D are not high by international standards. Combined government expenditures on R and D related to industry, agriculture, energy and civil space in 1982 amounted to over 0.4 per cent of GDP in France and FR Germany, and to between 0.20 and 0.25 per cent in the remaining countries, including the UK. The UK share of GDP spent on

Table 3 : Major Industrial Countries : % Changes in World Citation-Share by Field, 1973-82

Major Industrial Countries : % Changes in World Citation-Share by Field, 1973-82

	Canada	France	FRG	Japan	UK	USA	USSR	Rest of World
Biology	+13%	-2%	+13%	+32%	-4%	-5%	-45%	+6%
Biomedical Research	-9%	+10%	+48%	+83%	-28%	-4%	-6%	+3%
Chemistry	-14%	+3%	+4%	+59%	-12%	-9%	-13%	+11%
Clinical Medicine	+2%	+17%	+3%	+84%	-11%	-4%	-27%	+6%
Earth and Space Sciences	-6%	+9%	+66%	+35%	-5%	-3%	-34%	+12%
Engineering and Technology	-23%	+8%	-11%	+91%	-21%	+4%	-51%	+30%
Mathematics	-10%	+19%	+3%	+53%	-15%	-13%	+5%	+42%
Physics	-23%	+13%	+35%	+69%	-22%	-15%	-23%	+37%
All Fields Combined	-7%	+8%	+14%	+65%	-15%	-5%	-27%	+11%

Source: CHI Research /NSF "Science Literature Indicators Data Base" (copy held at SPRU)

Source: Irvine, J., et al., "British Science - An End to the Decline?", SPRU.

industry and space R and D has decreased since the mid-1970s.

Second, the economic justification for government expenditure on applied R and D for economic purposes is complicated and controversial. There is, however, general agreement that:

(i) such expenditures should complement the activities of commercial firms;

(ii) the justification for state spending on them decreases as the expenditures come closer to what firms typically do themselves, namely, development, engineering and marketing for specific products and production processes;

(iii) in so far as government does finance industry-related development, this should be performed, or at least determined, by producers and/or users of the product or process. In this context, it is hard to justify the continuing expenditure of more than £200m on development activities in relation to energy (in fact, expenditure on the fast breeder reactor) within government laboratories.

Third, Table 2 shows that defence R and D accounts for about half of British government expenditures on R and D. Three questions should be asked about it:

(i) Why are France and FR Germany able to provide effective nuclear and non-nuclear defence with a consistently small expenditure on defence R and D as a percentage of GDP (see Table 2)?

(ii) What are the effects of high levels of defence R and D on the deployment of scarce talent in science and engineering, in general; and on the strategies and

competitiveness of the British electronics industry, in particular?

(iii) Why does spending on defence R & D go on rising steadily as a proportion of the remainder of R & D?

Fourth, there has been no improvement from the unsatisfactory level of R and D activities financed by UK industry, identified by the Select Committee in its Report on Engineering R and D in the early 1980s. R and D expenditure in industry decreased in real terms between 1981 and 1983, and in 1984 Britain's share of US patenting was 36 per cent that of FR Germany, and 20 per cent that of Japan. Table 4 shows that, within Western Europe, British firms' expenditures on R and D are proportionately smaller than those of FR Germany, Switzerland and Sweden, and have grown more slowly than in all other countries since the late 1960s.

Table 4. See attached.

Table 4. Intra European Variations in Industry-Financed R&D in 1982

	SHARE % (1982)	PROPORTION OF VALUE ADDED (%) (1981)	PER CAPITA (1982)	GROWTH % PA 1967-82	DEFENCE AS A % OF GERD (1982)
W Germany	36.1	1.76	94.2	5.88	4.1
France	18.8	1.04	55.8	5.93	23.8
UK	16.5	1.31	47.3	0.90	27.4
Italy	8.9	0.60	25.3	5.52	2.9
Switzerland	5.0	n.a.	123.6	1.21	1.6
Sweden	4.9	1.85	95.6	6.13	9.6
Netherlands	4.5	1.10	50.4	1.54	1.5
Belgium	4.1	1.31	66.7	7.15	(*)
Denmark	1.0	0.72	29.9	4.56	(*)
Ireland	0.2	0.37	10.1	6.46	(*)

(*) In Belgium, Denmark and Ireland Defence R&D accounted for less than 1% of GERD.

