Public Policies for 'the Exploitable Areas of Science': A Comparison of the United Kingdom, Japan, the Netherlands and Sweden

1989
PUBLIC POLICIES FOR THE
'EXPLOITABLE AREAS OF SCIENCE'

A comparison of the United Kingdom,
Japan, the Netherlands and Sweden

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OCCASIONAL PAPER NO 9
AUGUST 1989

Australian Science and Technology Council
Canberra
The Australian Science and Technology Council (ASTEC) is a statutory authority of the Commonwealth Government. The Council is the Government's principal source of independent advice on a wide range of policies and programs related to science and technology. The fifteen members of the Council are drawn from science, industry and the trade union movement. They are supported by a full-time secretariat.

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ASTEC OCCASIONAL PAPERS


PREFACE

This paper was originally prepared in 1957 while the author was on secondment to the University of Manchester, UK. It is published now as a background contribution to ASTEC's current study of priorities and priority-setting mechanisms for science and technology in Australia.

The paper examines the mechanisms and administrative arrangements that governments have adopted for promoting the "exploitable areas of science", i.e. those areas of strategic research accorded priority by virtue of their potential national importance (usually for industrial and economic development). Such policies require closer integration of "internal" and "external" criteria in allocating scientific research resources and imply a greater interaction between the "gatekeepers" of basic research and broader policy-makers. A comparative analysis of public research policies in the United Kingdom, Japan, the Netherlands and Sweden focuses on the implications for the higher education research sector and the part played by evaluation and forecasting processes.

Recent British Government policies for the "exploitable areas of science" rectify features of the UK research infrastructure that have hampered a coordinated policy for economically exploitable research, but may be hard to implement against a background of declining public support for scientific research in the universities. In Japan, the selection and support of "exploitable areas" is determined by a largely consensual, but industry-driven planning process; the universities enjoy little formal involvement. The Netherlands and Sweden include the widest community in the determination of research priorities. Swedish policies for the "exploitable areas" are well coordinated and integrated, but a lack of national coordination is evident in the Netherlands.

Three common policy elements are identified: specific provision for strategic research; structures or institutions to fund, perform and exploit research; and national forecasting, planning or coordination mechanisms to direct or facilitate the process. The elements find expression in new high level coordination bodies; moves away from a narrow 'sectoral' approach to research; and marshalling university research through more explicit allocation of research funds, closer ties with industry, and establishment of collaborative research programs and centres in priority areas. Intercountry differences in the selection and scope of priority areas are a function of existing research and public policy infrastructures, especially the balance of the different research sectors. The role of research councils provides an illustration.

Understanding the origin of these differences allows other industrial economies to benefit from the policy development experiences of the countries studied.

In Australia, provision for research into strategic exploitable areas broadly mirrors that of the countries studied. Although the sources of research funding and performance are plural, Australia has avoided the Swedish and British over-sectorisation of research. This is in part due to CSIRO's long and predominant role in carrying out strategic research of national importance. Like the Dutch TNO, the Organization has over the past few years become more oriented towards industry's research needs, particularly those industrially-related technologies such as materials, information and communications technologies. Industry and other external sources of research funding are being actively sought to augment direct public funding. It will be necessary to ensure that increased external funding does not lead to too great an emphasis on short term applied research to the detriment of essential longer term strategic research.

The Industry Research and Development Board's Generic Technology Grants Scheme, established in 1986, provides funding for collaborative R&D in certain fields of technology of national significance for future industrial development: biotechnology, new materials, communications and information technology. Priority areas are identified within each technology, but (unlike the Japanese NGBT program or the Dutch IOPs) the grants support individual projects rather than more integrated programs of research.

The higher education sector is also being called upon to enhance its contribution to strategic research in national priority areas. Research funds are increasingly to be channelled through the Australian Research Council's competitive funding schemes, with a greater proportion flowing to program funding for Special Research Centres and Key Centres of Teaching and Research. Several of these centres are in priority "exploitable areas", such as microelectronics, software
engineering, laser applications and gene technology. However, none are of the scale of the British interdisciplinary research centres. The recent review of higher education research policy has recommended the establishment of "strategic research centres", and the government has asked the ARC and IR&D Board to consider this proposal jointly. The ARC has also nominated specific priority areas for preferential research grant funding, including materials science, cognitive science, and marine science and technology.

National planning, forecasting and coordination of strategic research priorities has not been uniform or centralised in Australia. ASTEC has played a role in generating reviews and reports on specific disciplines or research sectors: e.g. telecommunications, microelectronics, medical research and biotechnology. ASTEC and other bodies have evaluated the adequacy of particular institutional arrangements and programs. There is however no systematic evaluation of academic research directly comparable with the UK research councils' discipline reviews, or the Netherlands' exploratory commissions.

In common with the countries studied, policy coordination mechanisms in Australia have been significantly strengthened recently. The establishment of the Prime Minister's Science Council and the associated Coordination Committee of officials provides obvious forums for the discussion and selection of national priority areas for scientific and technological research. But an informed Australian debate on "exploitable areas" will require more widespread application of explicit evaluation and forecasting techniques throughout the research sector, academia and industry.

Dr Luke Georghiou, Coordinator, PREST, kindly agreed to supervise this study. I thank him for providing much of the source material and helping me structure my ideas. I also thank Dr Philip Gummett, Mr Michael Parker and Ms Lynne Thomson for their comments on my draft. I benefitted from discussion with Professors Roger Williams and Michael Gibbons; Dr John Bell, then Head of Science and Technology Policy Division, OECD, Paris; and Dr Allan Hoffman, Executive Director, Committee on Science, Engineering and Public Policy, Washington. Dr Ken Green provided me with the inspiration to undertake the M.Sc. course in the Structure and Organisation of Science and Technology. This was made possible only by a Postgraduate Study Award from the Public Service Board. I thank the Departments of Science, and Industry, Technology and Commerce, and in particular Mr Neville Hurst, for enabling me to obtain the Award and for their subsequent support.

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CHAPTER 1
RESEARCH POLICY AND THE CONCEPT OF EXPLOITABLE SCIENCE

INTRODUCTION

In July 1987, the United Kingdom Government announced its support for the creation of a Centre for Exploitation of Science and Technology (CEST) with the objective of identifying and promoting those areas of science important for the long term economic health of the country (New Scientist 1987b). The Centre is located in the Manchester Science Park. The Government was guided by the conclusions of a high level policy advisory body, the Advisory Council for Applied Research and Development (ACARD), that it would be "both feasible and desirable to create a framework for an agreed process for generating strategic exploitable science priorities" (ACARD 1986, p 10). In itself, the Centre is a relatively modest initiative with a budget of only £1 million a year. Its importance lies in the influence it will provide industry in planning basic research. Together with complementary moves towards greater selectivity, concentration and coordination in publicly funded research, CEST represents a significant redirection of Britain's fundamental scientific effort towards economic ends.

Britain is not alone in focusing public policy attention on the links between basic science, technological innovation and economic and industrial performance. Japan's industrial success in particular is a powerful exemplar in prompting all industrial nations to scrutinise their national research and innovation strategies.

The current study takes an Australian perspective on "exploitable science". Australia possesses a well developed and respected publicly supported research sector, but lacks a traditional base of research intensive and technology intensive industries. Capitalising upon existing research excellence and boosting R&D by industry are therefore seen as the most significant challenges currently facing the Australian science administrator.

Support of specific priority areas of science for social, economic or other national goals is of course not new. What is perhaps novel is the systematic approach to linking the research and productive sectors that the concept of "exploitable science" would seem to imply. If successful, the development of public policies for the "exploitable areas" of science will have wide-ranging effects on the research, technological and industrial infrastructure in both the public and private sectors. This paper sets out to examine these implications, particularly for the organisation and support of fundamental scientific research.

THE PRESSURE FOR RELEVANCE

A perception of the increasing importance of scientific and technological knowledge to international production and trade (and therefore to national economic performance) has led governments to examine more closely the interactions between the research and productive sectors. Many governments, Australia included, are seeking to restructure their economies through a process of what Rothwell and Zegveld call 'reindustrialization', i.e.

"the structural transformation of industry into higher added value, more knowledge intensive sectors and product groups, and the creation of major new technology-based industries and products serving new markets" (1985, p 20).

Implicit in this concept is the assumption that the emergence of new technological possibilities contributes to the regeneration of existing industries, and the creation of new ones based on knowledge-intensive goods and services. Certainly, Rothwell and Zegveld (1985) contend that higher added value is generally synonymous with greater technological intensity at least within manufacturing industry. But perhaps the nature of the complex relationship between technological change and industrial and commercial innovation is less important in this context than governments' belief, demonstrated by their actions, that one exists.

1
There is also a belief that a closer relationship between technology and science is emerging in certain areas, particularly in what have been termed the "generic" technologies, i.e. those with a very broad potential economic application like information technology (IT). The rise of biotechnology is often given as an example of the essential proximity of esoteric fundamental research and industrial development. In the words of Stankiewicz (1982),

"we have now entered a phase of development in which the 'forcing' programs for basic technologies are increasingly undertaken for economic strategic rather than military strategic reasons" (p 97).

Such economic concerns have led to the dual demands, (1) that publicly funded research be more "relevant" to industrial or other needs and (2) that industry make more use of, or better "exploit", the output of the research sector. To take a British example:

"What is clear is that the UK must take its own initiative to ensure that it does not fall further behind other nations in its economic exploitation of research. The competitive edge we need can come from the science base if this is properly utilised" (ACARD and ABRC 1986, p 14).

In Australia, too, a report by the Australian Science and Technology Council sees no conflict between the pursuit of excellence in research and a need for relevance to economic or social issues (ASTEC 1987). The Council considers that "the potential exploitability of the research must be an important criterion for the support of basic research" (p 16), and that more of this research should be in fields that contribute to Australia's "industrial capacity". The principal recommendation of the report (now implemented) is that an Australian Research Council (ARC) be established to promote and support research within the higher education sector.

Among the proposed objectives of the ARC are,

"to promote research which will contribute to national economic and social development; and

"to encourage interaction between the higher education sector and industry and government research sectors" (ASTEC 1987, p 6).

ASTEC notes that the ARC would be well placed to bring researchers and users of research together for the purpose of identifying research priorities and to fund these priority areas. It does not suggest specific priority setting mechanisms however.

STRATEGIC RESEARCH AND EXPLOITABLE AREAS

The research and development spectrum is commonly regarded as consisting of three distinct, but not discrete, categories:

(1) basic research, undertaken primarily to acquire new knowledge and without any particular application in view;

(2) applied research, also undertaken to acquire new knowledge, but directed towards a specific practical aim or objective; and

(3) experimental development, which draws on existing knowledge to produce or improve products and services, etc (OECD 1981 - "Frascati Manual").

Many agencies find it useful to recognise an intermediate category, termed 'strategic', that is neither basic nor applied research under the OECD definitions. For example, the Australian Bureau of Statistics regards "strategic basic research" as:

"research directed into specified broad areas in the expectation of useful discoveries. It provides the broad base of knowledge necessary for the solution of recognised practical problems" (ASTEC 1985, p 157).
A similar definition is advanced by Irvine and Martin (1984a, p 4) and more specific definitions abound (e.g. see Mason 1983, pp 13-14). In official UK statistics, strategic research is defined as:

"applied research which is in a subject area which has not yet advanced to the stage where eventual applications can be clearly specified" (Cabinet Office 1986, p 183).

The strategic component of basic research is thus excluded, leading to criticism that British Government figures understate the true "strategic" research contribution of the university sector (ABRC 1987).

"Exploitable areas of science" is a term coined by ACARD in its report of the same name published in May 1986. An exploitable area is defined as:

"One in which the body of scientific understanding supports a generic (or enabling) area of technological knowledge; a body of knowledge out of which many specific products and processes may emerge in the future" (p 11); and, "where a basis for profitable commercialisation can be anticipated within a period of ten to twenty years" (p 19).

Commercialisation here means "the transformation of scientific understanding into profitable new products and processes by UK firms" (ACARD 1986, p 19).

Thus, while "strategic research" is capable of interpretation as a relatively neutral term defined by the objectives of the researcher, "exploitable areas" is not. The process of defining "exploitable areas" must take place in the wider society; it is therefore a politically determined concept and will vary with the objectives of different societies. A more general definition of "exploitable areas" would therefore be, "areas of strategic research accorded specific priority within the national research system by virtue of their potential national importance". Even though the "generic technology" base will be identified as such a priority area by many governments, there is no reason to feel constrained by ACARD's rather narrow definition, tied as it is to "profitable commercialisation". The ACARD report acknowledges the importance of social and non-market forces in influencing research priorities but its remit is confined to economic, and more specifically commercial, potential.

POLICY QUESTIONS

The rationale for a public policy for the commercially exploitable areas of science is quite clear:

"if early identification of promising areas of strategic research is possible, then targeted support by government can increase the likely future economic and technological benefits to industry - especially if effective knowledge-transfer mechanisms exist between academic institutions and industrial enterprises" (Irvine and Martin 1984a, p 2).

But "targeted support" implies increased selectivity and funding of fundamental scientific research on the basis of "external" or "extra-scientific" objectives. The traditional view denies the feasibility of such an approach to research selectivity. Ben-David, while acknowledging that public funding of science must rest to a degree on its economic utility, contends that exploitability is simply the product of flexible organisation and imaginative enterprise:

"there is no direct relationship between specific kinds of fundamental research and the eventual application of the findings in practice ... success in exploiting science for practical purposes does not, therefore, result from the guidance of fundamental research by practical considerations but from constant entrepreneurial activity aimed at bringing to the attention of potential users whatever may be relevant for them in science, and vice versa" (1968, p 56).

Current views imply that more than simply organisational change is necessary:

"If research policy is to result in downstream innovation, there can be no question of keeping action on the scientific infrastructure separate from measures to promote the transfer of
knowledge and its application to the economic and social system as a whole" (Salomon 1985, p 89).

Irvine and Martin go so far as to contend that:

"the long-term vitality of the basic research system, and indeed its capacity to provide the knowledge and skills to help solve the pressing social and economic problems facing the world today, is dependent on the ability to support promising new areas of science" (1984b, p 77).

The main impediments they identify are an increasing rigidity in resource allocation for basic research and the lack of adequate means of linking scientific endeavour with socially determined priorities.

Two aspects of "exploitability" must be stressed. Firstly, it is of necessity selective. Secondly, it must be considered on a time-scale relevant to fundamental research. To quote the British Advisory Board for the Research Councils (ABRC),

"The argument does not imply that [Research] Councils should be doing less 'basic' research and more 'applied' research. The implication, rather, is that judgements of potential utility should play a greater part in determining the relative level of effort to be devoted to different fields of 'basic' research" (1987, p 17).

However, as Stuart Blume suggests, this provides additional challenges for the research system:

"the new era of science policy is one in which science and technology are to provide the strategic opportunities for renewed growth and national welfare. But one must recognise those opportunities, and this is by no means a familiar task" (1986, p 55).

But recognition of opportunities alone is not sufficient. Effective implementation within the research system and application outside it are consequent and crucial tasks if such opportunities are to be realised.

The advent of closer relations between the commercial and public (particularly the higher education) research sectors has been seen as heralding the "industrialisation" of the research system (OECD 1987a). This process appears far more marked in the larger industrial countries.

Too great an emphasis on new forms of research support (especially industry contracts and highly specific government grants) may create dependencies that may prejudice universities' other roles, especially their role in criticising government priorities (Taylor 1987). There is also a risk of creating division within the academic research system between those areas or researchers that produce commercially "exploitable" knowledge and those who do not. But these concerns are not new, and are perhaps more relevant to short-term applied research than to strategically exploitable areas.

An important distinction can be made between universities' indirect contribution to innovation and growth, by provision of skilled graduates and general research expertise, and their direct contribution such as consultancy and establishment of new technology based companies. Sir Bruce Williams reasons that "the indirect contribution of the universities to innovation and economic growth will continue to be much more important than their direct contributions" and "further pressures on the universities to increase the proportion of relevant research ... could be counter-productive" (1986, p 171). But "exploitable areas" fall within the "indirect" contribution under this classification. Indeed, if a policy for these areas is to be meaningful it must eschew the pressure for short-term "direct" goals.

Gibbons (1985a) denies that external pressure for utility and relevance implies a changing role for the academic research system. Rather the debate is about development of the existing system, about "mechanisms and administration rather than about fundamental values" (p 18).
AN APPROACH

It is on mechanisms and administration that this paper focuses. These include the evaluation and forecasting mechanisms that attempt to identify potentially exploitable priority areas (what Irvine and Martin (1984a) call "foresight activities"); the funding and advisory channels that ensure the implementation of research priorities; and the mechanisms that inter-relate the determination of research priorities with the wider social, industrial and commercial constituency. These issues are important not only for the higher education system but for publicly funded research in general. However the role of the higher education research system (broadly defined) is particularly important given its responsibility, in most advanced countries, for the great majority of basic scientific research performed, and much of the potentially exploitable strategic research.

In the early 1980s many countries responded by selectively promoting research in priority areas of commercial relevance, notably information technology, biotechnology and new materials. A recent analysis (OECD 1987a) suggests that France and Japan in particular have been successful in translating priorities in these areas into research output (i.e. as measured by publications). Some other OECD countries however have not; in some the published output of the "priority" fields has actually declined. The report suggests that public policy mechanisms for managing research resources in some countries may be flawed. The greatest weakness seems to lie in securing consensus about emphasis on priority areas within pluralistic public research systems.

The core of the current study is a comparative examination of mechanisms for the selection and execution of research into the "exploitable areas" of science in four OECD member countries. These countries are addressing essentially similar research policy problems against a background of widely differing scientific, socio-economic and political structures. The rationale for such an approach is suggested by Dore (1983):

"Decision-making procedures in this field are in most countries still very much a matter of trial and error. It is while they are in that state of flux that countries can learn most readily from each other" (p 2).

Since 1983 more trials and no doubt more errors have been perpetrated, but given the necessarily long time-scale involved it is still premature to declare any particular model for promoting exploitable science a success.

The countries examined are the United Kingdom, Japan, the Netherlands and Sweden. For each, the development and implementation of public policies for what may be broadly termed the "exploitable areas" of science is reviewed in the context of national structures for scientific and technological R&D. Given the lack of internationally comparable statistics on "strategic" research, the approach is primarily descriptive. Where available, budgetary figures are given to provide some indication of the relative importance of various priority programs. Clearly in a study of this length, no treatment can be comprehensive, particularly in the case of the larger countries. Attention is therefore focused on what appear the more significant policy developments and programs.

The UK developments (Chapter 2) are especially topical and have considerable relevance to Australia given its largely British-derived university research system. The "exploitable areas" debate is fuelled by Japan's high-technology based industrial success. Chapter 3 reveals the changing emphasis of Japanese public research policy. The Netherlands and Sweden (Chapters 4 and 5) are medium sized economies whose industrial strengths owe much to an intensive research base. Chapter 6 addresses the theoretical and technical problems in identifying areas of scientific research with potential for exploitation. Chapter 7 attempts to identify common policy approaches, the origin of differences, and some lessons for research policy.

It would be equally valid to examine policies for strategic research in other advanced countries, particularly the US, France and West Germany. All are covered in some detail in Irvine and Martin's "Foresight in Science" (1984a).
Related policy issues

Several related policy issues fall outside the scope of this study. The question of international cooperation in "exploitable areas" of research is important, particularly for the smaller industrial countries. While governments seek national economic advantage through investment in exploitable science there are cases where internationally collaborative research may be scientifically or politically expedient.

This is particularly so where close economic links already exist, as for example within the European Community (EC). Cooperative R&D programs are becoming more accepted within the EC, partly to counter technological dependency on the US and Japan. A strategic program of R&D in IT (ESPRIT) commenced in 1983 has provided a model for other initiatives in telecommunications (RACE), a biotechnology "action program" (BAP), and basic research in industrial technologies (BRITE) (Sharp and Shearman 1987, Arnold and Guy 1986). These activities are coordinated under the umbrella of the Framework program (EC 1987) the second phase of which (1987-91) is now under way after protracted wrangling over its content and budget, particularly on the part of the UK government. Even so, Britain is increasingly supporting EC programs like ESPRIT 2 rather than embarking on major new national initiatives. A significant feature of the EC R&D programs is the formal participation of non-member "EFTA" countries such as Sweden and Switzerland.

In the past, Australia's opportunity for participation in such international initiatives has been limited. It is likely that Australia will need to address with renewed vigour the complex question of participation in international collaborative programs of strategic research. However, these issues are not further considered here.

The long-term economic contribution of military R&D is an important policy question, particularly in the UK and US. In general, military R&D is skewed towards experimental development in support of equipment procurement (e.g. see Figure 2.1) and substantially favours particular areas like information technology. The UK government is committed to reducing the level of military R&D and increasing technological "spin-off" (UK Government 1987). Although the proportion of military R&D in Australia is relatively high (OECD 1987b), it does not approach that of the UK and US and public investment in military R&D is not seen as a pressing issue in Australia.
CHAPTER 2
"EXPLOITABLE AREAS": THE BRITISH DEBATE

There is a long history of selectivity, concentration and priority setting within the British research system. Frequently, measures have been directed towards the achievement of economic or industrial goals. The periods 1945-46 and 1962-63 in particular saw strong but largely unsuccessful attempts to link more closely the management of fundamental and industrial research (Gummett 1980). Yet it is only within the last five years or so that attention has turned to an integrated policy for what have come to be known as the "exploitable areas of science".

THE RESEARCH INFRASTRUCTURE

The science base

Public funds for university research in the UK are delivered through two main channels, the University Grants Committee (UGC) and the research councils. Together these constitute the so-called "dual support" system and both are responsible to the Secretary of State for Education and Science. The funds allocated to the research councils, along with small grants to certain other research bodies, are known formally as the "science budget". The "science budget" together with the UGC funds attributed to research and research training are sometimes called the "science base" and amounted to £1209.5 million in 1985-86, or about 55% of Government expenditure on civil R&D (Cabinet Office 1986, Table A.1). The remainder is R&D commissioned by individual departments pursuant to their official functions. A proportion of this money also finds its way into the higher education sector.

Figure 2.1, based on official statistics, shows UGC and research council support strongly oriented towards the "basic" end of the research spectrum. Government departments primarily support "specific applied" research and experimental development, but are also responsible for about 45% of all "strategic applied" research. However, the limitations of this classification of R&D activities should be noted (see Chapter 1).

The Government's strategy for sustaining the "science base" stresses four elements:

(1) greater concentration and selectivity;
(2) a closer and better working relationship with industry and commerce;
(3) more funding from private sources; and
(4) better management and value for money (House of Lords 1986, Vol II, p 580).

However, a Parliamentary review of the science budget in 1985 found that "while it remained Government policy to maintain the level of the science vote in real terms in order to protect basic science ... that objective was not in practice being achieved" (House of Lords 1986, p 19). In particular, no account had been taken of declining UGC funds and the declining proportion of research council funds available for university research. The House of Lords Select Committee also consider that "both parts of the dual support system are now inadequately funded" (House of Lords 1986, p 56).