Method: R and D expenditures and Industrial Value Added (at constant 1975 prices) converted to US dollars using 1975 purchasing power parities.

Source: As quoted in Patel, P. and Pavitt, K., "Measuring Europe's Technological Performance: Results and Prospects", SPRU, 1985.

6. Organisation and Management

The organisation of R and D raises complex management questions. It calls for the establishment of clear objectives and strategies, the making of clear choices and effective operation through the design of organisations which make the best use of money and people and through effective planning and budgeting.

The solution to such difficult questions is not helped by the fact that scientists lack training in business management and in economics, though it is discouraging to note that economists themselves show little interest in and therefore little understanding of the issues of science policy. Scientists tackle the organisation and management of science quite differently from both businessmen and economists. One result is that scientists who currently feel deprived of funds have learned how to become politically sophisticated while remaining economically inarticulate. Since too many politicians fall into the same category, there is potential for an unholy alliance which endows spending on science with too many of the characteristics of a public works programme where money is spent simply to keep people employed.

(a) Strategic Choice

The ABRC, my own research council and to judge by their Corporate Plans other Research Councils, find choice difficult. From 1945 to 1978 growing funds made choice unnecessary. Now that money is and will remain short, in the end choices do have to be made, but they are often pushed back into the budgeting process. If more money is to be spent on project X (a supercomputer say), cost benefit analysis is rarely used to make an explicit decision that a new project Y is inferior and should be rejected. Nor does the decision to go ahead with X often lead to an explicit decision to abandon a long-established project Z. Instead, when budgets are next being worked out, the decision to

proceed with X leads to aggregate bids for funds which exceed funds available. Within a research council this frequently leads, in a British way, to a proportional reduction in expenditure over a wide area rather than an explicit choice. When the decision to spend more on project X is made by the ABRC the result will be a reduction in funding for one or more Research Councils. These Councils are forced to choose what to abandon so that project X may go ahead even though, at the time when X was being chosen, no explicit decision to cut back on any particular projects was made. Indeed, those in the ABRC deciding to back increased expenditure on X might have been surprised had they realised what would be the effect of their decision.

b) Equipment and Bureaucracy

Perhaps the most worrying aspect of science - especially big science - today is that it appears to be too much equipment-driven. The fact that modern equipment makes new lines of research possible should not be allowed to bias research programmes too much in those directions.

A new manifestation of this arises from the development of super-computers, which make more pervasive a phenomenon previously confined largely to nuclear physics and to astronomy. The amount of information and analysis which even a personal computer - let alone a super-computer - now produces can overwhelm all but the most perceptive researcher.

The ultimate aim of basic science has been to produce new knowledge, which means simplification. That notion is now threatened. There is, for example, a danger of changing the concept of a "model". In the past, the role of the mathematical model was to reveal the essence of a complex situation by identifying, say, the four or five most

important variables in that problem and the relations between them. In modelling the economy, a dozen or so equations have enabled economic forecasters to produce reasonably accurate predictions for the UK economy. The human brain can then (almost) comprehend what is going on. This is impossible with the five hundred plus equations of the Treasury model.

Now, listening to experts describing the "models" which the super-computer is expected to produce in various scientific fields one wonders whether these computers do not simplify but merely reproduce that economy. Instead of providing models which give a simplified representation of reality, they attempt to replicate reality. There is therefore a serious danger that huge sums of money spent on very big computers may actually slow down the production of scientific knowledge by substituting computational power for thought, especially among researchers who are less than outstanding.

So far as spending is concerned a current example of the pressures from super-computers is the decision to divert £11m of the science budget in 1987/88 to the purchase of a second Cray computer.

As a case study of scientific politics this is excellent; as a case study of informal choice it is horrifying, the money having been committed without any clear discussion of alternatives. For example, the two Cray computers at the University Centres in London and Manchester are both used for day-to-day work; if smaller processors were installed for local work, the two computers would be freed for research.