University Grants Committee

The UGC both advises the government on the financial needs of the universities and provides the universities with general funds in the form of block grants for equipment, buildings and recurrent expenditure. The UGC contribution to scientific research is intended to provide "the basic 'floor' of research capability in university departments which is necessary if speculative
Total expenditure is £4582.1 million. R&D is categorised as basic research (B.R.), strategic applied research (ST.A.R.), specific applied research (SP.A.R.) or experimental development (E.D.). The Ministry of Defence figure for experimental development work is off-scale at £2005.8 million. Source: Cabinet Office 1986, Table A.23.

ideas are to be generated and developed to the stage where they may attract support from external sponsors" (Cabinet Office 1986, p 166). The UGC's total expenditure on research and development is estimated at £669.8 million (or 30.5% of Government civil R&D expenditure) for 1985-86 (Cabinet Office 1986, Table A.1).

UGC block funds traditionally have not been more specifically earmarked. Rather, each university has been left to allocate the funds received in accordance with its own priorities although the Committee has given assistance for specific schemes involving industry collaboration (Williams 1986). In 1981, an 8% budget cut forced the UGC to make drastic cuts (up to 44% in one case) in the allocation of funds to the universities (Booth 1984). Cuts were apportioned after an assessment of departmental quality and student and employer demand, i.e. teaching-related criteria, although account was taken of the level of research grants attracted (Gibbons and Georghiou 1986, p 54 et seq).

In 1984, however, the UGC announced their intention "to develop a more systematic and selective approach to our allocation of funds for research" (UGC 1984, p 15) and asked universities to draw up plans for their scientific activities for the Committee's examination. This approach was reflected in the 1986-87 allocation of funds which considered separately those resources based
on teaching criteria and those based on research criteria. Research resources were subdivided into four elements intended:

(1) to contribute to a basic research capacity (by providing a contribution to salaries and costs of academic and support staff) (41.5% of total research resources);

(2) to complement income from Research Councils under the dual support system, and also income from charities (14.5%);

(3) to provide an incentive for universities to increase their research income by way of contracts from other outside sources (2.0%); and

(4) to reward and encourage research which, in the informed judgement of the UGC, showed special strength or promise (41.5%) (Cabinet Office 1986, p 166).

The UGC's research evaluation methodology, and its secrecy, have been criticised (e.g. Gillett 1987). The House of Lords Select Committee recommended that the UGC's selectivity exercise should be repeated in two or three years and be more open to scrutiny (House of Lords 1986).

In April 1987 the Government announced its intention to replace the UGC with an independent statutory body, the University Funding Council (UFC) (Secretary of State for Education and Science 1987). The UFC's precise terms of reference are still under consideration, but the block grant is to be replaced by a contract system that ties expenditure to specifically agreed purposes. The UFC chairman is Lord Chilver, former Vice-Chancellor of the Cranfield Institute of Technology which is well known for its close links with industry. The Council members will be drawn from industry as well as academia. The selectivity policies of the UGC are to be further pursued by its successor. A parallel body is to be established for funding polytechnics and colleges.

The restructuring of the UGC is seen by university Vice-Chancellors as bringing them more closely under the control of the Department of Education and Science (New Scientist 1987a). Together with the selectivity exercises it has even been interpreted as signalling the collapse of the "dual support" system.

Research Councils

The other half of the "dual support" is provided by the five research councils (Table 2.1) whose functions have been summarised thus:

"The fundamental responsibilities of the Councils are the advancement of knowledge, the maintenance of the national research capability, postgraduate training and the achievement of practical benefits. The funds received through the Science Budget are used to support research in the institutes and laboratories that are within, or funded by, the Councils and to support research and teaching in the universities through research grants and postgraduate awards. In 1985-86 about 26 per cent of the Science Budget was used for research grants, 13 per cent for postgraduate awards and 34 per cent for the support of institutes and research units" (House of Lords 1986, p 18).

The total expenditure of the research councils in 1985-86 was £539.7 million, or 24.6% of total Government expenditure on civil R&D (Table 2.1). There is considerable variation between the research councils in the proportion of expenditure devoted to each function. For example, AFRC and NERC primarily support R&D in their own facilities whereas the other councils allocate a greater proportion for research grants and postgraduate awards. The SERC alone provides a substantial proportion of its funds for subscriptions to international scientific organisations (in particular, CERN)(ABRC 1983). Currently, 32% of the research councils' grant funds for university research fall under 'directed programmes' within identified priority areas (ABRC 1987).
TABLE 2.1

U.K RESEARCH COUNCIL EXPENDITURE (1985-86)

<table>
<thead>
<tr>
<th>Council</th>
<th>£ million</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science and Engineering Research Council (SERC)</td>
<td>284.5</td>
<td>52.7</td>
</tr>
<tr>
<td>Medical Research Council (MRC)</td>
<td>121.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Natural Environment Research Council (NERC)</td>
<td>65.2</td>
<td>12.1</td>
</tr>
<tr>
<td>Agricultural and Food Research Council (AFRC)</td>
<td>49.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Economic and Social Research Council (ESRC)</td>
<td>19.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

(Source: Cabinet Office 1986, Table A.1)

Science and Engineering Research Council

The SERC is by far the largest of the research councils and about 30% of its budget is disbursed as grants. SERC sees its primary function as maintaining and enhancing the research capability of the universities in all areas of pure and applied science and engineering outside those covered by the more specialised research councils. Within the Council are four Boards: Engineering, Science, Astronomy Space and Radio, and Nuclear Physics. Industry interests are represented, particularly on the Engineering Board.

The Council has adopted a policy of selectivity and concentration since the late 1960s when it attempted "to identify those subject areas of research where it was timely to give additional support with the hope that benefits in new knowledge or in social and economic matters would quickly accrue" (Williams 1986, p 146). The Council identified "priority fields" such as computer science, plasma physics, enzyme chemistry and polymers (Blume 1986, Gummett 1980). However, this policy does not appear to have led to a significantly increased concentration of grant resources in these areas (Farina and Gibbons 1979).

SERC now has a dual policy for research support. In addition to providing grants for unsolicited projects, "carefully selected areas of national technological importance" (SERC 1986, p 22) are supported by special Directorates and through "specially promoted programmes" (SPP). In 1982, for example, SERC set priorities for materials research and its Materials Committee is selectively funding worthwhile projects within certain priority areas, such as fine ceramics.

Directorates are established by the Engineering Board to provide intensive support for high priority areas over a limited period. Current Directorates promote Biotechnology, Information Technology, the Teaching Company Scheme and the Application of Computers to Manufacturing Engineering (ACME). ACME Directorate grew out of an SPP in robotics. The Directorates are seen as a "mechanism for designing and implementing research policies in areas of perceived national need" (OECD 1984, p 42) and are used where existing mechanisms provide an inadequate basis for development.

Directorates are transitory. From the outset the research program is developed with "customer" input and as it progresses the balance of funding shifts towards industry. Thus the former Directorates for Polymer Engineering and Marine Technologies are now established as limited companies and rely increasingly on support from the academic and industrial community.
With the introduction of SPPs the proportion of grant funds available outside these areas was reduced substantially. SPPs appear to cover the entire research spectrum. Current programs are in the areas of electroactive polymers, combustion engines, construction management and high speed machinery design. SERC claims that, of 19 SPPs supported since 1977, most were successful, but cautions that "even greater care [is] to be taken when starting future SPPs" (SERC 1986, p. 23). Programs are generally evaluated on the basis of peer review, adjusted to include criteria of industrial relevance (Gibbons and Georgiou 1985).

Within the Science Board also an increasing fraction of the grants provision is being directed into multidisciplinary special initiatives in strategic research" (SERC 1986, p. 26). Current programs are in low dimensional structures (semiconductors), protein engineering, chemical sensors, non-linear systems, image interpretation and invertebrate neuroscience. Initiatives are planned in the research areas of interfaces and catalysis, molecular electronics and molecular recognition (SERC 1986).

A series of schemes has encouraged cooperative research or training between universities and industry. One of the most successful is the Teaching Company Scheme, promoted jointly with the Department of Trade and Industry (DTI), which provides funds for graduate R&D within manufacturing industry. Over 200 projects are receiving support, with industry contributing about 35% of the cost.

Interdisciplinary research centres

In July 1987, SERC announced plans to set up a series of interdisciplinary research centres (IRC) to focus on potentially exploitable research areas. The centres nominated by the Engineering and Science Boards (some deriving from the Boards' existing priority fields) are:

- surface science (University of Liverpool, with funding of £10 million over six years);
- synthesis and characterisation of semiconductors and novel materials (proposed: Imperial College);
- molecular sciences (jointly with MRC) (Oxford University, £6-8 million);
- lasers in manufacturing;
- engineering design (University of Glasgow, £7 million);
- process simulation, integration and control (jointly with AFRC); and
- high-temperature superconductivity (small devices applications, Cambridge University).

Other areas are also being considered (Hall 1987, Turney 1987a, Hadlington 1988a). Superconductivity research receives priority treatment: two of the new centres will be in this area. In association with the Department of Trade and Industry, the Science and Engineering Boards are also to provide £3 million over three years for research into the theory and application of high-temperature superconductivity (Hall 1987). In addition, SERC has made £750,000 available immediately for superconductor research.

The centres are modelled on the MRC's research units, being attached to universities but largely run by the Council. Bids for the centres (the first three to open in October 1988) were sought from individual universities and polytechnics or consortia. The centres are intended to combine basic, strategic and applied research but with an "overall thrust towards application" (ABRC 1987, p. 10) and will involve close links with industry. The ABRC intends that such centres will have a lifetime of about ten years and will eventually absorb a large proportion of research councils' university grants (ABRC 1987).
Advisory Board for the Research Councils

Coordinating the research councils, but without formal executive powers, is the increasingly influential Advisory Board for the Research Councils (ABRC), established in 1972. The ABRC's terms of reference cover all research responsibilities of the Secretary of State for Education and Science and it is thus a key policy advisory body particularly for basic and strategic research. In particular, it largely determines the allocation of resources between research councils. Its members include the executive head of each Council, government department scientists and independent distinguished scientists.

ABRC has, with ACARD, been prominent in the debate over university-industry relations and exploitable areas. With the UGC and the research councils both disbursing funds on a selective basis, effective consultation is essential to ensure that the selectivity exercises proceed in harmony.

ABRC has recently taken the initiative in proposing criteria for major reform of the university research system (ABRC 1987). While arguing for increased funding of scientific research, the Board sees a need for increasing the concentration of research among universities. In particular it proposes a three tier classification: the top fifteen or so universities (designated "Type R") would perform substantial research across a wide range of fields. They would also host the research councils' interdisciplinary research centres. "Type X" universities would accommodate substantial research activity in particular fields, while "Type T" universities would lack advanced research facilities; research being limited to that ancillary to teaching functions.

At the same time, UGC/research council subject review committees have taken a similar approach. The first of these was the Oxburgh Committee on Earth Sciences which recommended three levels of department, concentrating the major research facilities in departments designated as equipment centres. The UGC now proposes to classify university Earth Science departments into three types, with differing provision for research, although its classification is more flexible than that proposed by Oxburgh (Hadlington 1988b).

DEPARTMENTAL RESEARCH

The third source of public research funds is the individual government departments (including the UK Atomic Energy Authority, UKAEA). By far the largest spender is the Ministry of Defence, but in the "civil" domain the most significant are the DTI, UKAEA and the Ministry of Agriculture, Fisheries and Food (Cabinet Office 1986). As Figure 2.1 shows, the departments' research activities are oriented towards applied research and experimental development.

Since the implementation of the "Rothschild Report" (Rothschild 1971) in 1972 there has existed a "sharp distinction between curiosity-motivated and mission-oriented research for administrative purposes" (Ashworth 1984, p 26). Departmental R&D has generally adopted the "customer and contractor" approach, i.e. departments commission research from government laboratories (either under the aegis of individual departments or the research councils), through the research councils to the higher education research sector, or to industry. Not all departments have found these arrangements satisfactory. In 1981, "commission" funds for health research were returned, through the science vote, to MRC control (Mason 1983).

The problem is that applied short-term research tends to be both more specifiable and more urgent than, and be pursued to the detriment of, longer-term strategic research. A government official acknowledges that such research "falls awkwardly between the interest of both research councils and departments" (Courtney 1984, p 38). The coordination problems inherent in such a sectoral system can also lead to the neglect of often multidisciplinary strategic research.

Department of Trade and Industry

The DTI has prime responsibility for technology and innovation policies and specific industrial R&D and technology awareness programs. Within DTI, the Technology Requirements Board provides advice to Ministers and to the Department's divisions on S&T policies and on priorities.
between sectors and technologies. The Board comprises leading industrialists as well as the heads of the ABRC and SERC and is supported by sixteen advisory committees. One aim of setting up the Board in 1985 (replacing sectoral Research Requirements Boards) was to focus on collaborative ventures and generic technologies (House of Lords 1986). The House of Lords Select Committee criticised the level of DTI support for industrial R&D and the Board has recently recommended a doubling of the department's R&D expenditure over three or four years (Fagan 1987). Universities receive less than 1% of the DTI's R&D budget (only £2.2 million in 1981-82) (Gibbons and Georghiou 1985).

DTI's first pre-competitive, collaborative R&D program was the Joint Optoelectronics Research Scheme, dating from 1982, which supported over 20 university/industry cooperative projects.

DTI's LINK scheme, launched in December 1986, has the aim of "fostering of strategic areas of scientific research directed towards the development of innovative products, processes and services by industry" (UK Government 1987, p 5). The scheme subsidises half the cost of collaborative research programs between the public research sector and industry (who pay the other half) and is expected to cost £210 million of public money over five years. Some of these funds (£25 million by 1991-92) will come from the Science Budget (through research councils) and the rest from government departments, most from DTI.

The first five programs under the scheme, announced in February 1988 (DTI 1988), are:

- molecular electronics (£20 million);
- advanced semiconductor materials (£24 million);
- industrial measurement systems (£22 million);
- eukaryotic genetic engineering (£4.7 million); and
- nanotechnology (£12 million).

The SERC is participating in all but the last of these programs. A LINK Steering Committee, comprising representatives of Government departments, research councils and the higher education sector, has been formed.

The Alvey program for IT

The Alvey program, established in 1983, marks a significant departure in UK Government support for R&D and innovation both in terms of its scale of funding and the extent of collaboration. Alvey is a cooperative program of pre-competitive research in the enabling technologies of IT, involving both industrial and academic research sectors (Arnold and Guy 1986). The scheme aims to build up technological strengths in specific targeted priority areas. About 260 projects are being funded including "demonstration" projects. Government funding (£350 million over five years) derives from DTI and the Ministry of Defence (£150 million each) and SERC. Where industry is involved in a project it is expected to contribute 50% of the funding. University based projects are funded in full through SERC.

Alvey is a "directed" research program, in that the Director has full power to commit funds, but has generally operated on a "research proposal" basis. Strategies have been published for each of the four broad areas to be covered (intelligent knowledge-based systems (IKBS); man-machine interface; software engineering; and VLSI and computing architecture). Project selection procedures have varied with the topic. In the academically-based IKBS area selection was largely by peer review, whereas the Ministry of Defence-administered VLSI projects were chosen by government committee (L. Georghiou, pers. comm.).

The Alvey approach has not met favour in other potentially exploitable areas. The report of the Materials Advisory Group ("Collyear Report") (Department of Trade and Industry 1985) identified a substantial British corpus of expertise on new materials but saw little effort to translate research findings into industrial products. The Collyear Report identified four classes
of material (including engineering ceramics) and three enabling technologies of crucial significance for the future of UK industry. Collyear concluded that any effective national program to promote R&D into new materials, the processes of their production and their industrial application required the participation and resources of both Government, academia and industry. The Group recommended an ambitious five year collaborative program at a cost of £120 million to develop new materials. However, the suggested mechanisms were somewhat ill-defined and, more importantly, the Government appeared unconvinced about the necessity for the level of public expenditure recommended.

THE DEVELOPMENT OF POLICY FOR THE "EXPLOITABLE AREAS"

The debate about policies for the "exploitable areas" appears centred around three main concerns: greater "relevance" for university research, funding arrangements for strategic research, and coordination mechanisms. The "Annual Review" process (Cabinet Office 1986) has helped to focus attention on weaknesses in priority setting. There is considerable policy interest too in the form of links between academic and industrial R&D.

Of fundamental research in the higher education sector an ACARD report prepared in collaboration with the ABRC remarks:

"it must be admitted that some work may be of less urgency, importance or even interest. Such work, together with an increasing teaching load, has pre-empted resources which might otherwise have been devoted to areas of research which are both academically worthwhile and have industrial relevance" (ACARD 1983, p 7-8).

The report went on to recommend the establishment of a fund to support the infrastructure and basic research needed to complement industrial applied research. The Government was asked to provide to the universities and polytechnics an amount equivalent to 25% of their earnings from the commercial sector. The report also called for greater collaboration between DTI and SERC in supporting such research.

The question of funding mechanisms for "exploitable" research also arises in the 1980 report on biotechnology by ACARD, ABRC and the Royal Society (ACARD 1980):

"Strategic applied research is, in general, ill-served by our research funding mechanisms and the way they are being applied, especially in areas where there are neither established university departments to promote it, nor well-developed industries to provide market pull".

In 1981 the House of Lords Select Committee on Science and Technology raised concern that too rigid a distinction between basic and applied research was leading to the neglect of important areas of research. In response the Government asked ACARD and ABRC to address these issues especially in the context of long-term, directed research (Mason 1983). In a report to the ABRC, Sir Ronald Mason concluded that:

"strategic research, which should be integral to [departmental] commissions, is not adequately covered; it is being increasingly supported from the Science Vote, with a consequent reduction in funds available for basic studies; the links between basic, strategic and applied science are not being properly reviewed" (Mason 1983, p 10).

The ACARD report "Exploitable Areas of Science"

The ACARD report "Exploitable Areas of Science", released in May 1986, emphasised the crucial importance of exploitable areas of science and technology to Britain's industrial and economic development. The report asserts that "economic and social factors have been given less weight
in the formulation of science policy than is justified" (p 16). Its prime focus however was on the lack of appropriate information or even of a forum to address the choices that needed to be made:

"a process is needed to prioritise and guide a substantial proportion of that part of the national scientific resource be it Research Councils, Ministry of Defence or Department of Trade and Industry, and to stimulate its effective exploitation to the benefit of the United Kingdom" (ACARD 1986, p 9).

The report therefore recommends that such a process should be established with some certainty of continuity; the broad objective being "to seek to organise science in such a way that it leads naturally to exploited technology" (p 23). The need to draw upon international research is also acknowledged.

"Four key elements in the process" are identified (ACARD 1986, p 42):

(a) the gathering of information on a continuing and permanent basis and its communication to the relevant parties and bodies;

(b) the evaluation of relevant opinions and information, and the identification of exploitable scientific areas;

(c) the allocation of resources to the priority areas in science;

(d) the commitment to exploit the results of science to UK benefit.

However ACARD does not see any necessity for new science funding mechanisms. Rather it envisages "a more pluralistic approach to science funding, flexibility should be built into funding mechanisms to allow research programmes to be built up and ended as appropriate" (p 43).

ACARD commissioned a consultants' study (Segal Quince Wicksteed 1987) to suggest ways to give practical effect to the report. The core of the consultants' recommendations is the proposal for a Centre for Exploitation of Science and Technology.

ACARD's principal recommendations receive strong support from the House of Lords Select Committee (House of Lords 1986). The Select Committee also sees a four element process for exploitable areas: substantial input from the research councils; industrial and commercial influence to match; avoidance of insularity; and rigorous evaluation of the outcome of decisions. The aim, they propose, must be "to generate the soundest possible agreement on forecasts, to turn this into a set of research commitments, and to exploit the results as they emerge" (p 51). The process should answer directly to a proposed new Council on Science and Technology.

The issue of resources for exploitable research itself (rather than simply for the "process") is crucial. With declining resources, existing channels of research funding appear to be becoming more rigid, not more flexible. Thus while research councils, UGC and Government departments all fund strategic research, in fact an increasing amount is supported from the science budget. The Select Committee differs from ACARD in recommending that:

"In addition to the dual support system and the customer/contractor principle, a third method of public funding of R&D is required.

"To this end a process should be introduced for funding that strategic research which is of most significance to the United Kingdom's economic future. The Research Councils and Government Departments, as proxy customers in non-commercial fields, should retain their responsibility for some strategic research" (House of Lords 1986, pp 64-65).

Plurality of funding would be retained and "some funds from the Science Budget and commissions from government departments and industry would support work in the exploitable areas of science" (House of Lords 1986, p 51). However the Select Committee sees no alternative but to leave the responsibility for "non-commercial" strategic research with individual departments.
COORDINATION OF STRATEGIC RESEARCH

Given the decentralised British research system and the plurality of funding and performance, particularly for strategic research, the forms of coordination assume great importance. The role of the ABRC has been mentioned. Until recently the other main coordinating body has been ACARD, providing advice on applied R&D, its application, and its coordination with basic research.

Advisory Council on Science and Technology

In response to recommendations of the House of Lords Select Committee, the Government decided in July 1987 to replace ACARD with a body enjoying a wider membership and terms of reference. The new Advisory Council on Science and Technology (ACOST) reports to the Prime Minister and is responsible for providing advice to the Government on:

- "the priorities for science and technology in the United Kingdom;"
- the application of science and technology, developed in the United Kingdom and elsewhere, for the benefit of both the public and private sectors in accordance with national needs;"the co-ordination, in collaboration with Departmental Advisory Bodies [this includes ABRC], of science and technology activities; and"
- the nature and extent of United Kingdom participation in international collaboration in science and technology" (UK Government 1987, p 3).

The response also obliquely announces the strengthening of the Cabinet committee on science and technology, now to be chaired by the Prime Minister rather than by the Secretary of State for Trade and Industry (Turney 1987a). The existing Committee of Departmental Chief Scientists is enlarged to reflect wider responsibilities "including the Government's economic objectives for science and technology" (UK Government 1987, p 3). The Science and Technology Assessment Office, set up in the Cabinet Office in July 1986, is given explicit responsibility for "ensuring that all bodies involved in public R&D have regard to the economic impact and commercial exploitation of the work supported as well as other national benefits" (UK Government 1987, p 4).

Centre for Exploitation of Science and Technology

As mentioned in Chapter 1, the Government is also contributing to the establishment of the Centre for Exploitation of Science and Technology (CEST) as an independent focal point for the identification of "exploitable areas". The role of CEST appears limited to monitoring and, perhaps, raising awareness of, potentially "exploitable" science and technologies. The Centre will take an "industry pull" approach to exploitable areas of science, identifying strategic industrial sectors and examining which areas of S&T are needed to underpin them. Its staff will include economists and market analysts as well as scientists.

While CEST has no formal links with existing government R&D or policy bodies it is expected to develop a close relationship with ACOST. The Centre will be primarily led and funded by industry and business and thus has the potential to become an important "extra-bureaucratic" source of policy advice.