Another worrying issue is the cost of equipment for small science, especially in universities. Whitehall now refers explicitly to the "sophistication factor" to explain why the

cost of scientific equipment is rising faster than the pay of scientists. Indices are devised showing the size of the sophistication factor, the implication being that the extra cost of equipment has to be met if British science is to be "saved".

Yet this is one area where economics has important questions to ask. It is because I doubt whether such questions are being asked or answered that I want more economic thinking to enter the making of science policy. A major concern of economics has always been choice - choice based on economic/financial factors. An economist's natural reaction when faced by the "sophistication factor" is to ask questions like: As equipment becomes more expensive is it being used for as many hours a week as possible? Is it being bought by too many universities or research laboratories? Has account been taken of what economists regard as an important phenomenon - the labour/capital ratio? An economist would naturally ask whether the fact that equipment was more expensive meant that it was being used in conjunction with fewer people. Evidence of what has happened in British universities suggests not merely that this has not been the case, but that the opposite has happened. Small science appears to be equipment-starved and manpower-driven.

Between big science and small science is bureaucratic science - carried out in Government and Research Council laboratories and driven substantially by the desire for institutional survival.

We therefore have a spectrum where at one end big science (including big computers) is equipment-driven and at the other end small science is equipment-starved. Between them bureaucratic science readily takes up what funds remain.

I therefore wish to support the line taken in the editorial in Nature on 19/26 December, 1985, which the Committee will have noted, and which questions the role (and expense) of centralised institutions like the Rutherford Appleton Laboratory.

The new Cray is likely to be located at Rutherford Appleton Laboratory, pre-empting any attempt to consider the future of the laboratory, because once it becomes a major computing centre the case for its continuing existence will be almost impossible to challenge. If £11M is to be spent, there is the case for replacing the London and Manchester computers with a single Cray XMP48 in a non-university non-laboratory site, where its use would not be influenced by local needs for computing facilities. Funds could also be set aside to purchase array processors, available to any institution.

The discussion in this section leads to two major questions. First, how can we maintain expenditure on small science (especially in universities), given competition from big and bureaucratic science? Second, how can we keep the right balance between expenditure on equipment and on people? Before concluding that the science vote must be increased to help small science, one has to consider two other possibilities. First, can better use be made of expensive equipment by concentrating its use in fewer locations? Second, is spending too high, not so much on big science, as on bureaucratic science? In particular, the Committee may wish to consider the continued existence of large research council laboratories, in particular, Rutherford Appleton. While this laboratory ostensibly exists to provide services to recipients of research grants, it spends little less than the total amount of the grants it supports.

As well as offering procedures for choice, economics

emphasises the importance of the timing of expenditures and their results. It does not make economic sense to spend money where any benefits to which it might lead cannot arise for at least a decade. Yet a rigorous study of the timing of existing research expenditures would show that some substantial outlays - for example on nuclear fusion - are of this nature and could usefully be postponed. Again, small science is being sacrificed to big.

(c) A Single Research Council

A change sometimes suggested to solve problems like those just outlined is the creation of a single Research Council on the lines of the CNRS in France. My view is that this would merely change the way in which the problems manifest themselves and, in particular, reduce their visibility. It is true that, in a single research council, the centre might have a better understanding of what was going on in the individual divisions. It would almost certainly have a greater ability to ensure the changes that were seen as desirable did happen. But those at the centre of an organisation can never know everything that is going on lower down, not least because most of us deliberately seek to deprive the centre of at least some information in order to carry on operating as we are.

Even if what was happening throughout the organisation was clear to the centre, it would not necessarily be clear to outsiders. It is in the nature of human beings, in whatever organisation, to close ranks against outsiders and the creation of a single research council would simply shift the boundaries between insiders and outsiders. Deals would still be done and compromises would still made between the centre and the divisions. But these would no longer be deals between separate Research Councils which could not previously have been done because they would have been too public and would have required the connivance of

"outsiders" (e.g. the ABRC).