The Government appears to have rejected the House of Lords Select Committee's proposal for a substantial new source of funding for some strategic "exploitable areas" research.
CONCLUSIONS

While it is too soon to assess the likely impact of ACOST, the new coordination measures and CEST on strategic research and the exploitable areas, they clearly have the potential to propel the national research effort forcefully in this direction. Given the support of the ABRC, ACOST will have significant influence over "science budget" funds especially as the new UFC appears less powerful and more industrially oriented than its predecessor. The success of CEST will depend on the level of support and respect it manages to engender within, and influence it exerts upon, the public and private sector research communities.

The new arrangements go some way to rectifying features of the UK public research infrastructure that have hampered a coordinated policy for economically exploitable research. They do less for strategic research that may be nationally and socially useful in other ways. The ultimate success of these arrangements may be determined by whether they can be implemented effectively against a background of declining public support for basic scientific research, particularly in the higher education sector.
CHAPTER 3

INTERCOUNTRY COMPARISONS: JAPAN

Japan is challenging the US as the most R&D-intensive nation in the world. The national GERD of ¥8116 billion in 1985-86 represents about 2.6% of GDP, approaching the same proportion as the US and, in absolute terms, a similar level of expenditure to the USSR (BCCJ 1987, STA 1986). In the long term, Japan expects to increase R&D expenditure to 3.3% of GDP (CST 1984). In terms of "civil" R&D, 2.35% of GDP (OECD adjusted figure) in 1983, Japan is bettered only by West Germany (OECD 1987b). Industry and business funds perform by far the greater part of Japanese R&D while government funded R&D amounts to less than 20% of the total. Industry expenditure is predominantly applied research and experimental development, but basic research expenditure by industry has doubled in absolute terms since 1980 and now represents perhaps 35% of the national total (OECD 1987a).

Public funding of S&T (¥1525.3 billion in 1985-86) (STA 1986) is channelled through three main agencies: the Ministry of Education, Science and Culture ("Monbusho") (accounting for 47% of the national S&T budget in 1986), the Science and Technology Agency (STA) (27%) and the Ministry for International Trade and Industry (MITI) (13%) (BCCJ 1987). Although very little public funding directly subsidises research in private industry, it is estimated that 60-65% is aimed indirectly at improving industrial performance in the near and medium term (BCCJ 1987).

Since the early 1980s, the Japanese Government has developed a variety of programs to promote strategic research having potential for industrial application. In recent years, policy attention has turned also to the need to strengthen the infrastructure for "creative" basic research, seen as underpinning Japan's future economic and social development (CST 1984).

THE UNIVERSITY SECTOR

According to OECD (adjusted) figures, nearly 44% of government funded R&D in Japan was performed in the higher education sector in 1983 (OECD 1987b). However, government support of HERD declined by 2.4% between 1981-85, even though total government funded R&D increased by 10.6% over the same period. Nevertheless, expenditure on HERD (0.38% of GDP in 1985) is on a par with the US, and well above the UK, for example (OECD 1987/b). The higher education sector thus supplies about 16% of the national R&D effort.

Scientific research in the Japanese higher education sector is generally confined to the larger national universities. Monbusho is almost solely responsible for the provision of university research funds which amounted to $US2855 million (official figures) in 1985-86, or $US769 million for the national universities, excluding salaries and equipment (OECD 1985). A form of "dual support" system is operated, although special funds for facilities and equipment are also available to national universities. By far the largest component is the general funds for departments or research teams, determined on a standard basis taking into account the number of researchers and the nature of the research. General funds accounted for about 65% of government funded academic research in the natural sciences and engineering in 1982 (Martin and Irvine 1986) (see Figure A.2).

Basic research in the universities is also assisted by the "scientific research expenses subsidy" from the Japan Society for the Promotion of Science amounting to $US270 million in 1986 (Shimomura 1986).

Associated with the national universities are eleven academic research institutes such as those for Solid State Physics (Tokyo University), Mathematical Sciences (Kyoto) and Protein Research (Osaka). Institutes have also been established independently of a particular university for "joint use" by visiting researchers. Current policy is for new or reorganised institutes to become "joint use" as far as possible (OECD 1985). In general the institutes enjoy better funding and facilities than the universities (Anderson 1984).
The Science Council

Direct grants for research projects are disbursed through the Science Council, a body of academics and scientists appointed by Monbusho. Grants (totalling $US168 million in 1985–86) are awarded on the basis of recommendations by the Council's Review Committee on Grants in Aid or its specialist subcommittees of university professors, i.e. straight "peer review". In addition to general research grants (about 35% of the total), special awards are made for outstanding research and for research meeting strong scientific and social needs. These may be recurrent grants (e.g. those for cancer, natural disaster, environmental science and energy research) or for fixed, three-year terms (Anderson 1984), although the Council is planning to amalgamate the two schemes into a "priority area research" program (OECD 1985). It is admitted that, "at the final decision, human qualities such as reliability are considered as important factors of evaluation" (OECD 1985, p 12).

It is not clear how socio-economic priorities are taken into consideration within Monbusho and the Science Council. For especially significant programs, following advice from the Science Council, the Ministry consults with the Council for Science and Technology (see below) and other bodies. Funding priorities are determined within the framework of the national budget (OECD 1985).

The Science Council also maintains or supports a number of large research facilities, mainly "big science" but also including institutes for molecular biology, for example. The institute and national university research staff are regarded as Monbusho employees and, rather surprisingly, collaboration with industry is discouraged. Universities tend to join already established government/industry research programs rather than initiating independent programs (OECD 1984).

Although a relatively high proportion of university research may be categorised as applied research or even development (BCCJ 1987), direct financial support from industry is small.

Japanese companies' funding of US universities runs at perhaps $US250 million a year (not all for research), nearly twice as much as given to their own country's higher education sector. Indeed it has been estimated that "Japanese firms spend more in US universities than the university sector gets from [Monbusho] for special projects" (BCCJ 1987, p 3). For example, Japanese firms support basic research in cell biology and immunology at the Massachusetts Institute of Technology and also sponsor professorial chairs (OECD 1987a).

SCIENCE AND TECHNOLOGY AGENCY

The Science and Technology Agency (STA) has general responsibility, through the Minister for Science and Technology and the Prime Minister's Office, for national S&T research planning and coordination outside the university sector (i.e. primarily among other ministries and agencies). The Agency supervises most of the large national institutes and public corporations carrying out scientific activity, such as those for space and atomic energy. These two sectors absorbed 85% of STA's budget of ¥420 billion in 1985-86 (BCCJ 1987).

One such body is the Research and Development Corporation of Japan (JRDC) which administers the 'Program for Exploratory Research for Advanced Technology' (ERATO), an STA initiative started in 1981. The ERATO program's goal is to support fixed-term projects of basic research in interdisciplinary areas important to new technology. It is also seen as a vehicle for developing improved links between universities, research institutes and industry. The estimated budget for 1987 is ¥8 billion (Irvine and Martin 1984a).
Projects are selected on the basis of consultations with industry and through the STA's forecasting consultations. By 1983, projects had commenced or were planned in six areas of research:

- Ultra-fine particles (for electronics and life sciences applications);
- Amorphous and laminar materials;
- Fine polymers;
- Perfect crystals (for semiconductor purposes);
- "Bioholonics" (aggregation mechanisms of living organisms applied to engineering problems); and
- Bioinformation transfer.

Irvine and Martin suggest that the ERATO initiative was taken because of STA's view that Monbusho, "would have been unable to identify this research need or to target the necessary resources. Rather than wait for the basic-science community and the associated research-funding agency to come to terms with the task of identifying and supporting promising areas of science ... the Japanese have taken early and decisive action" (1984a, p 116-7).

Drawing on the experience of the ERATO program, the "Frontier Research Programs" sponsored by the Institute of Physical and Chemical Research (RIKEN), a further public research corporation responsible to STA, commenced in October 1986 (Shimomura 1986). With a budget of $US7 million for the first year this program supports basic research projects in the areas of "bio-homeostasis" (e.g. the ageing process) and materials research, including non-linear optical and bioelectronic materials. The biological projects clearly parallel MITI's much larger "Human Frontier" program.

Long-term forecasting

The STA is renowned for its long-term (thirty-year) science and technology forecasts, produced every five years or so. A two stage "Delphi" procedure is used, with the participation of industry, government bodies, and the universities and research institutes. The STA's approach is described in detail by Irvine and Martin (1984a, p 107 et seq.). Forecasting is based on four principles: future economic and social needs are considered as well as potential scientific and technological developments; all areas of S&T must be covered; the relative importance of research tasks, and therefore priorities, must be established; and the forecasts must be at the same time predictive and set objectives and time frames for their realisation. These aspects are discussed further in Chapter 6.

While the STA forecasts do not directly determine public sector R&D priorities, Irvine and Martin suggest that they do form a useful input to this process. The forecasting process forces researchers and policy-makers in all sectors to consider systematically future developments and provides a summary of current and planned S&T activities. In particular, the forecasts are an important guide to the intentions of the industrial research community (not least to other members of that community). On the negative side, the consensual nature of the forecasts may tend towards conservatism and lead to excessive competition in rather narrow fields commonly regarded as significant.

MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY

Responsibility for promoting industrial R&D lies with MITI, usually through the Agency of Industrial Science and Technology (AIST) which also administers the Ministry's research institutes. Of MITI's R&D budget (¥224.4 billion in 1983-84) about 20% is taken up by the institutes, 42% supports contract research, mainly in industrial laboratories, and subsidies for
industrial research account for a further 21% (Dore 1983). AIST's budget was ¥119 billion in 1982 (Anderson 1984). Since the late 1970s, MITI has become increasingly involved in programs of basic and strategic research, reflecting national concerns to strengthen the research base for long-term technological development.

Next Generation Base Technologies Development Program

The Next Generation Base Technologies Development Program (NGBT), commenced in 1981, is perhaps AIST's most significant foray into strategic research. Even though they account for only about 2% of MITI's R&D expenditure, program funds (¥1.28 billion in 1986) (OECD 1987b) have been used to catalyse a great deal of private sector research.

| TABLE 3.1 |
| THE NEXT GENERATION BASE TECHNOLOGY DEVELOPMENT PROGRAM IN JAPAN |

NEW MATERIALS

- Fine ceramics
- High efficiency separation membranes
- Conductive polymers (i.e. synthetic metals)
- Highly crystalline polymers (high performance plastics)
- High grade alloys with controlled crystalline structure
- Composite materials
- Photo-reactive materials

BIOTECHNOLOGY

- Bioreactors
- Large scale stable cell cultivation
- Recombinant gene engineering
- Bio-elements (the so-called "biochip")

ELECTRONIC DEVICES

- Super-lattice elements (atomic-scale devices)
- Three dimensional integrated circuits (ultra-large scale integration)
- Integrated circuits fortified for extreme conditions

The goal of the ten-year program is to promote cooperative strategic research into generic (or "base") technologies, i.e. those likely to have wide application in the 1990s. The priority fields chosen for support are shown in Table 3.1.

In order to execute and coordinate research in the priority areas (each of which has quite specific objectives) five ad hoc Research Associations were established covering fine ceramics, polymers, metal materials, electronic devices and biotechnology respectively. Each sub-program has an evaluation committee including academic representatives. The AIST commissions the research, either directly or through the Associations, and retains the patent rights. In addition, firms involved undertake not to patent in any area covered by the program. By 1983, 28 government laboratories, 80 private firms and 13 universities were involved in the program (Dore 1983). Other universities act as subcontractors to private companies.

Professor Dore's paper provides an insight into the evolution of the NGBT program and the priority setting process involved. An AIST working party (comprising academics, government scientists and industrialists), established in 1977 to formulate a long term plan for the development of industrial technology, was influential in identifying technological "seeds" (such as miniaturisation) and socio-economic 'needs' including, for example, energy supply and disaster prevention. These concepts were also encapsulated in the "Vision for the 1980s" one of the periodic forecasting documents produced by MITI's influential Industrial Structure Council, a statutory body.

Against this background the AIST proposed the NGBT program in March 1980. The rationales for such a government initiative included the long lead time anticipated before application and thus the high degree of commercial risk, and the potentially broad application of the technologies. Questionnaires were immediately sent to 200 firms to gauge the business sectors' priorities for basic research, and extensive canvassing took place with research institutes, private firms and industry R&D consortia. As examples, a questionnaire on biotechnology priorities was sent to the Fermentation Industries Association; and the electronic devices proposals circulated to the research directors of the seven largest companies in the field and to the head of a leading university semiconductor laboratory. Surveys of international research were also used to identify where Japan "lagged", e.g. in certain areas of biotechnology.

Irvine and Martin emphasise the crucial role of the industry associations in this process:

"while formally it may appear that strategic research priorities are determined by the interplay between MITI... and industry, in practice they are usually 'prepared' beforehand by informal working groups attached to the main industrial trade associations... The views put forward to MITI represent the consensus among the leading firms in each industrial sector on the long-term basic technologies in which they wish to become involved" (1984a, p 173).

Certainly, as Dore notes:

"There was no clear attempt to separate out questions of technological feasibility from questions of application and demand because these considerations were already married and traded off against each other when private firms set their own priorities" (1983, p 22).

Significantly, although the STA was also working on a program for promoting basic science (which led to ERATO), there was no direct coordination until both programs were virtually established.

The New Generation Computing Project

The well known and much larger "Fifth Generation" computer project represents an alternative approach to long-term promotion of strategic research. The project, managed directly by MITI rather than through AIST, will have a total budget of between ¥45 and ¥100 billion over ten years (Arnold and Guy 1986), the majority government funds. The centre-piece of the project is the Institute for New Generation Computer Technology (ICOT) set up in 1982. ICOT employs about fifty researchers, all seconded from industry and much work is contracted to industry also. Although the project has no specific commercial goals it appears more oriented towards medium
term outputs than is the NGBT program. Arnold and Guy (1986) suggest that attainment of the objectives of the project is perhaps less significant to Japan than the experience to be gained in artificial intelligence research and application.

The Human Frontier Science Program

MITI also carries prime responsibility for the development of an ambitious proposal for a 20 year internationally collaborative program of basic research into biological processes, the 'Human Frontier' science program. The program is estimated to cost in the order of ¥1000 billion, of which Japan would meet half. The Human Frontier is described as a world scale program of "very fundamental" basic research (AIST 1986, p 2), "focusing on applications for biological functions" (p 6). So, from the outset, the program is presented as a long-term technological solution to a wide range of socio-economic problems such as depletion of energy and other natural resources, environmental pollution and population growth and structure. The AIST acknowledges that Human Frontier,

"will promote not only the basic research and the development of fundamental technology ... but also international collaboration" (AIST 1986, p 7).

Even at this early stage, the proposed research program has been mapped out in some detail by AIST. Two streams of research are evident, the first concerning energy transfer within living organisms, and the second organic information processing mechanisms. While these are certainly basic research fields, the clear goal of the program is to exploit the knowledge of these biological functions in production processes. The energy cycle of the living cell will be engineered in vitro to produce "biomotors"; low-energy, pollution-free industrial processes will be developed on the basis of artificial membranes and "super-enzymes"; and "the human brain function will be explicated for application to the computer" (AIST 1986, p 14). Other specific goals include the prevention of the deterioration of metabolic functions due to ageing and the utilisation of nitrogen-fixing bacteria in industrial chemistry.

The genesis of the Human Frontier program is also significant. Following initial studies by AIST and support from the Industrial Structure Council, the program was approved by the Council for Science and Technology in May 1986, apparently with strong backing from the Prime Minister. MITI was instructed to promote the program, and only then was an interdepartmental conference convened with MITI, STA, Monbusho and other interested ministries and agencies.

A feasibility study committee of scientists from the national institutes, universities, industrial associations, companies and public corporations is established. International scientists will also be involved. Feasibility and related studies are planned for 1987-88 with a budget of ¥200 million. The program proper is planned to begin in the following financial year under a Centre for the Promotion of the Human Frontier Science Program.

COORDINATION OF POLICIES FOR STRATEGIC RESEARCH

Council for Science and Technology

The Council for Science and Technology (CST) within the Prime Minister's Office and under his chairmanship is nominally the prime policy making body for integration of research throughout the government sector. Since 1981 it has also provided "coordination funds" (totaling ¥6 billion in 1982) for cooperative research projects involving institutes, universities and industry. Special priority fields identified for the period 1982-84 (Anderson 1984) were:

- DNA extraction, analysis and synthesis;
- Safety of recombinant DNA techniques;
- Application of recombinant DNA technologies (e.g. vaccines);
- Biomembranes;
. Cultivation of experimental animals;
. Large super high-pressure generation systems;
. Superconductivity and cryogenics;
. Surface and boundary control technologies for high-performance materials; and

The "coordination funds" also support internationally cooperative research and surveys of international scientific activities.

A 1984 report acknowledges that "Japan is still somewhat behind in the fields of fundamental or basic research ... as well as in its supporting activities and infrastructures" (CST 1984, p 11). The Council proposes increased interdisciplinary and intersectoral cooperation, greater emphasis on evaluation of research, and a strengthening of CST's planning and coordination functions, particularly in the selection of priority research areas. This does seem to have happened in the case of the "Human Frontier" program.

Even so, the observer of the Japanese scientific infrastructure is immediately struck by the multiplicity of priority funding schemes for what are clearly "exploitable areas" of science and technology. Their similar emphases may arise through the process of "tapping the consensus" produced through industry forecasts, the work of the influential "think tanks", STA forecasts and MITI "Visions". However, although the fulfilment of social needs is well covered in such forecasts, these goals appear to find lesser expression in the concrete research programs.

The lack of formal coordination across the "vertical" sectors of Japanese government concerned with R&D (e.g. higher education or industry) appears surprising. As Dore remarks, "there is one large gap in these consensus procedures, however, and that is in the limited amount of contact MITI has with the university world" (1983, p 25). Whereas individual academics are involved in the consultative process through their membership of "think tanks" or industry associations, Monbusho and its Science Council appear to have little direct say in national policy. Interministry rivalry between Monbusho and the more prestigious MITI has produced the policy of "non-additionality". If a university or department receives a MITI research grant or contract, its Monbusho funds are reduced accordingly (Dore 1983). Coordination between MITI and STA also appears weak.

CONCLUSIONS

University research accounts for over one-third of the public expenditure on R&D in Japan. Yet a large proportion of university research is financed by general funds. Neither these funds nor the relatively small proportion of direct grant funds are allocated in a particularly selective or concentrated way. As a result the Japanese university system appears poorly placed to provide the kinds of fundamental and strategic scientific research that the promotion of "exploitable areas" may require.

Consequently, attention is now turning to the infrastructure for basic research. The private sector has been pressuring MITI to redirect its R&D support towards more basic research goals (Irvine and Martin 1984a).

In an unprecedented move, and perhaps in response to these concerns, the Japanese Cabinet in March 1986 promulgated three general guidelines for S&T policy:

(1) To promote science and technology richer in creativity, strengthening basic research and development which will develop next generation technology,

(2) to evolve science and technology giving appreciable consideration to the importance of international affairs, and
(3) to harmonise science and technology with man and society (Shimomura 1986, p 27).

These themes are essentially those of the CST's 1984 planning document and closely reflect the stated objectives of the 'Human Frontier' program. Their impact on the public research and scientific administrative system in Japan remains to be gauged.
CHAPTER 4

INTERCOUNTRY COMPARISONS: THE NETHERLANDS

The policies being developed by the Dutch Government for the promotion of selected areas of strategic research are of significance for a number of reasons. The agricultural sector of the economy is highly developed; the population of less than 15 million gives rise to a small home market. Despite the strong economic contribution of the industrial sector (dominated by the five major Dutch TNCs) there is concern about over-reliance on "older", energy-intensive products and processes. Dutch industry performs a respectable 53% of GERD, most of which is self financed (OECD 1987c, p 17). The R&D effort is heavily concentrated in the largest companies.

The national R&D infrastructure is diverse and well funded, accounting for 2.07% of GDP in 1986 (OECD 1987c, p 22). Military research accounts for only about 3% of government R&D expenditure. Although university research expenditure has shown a slight decline in recent years, it still stands at about 0.40% of GDP, a high figure in international terms. Government research institutes are also very significant, enjoying a level of research funding similar to that of the university sector. The largest of these is the Organisation for Applied Scientific Research (TNO).

Dutch science policy has for some time emphasised the importance of the broad social relevance of scientific research and avoided linking the work of government research institutes too closely with short-term market forces. There is also a tradition of consensual strategic planning for research.

With the adoption of more market-oriented technology policies, R&D is increasingly being expected to contribute to technological innovation:

"If Dutch R&D is at least to keep pace in scale, quality and applicability with that in comparable countries, it is necessary for the scale of the R&D effort to expand significantly. That expansion must take place entirely within and on behalf of industry and commerce". (Ministry of Economic Affairs 1984, p 5)

Thus government spending is tending,

"towards applied R&D in sectors aiming at the development of new technologies, or at enhancing technological progress leading to an improvement of the competitive strength of Dutch industry."

Since the late 1970s public policy initiatives have sought to focus on research priorities; ensure greater market orientation for the research institutes; stimulate transfer of knowledge from academia to industry; and establish collaborative research programs in certain priority fields. Although these objectives parallel those in many other industrialised countries, the particular structure of Dutch scientific research and administration has led to original and innovative policy solutions.

STRATEGIC RESEARCH IN THE UNIVERSITIES

The university sector receives most of its research support (over 80% in 1986) in the form of general funds, primarily through the Department of Education and Science (OECD 1987c). Although each university is autonomous, in practice funding negotiations with the Ministry are constrained by "agreed models" of resource allocation. For example, the research plans of the universities are expected to take national recommendations for specific disciplines into account.

Direct grants for scientific research are channelled through the Netherlands Organisation for the Advancement of Pure Scientific Research (ZWO) and the Technical Sciences Foundation (STW) and several smaller sectoral agencies and research institutes. Such grants accounted for less than
9% of university research funding in 1986 (OECD 1987c). The business sector contributes about 7.5% of university research funds (1986).

Government policy proposes to increase the proportion of ZWO research funding to 16% by 1990 (Blume 1986) as part of a strategy to improve the planning and selection of priorities within university research. As the contribution of general funds to university research is so large, any move towards greater selectivity and promotion of areas of strategic research needs to address the use of these funds. Some universities (e.g. Leiden) have taken steps to allocate funds on the basis of research quality. An important policy innovation was the introduction in 1981 of "conditionally financed" research programs.

"Conditional financing"

The "conditional financing" system is intended firstly to improve the quality and efficiency of university research, but also to stimulate universities into meeting "society's needs for specific research" (OECD 1987c, p 56). The university decides whether research programs are to be included in this component of funding. Funds are primarily directed to large research programs of at least five years duration. Conditionally financed programs are protected from budgetary cuts by the university and the Ministry.