What is worse the move to a single research council would hold back changes in the management of the research councils: the development of clearer research strategies, the more effective allocation of research funds and so on. The disruption caused by changes in organisation would delay the very changes in policy making and management which the advocates of a single research council suppose it would achieve. In the typically British way, we should change the organisation rather than tackle the problem. Nothing could be more counter-productive.

Putting this another way, to suggest creating a single Research Council is rather like saying that if we move round the furniture in the sitting room we shall make it warmer. But we are then so busy that we have no time to discover why the fire is going out.

Provided that Research Councils produce good Corporate Plans, the fact that they <u>are</u> separate means that what is happening in each Research Council will be reasonably transparent and open to wide public discussion. Perhaps this is the best one can hope for.

7. Conclusions

The following conclusions which emerge from the above discussion may be relevant to the Committee's deliberations.

First, we must beware of too narrow a definition of what in government-funded R and D is "strategic" for long-term economic development. The purpose of such research should be to establish a diversified, outward looking, high quality base of knowledge, skills and networks which adapts to the emergence of new research fields and supports technical problem-solvers during their

working lives. It is therefore not necessary to restrict this entirely to strategic research fields currently defined as having potential applications within ten year's time. It should cover small basic science, too. It would also be unwise to substitute tactics for strategy: in other words, the establishment of priorities within science and engineering disciplines, should not crowd out consideration of the proper allocation of resources amongst them.

Second, it should be recognised that a diversified, outward looking, high quality and flexible system of basic research and training is best established in and around universities. Laboratories funded by Research Councils and undertaking basic research (the annual expenditure of which in 1983/4 was £181.1m, compared to £124.3m in universities) should all be linked more closely to the national and international academic community, through their contributions to post graduate training and to the academic evaluation of research output. Perhaps some should be closed or, as indicated in the following paragraph, made to compete for more of the funds currently allocated to them by Research Councils.

Third, where the purpose of government laboratories is to develop specific hardware, the customer/contractor principle should apply. Thus, SERC laboratories providing special facilities for universities should be funded by university customers, rather than directly by the SERC; this would require a re-allocation of funds from the SERC laboratories to universities, but it would result in a closer matching of equipment expenditures to universities' needs. Similarly, for example, nuclear reactor development should be funded by the electricity supply industry, and the firms developing and making the equipment.

Fourth, more generally, the rule should be that basic research be done in universities and Research Council laboratories, and development in firms, when this is concerned directly with the promotion of economic development. Intramural R and D

expenditures by government should be concerned mainly with providing government with the scientific and technological competence necessary for decision-making, with regulatory functions, and with the provision of generally important applied research results.

Fifth, in any government machinery for basic research, three separate functions are essential and should remain distinct: first, the policy-making or strategic function of deciding the level and distribution of funding; second, the function of evaluation (ex ante and ex post) and dissemination and third, the function of execution. In the British system, the first function is weak, and should be strengthened, whilst the second and third are not sufficiently distinct. For these reasons the ABRC should be made more effective, in strategy setting, as well as in its monitoring and evaluation functions. The ABRC should not, as it is increasingly tending to do, seek to instruct the Research Councils on how to manage their own affairs, but should clarify its own objectives and strategy. If it is to go beyond this and make clear choices between broad research areas it will need to be constituted differently. The functions of the Research Councils in managing their own laboratories and in assessing and funding competitive research applications from others, should also be clearly separated.

Sixth, where the use of the best methods for economic assessment and/or management can increase the effectiveness of spending on science, systems should be improved and people trained to permit this. Particular attention should be paid to the balance between, big, small and bureaucratic science.

These changes should help make the system of government funded R and D more responsive to the needs of the British economy. But I must finish, unfortunately, with a note of caution. Government funded R and D inevitably plays a role which supports the technical activities of firms. If firms are unwilling or unable

to take advantage of this support, no reform can be of avail. The Committee should therefore note, with disquiet, the numerous signs of lack of technical (and marketing) dynamism in British firms: the low level and rate of growth of R and D expenditure and patenting; the heavy dependence of the electronics industry on government funded R and D, and on government orders; and so on. These are subjects to which it may have to return.

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