Programs must receive a positive assessment in an external review, either by an ad hoc evaluation committee or, more usually, by ZWO or the Royal Netherlands Academy of Arts and Sciences (KNAW). Criteria of assessment determined by the Minister include scientific quality and value (scientific relevance and the size and coherence of the proposal) and, where applicable, social relevance. So, although primarily a peer review, government, industry and consumer representatives were included on some panels. The significance of conditional financing lies in its program rather than project orientation, and the scale of the evaluation required (50% of all university research by 1987) (Gibbons and Georgiou 1986).

After some discrepancies in evaluation procedures (some evaluators were reluctant to attempt socio-economic judgments) a clearer and more formal assessment process was introduced (Blume et al 1985). Even so, in the opinion of the OECD Examiners (OECD 1987c), the objectives of the scheme have not been met, and they recommend strict peer review in the initial evaluation phase. Blume and Spaapen (1988, p 30) conclude that "the system has had some positive effects, even though external evaluation failed to select the best research."

Project funding: ZWO and STW

ZWO is structured into about 15 discipline oriented Foundations covering the sciences, medicine, social sciences and humanities. Within the Foundations, "working communities" of researchers evaluate research proposals using informal criteria of scientific quality and originality. Their recommendations are usually accepted by the Foundation. About one-fifth of grant funds are allocated by central ZWO committees rather than the Foundations (Blume et al 1985). Much of ZWO's grant budget funds research projects by postgraduate students, although in future their salaries are to be met by general university funds (OECD 1987c). In recent years ZWO funds have started to be used for applied research and Foundations have selectively funded priority fields.

It has been suggested that the current structure of ZWO, while well designed for coordination, is less well adapted to ruthless pursuit of research quality or the formulation and implementation of research priorities (Blume 1986).

STW was established in 1981 to stimulate technological research especially in the higher education sector. About 80% of the total annual STW budget (30 million Guilders) derives from the Education and Sciences Ministry, with the remainder from the Ministry of Economic Affairs (Minister of Economic Affairs 1986). Projects are funded on the basis both of their quality and potential utility; but proposals seem more assured of success where an active commitment by a specific user can be demonstrated (Blume et al 1985). Evaluation procedures within STW are more formal and quicker than in ZWO. Proposals are rated against specific criteria in a two-stage
process (see Chapter 6). In 1985, 384 projects involving 343 firms and research and higher education institutes were under way (Minister of Economic Affairs 1986).

In 1984, the government announced plans to merge ZWO and STW into a Netherlands Organisation for Scientific Research (NWO) with a mandate to finance applied technological and natural science research through "swift and flexible" procedures (Ministry of Economic Affairs 1984, p 10).

STRATEGIC RESEARCH IN GOVERNMENT INSTITUTES

The Netherlands has a broad system of some 180 government research institutes. Some are "para-university" in the fundamental character of their research and are managed through the ZWO or KNAW. Examples are the institutes concerned with embryological research and information technology. Others, such as the Agricultural Institutes, concentrate on more user-oriented applied research and are responsible to the appropriate Ministries.

TNO performs strategic and applied research in the fields of industrial technology, defence, health, food, and technology and society (OECD 1987c). The TNO and the five Major Technological Institutes (GTIs) have a combined annual budget of about 900 million Guilders. Currently, TNO is the responsibility of the Minister for Education and Science and also maintains financial and administrative links with other Ministries. Government proposals in 1986 aimed to bring TNO and the GTIs under the umbrella of a new statutory Technology Institute, but this now appears out of favour (see below).

In recent years TNO has been reorganised into a centrally managed body with a Divisional structure. There are two components of Government funding; a subsidy for background research guided by TNO's strategic plan (about 15% of the total budget), and special purpose "target subsidies" for medium- and long-term programs agreed with the particular ministry funding the research (van Spiegel 1986). The Organisation has also been required to increase revenues from commissioned research from the private sector. These accounted for 36% of TNO's budget in 1985. Similar procedures are being introduced in other large institutes concerned with strategic and applied research (OECD 1987c).

TECHNOLOGY POLICY AND THE RESEARCH SECTOR

Within the market-oriented technology policy extremely high priority is accorded to industrial-technological R&D and to the concept of technological priority areas. One goal is therefore to promote more active orientation of the technological infrastructure (universities and research institutes) towards the need of industry" (OECD 1987c, p 42). The Government is encouraging the universities to increase industrial contract work and to promote staff exchanges with the private sector. The most significant bridge between the research and business sectors lies in the innovation-oriented research programs (IOP).

Innovation-Oriented Research Programs

The IOPs are intended "to redirect a significant part of the research carried out by institutes ... towards fields and themes which are important in the medium term for society and in particular for the market sector" (OECD 1987c, p 49). The programs focus on university research, but research institutes are also involved. The 1984 "Zegveld Report" recommends that IOPs be given "a pivotal function in the process towards reinforcement of the relation between the market sector and the university world" (Ministry of Economic Affairs 1984, p 14). Thus, "the core of the IOP formula is that potentially interested firms be allowed a major input in the preparation of the institutes' research programmes" (Minister of Economic Affairs 1986, p 19). An essential feature of the IOPs is the creation of a program commission including users who support the particular field of research.
TABLE 4.1

INNOVATION-ORIENTED RESEARCH PROGRAMS (IOPs) IN THE NETHERLANDS

IN PROGRESS (1986)

<table>
<thead>
<tr>
<th>Program</th>
<th>Commenced</th>
<th>Duration (Years)</th>
<th>Budget (m Gld.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biotechnology</td>
<td>1982</td>
<td>8</td>
<td>50.4</td>
</tr>
<tr>
<td>Construction</td>
<td>1983</td>
<td>5</td>
<td>18.8</td>
</tr>
<tr>
<td>Membranes</td>
<td>1984</td>
<td>8</td>
<td>25.8</td>
</tr>
<tr>
<td>Equipment for the handicapped</td>
<td>1984</td>
<td>4</td>
<td>13.7</td>
</tr>
<tr>
<td>Polymer composites</td>
<td>1985</td>
<td>3</td>
<td>11.9</td>
</tr>
<tr>
<td>Engineering ceramics</td>
<td>1985</td>
<td>8</td>
<td>29.6</td>
</tr>
<tr>
<td>Integrated circuit technology</td>
<td>1985</td>
<td>7</td>
<td>27.4</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>1985</td>
<td>7</td>
<td>16.0</td>
</tr>
<tr>
<td>Metals (modern alloys)</td>
<td>1986</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

PRELIMINARY STUDIES

- Catalysis
- Recycling non-ferrous metals
- Medical technology

UNDER CONSIDERATION

- Signal processing
- Optical electronics
- Maintenance and repair technologies
- Environmental noise control
- Explosion engines

(Source: OECD 1987c, p 50; Minister of Economic Affairs 1986)
A systematic evaluation of the field precedes the establishment of an IOP (Blume et al. 1985). An initial document, prepared by experts, provides the basis for discussions with prospective participants from the research sector and industry; market studies are also performed. Social as well as technological and economic priorities are evident in the selection of IOP topics (Table 4.1).

The biotechnology IOP is regarded as particularly successful in mobilising university researchers, ZWO and industry and has become an exemplar for the succeeding programs. It comprises projects related to manufacturing, environmental pollution (waste disposal etc), agriculture and health care. Of the 10.1 million Guilder budget in 1986, over half was for industrial-related biotechnology research (Minister of Economic Affairs 1986).

The IOPs (like other technology programs) are the responsibility of the Ministry for Economic Affairs and are funded equally by that Ministry and the universities. Other Ministries contribute to the funding of specific IOPs. The financial contribution of industry however appears to be negligible. In 1985 the IOPs' budget was 30 million Guilders, or equivalent to slightly less than one-quarter of ZWO university research grant funds.

The OECD Examiners view the IOPs as too removed from specific successful industrial activity to be innovation-oriented in a generally accepted sense. They have more of the characteristics of "exploitable areas":

"IOPs appear to be focused on supporting research which is expected to provide a strategic background for development of technology. As such they should be seen as competing with, rather than complementing other government initiatives in funding research" (OECD 1987c, p 101).

They continue,

"Some of the IOPs give every indication of achieving their goals of stimulating and strengthening research in strategically selected areas in both the universities and in industries, and of strengthening the co-operation between the two in well-defined programmes. It is important that a responsive steering mechanism promoting research excellence in areas of potential strategic value to the economy within both the universities and industry be maintained" (p 104),

and suggest that responsibility for the IOPs might be transferred to STW, as the most appropriate organisation to assume enhanced responsibilities for the evaluation of generic technologies.

"Spearhead" programs

These are temporary programs designed to promote research in specific broad fields, formulated in cooperation with both public and private sector research organisations and interest groups. They include programs on new generic technologies, e.g. the informatics stimulation plan (INSP) and materials research, but also programs in areas of national and social concern (e.g. research into labour and technology, and soil protection). Funding and coordination seems to be tailored to the specific needs of the area. For example, INSP receives major funds from the Ministries of Economic Affairs, Education and Science and Agriculture and Fisheries and is also attracting support from the business sector. A short-term (1984-88) Stimulation Project Team for IT Research (SPIN) has been established to stimulate and coordinate strategic research, particularly that on the borderline between informatics and other disciplines. SPIN will establish and manage research programs in consultation with industry and the scientific community, and funded by the Ministries mentioned above. Work on artificial intelligence and software engineering is included (Minister of Economic Affairs 1986).

Some strategic research objectives of the IOPs and the "spearhead" programs are similar, as the OECD Examiners have noted (OECD 1987c). However, the latter incorporate broader goals, such as training, diffusion of existing technology and public awareness. INSP, for example includes measure to expand IT expertise in certain institutions. Both INSP and the materials program have given rise to several more narrowly focused IOPs.
COORDINATION MECHANISMS

The Dutch Government recognises the need for "a continuous process of setting priorities in research, reflecting the changing needs of society and promoting new research of good quality" (OECD 1987c, p 64). This process involves selective promotion (or retrenchment) of specific fields of research by the Minister for Education and Science, after advice from the KNAW, the Advisory Council for Science Policy (RAWB) or the exploratory commissions (see below) and after consultation with Parliament. One example is the stimulation of specific medical research in the public interest.

Sector Councils

Broadly based sector councils and "programming committees" have been a feature of Dutch science policy since the late 1970s, although they have only recently been accorded legal status. They are high level consultative and advisory bodies for fields of application of research (e.g. Agriculture; Energy; and Environment) and comprise researchers, user representatives (social and business groups) and government officials. Their primary task is to provide advice to appropriate Ministers or research organisations on the "main themes of research, from a multi-year perspective" (OECD 1987c, p 37) and therefore involves prospective evaluation and planning. They are primarily consultative and coordinating forums with no research funding responsibilities, but have some access to science budget funds through the Minister for Education and Science. Not all sector councils have been successful: dissent in the Council for Energy Research (REO) led to its abolition.

Councils may be requested to evaluate research proposals, such as those submitted for "conditional financing", with regard to the Council's sectoral priorities. The criterion of social relevance is important in these assessments (Blume et al 1985).

Exploratory Commissions

Exploratory or surveying commissions (Verkenningscommissies (VC) in Dutch) are also important in the priority forming process. These are small ad hoc commissions convened by the Minister responsible for science policy to examine research within a particular scientific discipline or sector. The objectives of the VCs are to evaluate the quality and effectiveness of Dutch research; assess the significance of developments in that field for other fields, and vice versa; assess the elements for future policy in the field, particularly as regards state financed research; and to make recommendations about its development (Blume et al 1985). The VCs are expected to address the need for setting priorities and "to find space, through proposals for ending or phasing down existing research, for new work consonant with emerging policy objectives and priorities" (Blume 1986, p 17). VC members are drawn primarily from academia, but may include members from TNO or Industry. Recent VCs have been concerned with biochemistry and molecular biology (1982) and informatics and communication science (1983).

The evaluation approach adopted by different VCs has varied widely. Some have used bibliometric indicators to assess quality. While some (notably the Chemistry VC) have produced a consensual policy blueprint for the future development of their fields, the findings of others like the Biology VC have been less widely accepted. Gibbons and Georgiou (1986) comment on the difficulty of assessing the value of the VCs as a policy instrument for evaluating research. They appear most useful where closely coordinated with other evaluation activities (as in the case of the Chemistry VC). The OECD Examiners believe that the VCs need clearer terms of reference and time frames and a more mixed membership, including foreign representatives (OECD 1987c).

In September 1986 the Dutch Government announced increased funding and new goals for technology policy. These include "promoting market-orientation, flexibility and quality of research in the public sector" (Minister of Economic Affairs 1986, p 8). They also proposed a new Statutory Institute for the implementation of technology policy (including funding) and intended to "play a pivotal role in the science and technology system" (p 8). The detailed function
and structure of the Institute were to be addressed by an Advisory Committee on the Expansion of Technology Policy (the 'Dekker Committee').

Reporting in April 1987, the Dekker Committee was not in favour of a central technology institute, but called for a separate advisory body to promote coherence in technology policy, cooperating with or even merged with the science policy council, RAWB (Veenemans 1987). The Committee also recommended, inter alia, increased contacts between the private sector and the research institutes. The RAWB reportedly sees Dekker's recommendations as subordinating university research to the wishes of the private sector, and prefers the establishment of an independent body to advise on both science and technology policy (Warringa 1987).

**Technology assessment**

The Netherlands Organisation for Technology Assessment (NOTA) was established in 1986 with a small budget (Leyten and Smits, 1987). NOTA appears to have no formal policy development role although it will present a policy-oriented report to Parliament every two years.

**CONCLUSIONS**

Blume (1986) characterises Dutch science policy in the 1980s as being "marked by a re-emergence of concern with the longer term, with co-ordination (and new approaches to co-ordination), and development of new policy tools appropriate to the new strategic thinking, planning and co-ordination" (p 69). But, as he notes, these concerns have selective application to specific fields of science and technology deemed important. In particular, innovation in certain advanced technology sectors is seen as the over-riding priority. Since 1982, this aspect of technology policy has been the responsibility of the powerful Ministry of Economic Affairs which, Blume reports, is reluctant to be party to a more coordinated science and technology policy.

Given the plurality of the Dutch R&D system, and the independence of its parts, such coordination is particularly important to unite the "partial visions" of, for example, the Sector Councils, VCs and other planning agencies. Because of what Warringa (1987, p 7) terms the "notoriously piecemeal nature of the country's science policy", such national coordination has not yet been achieved. The consensual and consultative approach to policy making has lead to continuity (particularly in institutional structures), rather than rapid change, in adapting to the development and implementation of policies for "exploitable areas" of science.
CHAPTER 5
INTERCOUNTRY COMPARISONS: SWEDEN

Like the Netherlands, Sweden is a small economy (population eight million) with a limited (but "critical and demanding") home market (OECD 1987d, p 29). Sweden spends a very high proportion (about 2.7%) of its GDP on R&D. Military research accounts for 26% of national R&D expenditure. Swedish industry and its exports are highly specialised. Although one of the few net exporters of technology, Sweden's industrial base also relies heavily on low R&D intensity industries such as wood and paper products. Even so, 60% of national R&D is funded by the business sector. Industrial R&D is overwhelmingly experimental development rather than basic or applied research (OECD 1987d).

The research infrastructure and policies are shaped by the consultative democratic nature of Swedish society. The Riksdag (parliament) is closely involved in determining specific industrial and research policies; however this does not imply a "top down" approach to research planning. Research funding in Sweden is highly pluralistic and there is great emphasis on sectoral planning which takes place within what has been called "one of the most open and articulated planning systems in the OECD area" (Gibbons 1985b, p 26). Multi-year programs evolve through extensive consultations between researchers, interested individuals and organisations. As Leyten and Smits (1987, p 2) comment, "the procedure is set up in such a way that the final programme is able to count on wide support".

Recent Swedish S&T policy is characterised by a strong growth in public spending on R&D (SKr 4894 million in 1986-87), particularly in basic research, priority areas and the higher education sector, and by specific measures to increase coordination and priority setting across research sectors (Swedish Cabinet Office 1987b).

STRATEGIC RESEARCH IN THE HIGHER EDUCATION SECTOR

About a quarter of R&D in Sweden is carried out within the higher education sector, which is quite closely controlled by the Government and Riksdag. All permanent research activities are financed out of general funds ("faculty grants") and their allocation provides the government and parliament with means to determine priorities both between subject areas and between research institutions. An even more powerful instrument is control over the establishment (and presumably abolition) of professorial chairs and the scope of professorships. A certain proportion of general funds may also be earmarked for specified research areas: recent examples being microbiology and marine technology (OECD 1987d). Research "themes", nominated by the Riksdag, may form the basis for problem-oriented research programs. A recent example is the "Technology and Social Change" program at the University of Linköping. Subject to these constraints, individual higher educational establishments are free to allocate the research and research training funds they receive from the Ministry as they see fit.

As a result of the "sectoral" research policy (see below) the level of external funding of university research is high. Some sectoral agencies also fund professorial chairs. About 7% of higher education research is funded by the private sector (OECD 1987d).

Coordination and planning of higher education research is part of the function of the National Board of Universities and Colleges (UHA) within the Ministry of Education and Cultural Affairs. UHA's planning role is particularly important for long-term research given the high level of university research commissioned by sectoral agencies. Significantly, membership of the five planning committees of UHA (one of which is responsible for natural sciences and technology) comprises representatives of trades unions, interested organisations, government agencies and the business community as well as the education and research community (Gibbons 1985b). UHA also performs university-wide evaluations of research fields (e.g. chemical engineering in 1984) using international peer review teams.
Research Councils

Five primary research councils provide direct research grants to the universities (Table 5.1) although their total budget amounts to less than ten percent of public support for research in the higher education sector. The councils support research on the basis of scientific quality and are also "required to address themselves to research needs in fields of importance to society and to encourage the dissemination of information concerning research and research findings" (OECD 1987d, p 35). Several smaller research councils support applied research in narrower sectoral fields.

TABLE 5.1

MAIN SWEDISH RESEARCH COUNCIL BUDGETS (1985-86)  

<table>
<thead>
<tr>
<th>Council Name</th>
<th>SKr million</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Sciences Research Council (NFR)</td>
<td>259.5</td>
<td>41.1</td>
</tr>
<tr>
<td>Medical Research Council (MFR)</td>
<td>183.4</td>
<td>29.0</td>
</tr>
<tr>
<td>Council for Research in the Humanities and Social Sciences (HSFR)</td>
<td>84.8</td>
<td>13.4</td>
</tr>
<tr>
<td>Swedish Council for Forestry and Agricultural Research (SJFR)</td>
<td>60.0</td>
<td>9.5</td>
</tr>
<tr>
<td>Council for Planning and Coordination of Research (FRN)</td>
<td>44.1</td>
<td>7.0</td>
</tr>
</tbody>
</table>

(Source: OECD 1987d, pp 37-38)

The Natural Sciences Research Council (NFR) operates a comprehensive procedure for evaluating the quality of the research projects it funds. Discipline-based teams of Swedish and international experts assess individual research projects, but are also expected to be "forward looking" and comment on the general orientation of NFR-funded research. They therefore provide some guidance on future priorities (Gibbons 1985b). These independent evaluations indicate scientific strengths and weaknesses but make no attempt to address socio-economic criteria.

The role of the Council for Planning and Coordination of Research (FRN) is "to initiate and support research of great societal importance in collaboration with research councils and sectoral bodies" (OECD 1987d, p 35). FRN coordinates major cooperative programs within certain priority areas, particularly in novel, interdisciplinary areas. The Council is also responsible for promoting the dissemination of research results. It is not an executive coordinating body for the research councils but enjoys equal status with the other councils. However, whereas they are largely composed of scientists, FRN includes representatives of interest groups and parliamentarians. The Secretariat for Future Studies (SFS) is now located within FRN. Although influential, SFS has no formal policy development or planning role (Leyten and Smits 1987).
STRATEGIC RESEARCH BY GOVERNMENT AGENCIES

Swedish government research policy is predominantly "sectoral", i.e. "for each sector of society to take responsibility for building up the research required for both short-term and long-term creation of knowledge" (OECD 1987d, p 36). It also generally eschews the creation of independent sectoral research institutes, preferring to build up expertise within, or closely associated with, the higher education research system. Exceptions are the Swedish National Defence Research Institute (FOA) and the Centre for Working Life. There are about a hundred sectoral bodies funding R&D, some of which are special sectoral research coordination bodies. However, about 75% of public R&D funding is channelled through three Ministries (Education, Industry and Defence).

Sectoral agencies do carry out evaluation of their programs, often to determine their contribution to the achievement of specific social needs. There is also a concern with research quality. International experts have been involved in evaluation teams, but it has proved difficult for them to address the extra-scientific questions posed by the agencies (Gibbons 1985b).

One of the most pressing problems in Swedish research policy is maintaining an appropriate balance between basic/strategic and applied research. It is acknowledged that the pluralist "sectoral" approach to research funding has tended to promote short-term research rather than the accumulation of knowledge essential for the long-term. Government policy is to ensure that the sectoral agencies develop in such a way that this latter objective can be met.

COORDINATION MECHANISMS

Given the Swedes' "sectoral" research policy, coordination between sectoral agencies, industry and the higher education system is crucial. In 1983 each mission-oriented research board was required to submit to the Government a five year plan for the development of its research portfolio and to nominate priority areas. The UHA was then asked to relate these plans to a similar set of five year plans for research in the universities and colleges (Gibbons 1985b). This assessment was a formal input into the Research Bill process (Gibbons and Georgiou 1986).

At a higher level, the Prime Minister has overall responsibility for coordination of S&T questions and chairs the Research Advisory Board. The Board's working committee includes both ministers and scientists (Swedish Cabinet Office 1987b). The OECD Examiners regard this as "an outstanding government structure which nurtures and actively promotes the interface of basic science with industry, with a coordinating overview on national benefit" (OECD 1987d, p 69).

The development of university/industry relations is seen as particularly important for Swedish technological and industrial progress (OECD 1987d). There is political consensus that intellectual capacity must be focused on industrial and economic problems and "the obligations of the universities to work also in the interests of industry are taken for granted" (OECD 1987d, p 62). Individual companies, particularly in the R&D intensive pharmaceutical and electronics industries, have established close research links with universities. To a considerable extent government agencies act as intermediaries. In the mid-1960s public bodies such as the Foundation for the Exploitation of Research Results (EFOR) were set up to assist industrial application of scientific research (Blume 1986). The most significant agency today is the National Board for Technical Development (STU).

National Board for Technical Development

STU is a sectoral agency for industry, but plays a central role in supporting technology-related R&D and promoting the commercialisation of research. STU's objectives are:

"achieving and maintaining research and industrial technical competency in areas which are regarded as significant to modernization of Swedish industry; stimulating and providing a solid basis for technical innovation and the commercial realization thereof; coordinating in such a way that national R&D expenditure is to the benefit of society and brings the social goals closer" (Leyten and Smits 1987, pp 3-4).
The Board recognises that "technical research designed to develop basic competence and knowledge must be of a long-term nature and should have specific goals if industry and society are to make proper use of it in the future" (STU, quoted by Gibbons 1985b, p 9). Within STU, research resources are increasingly being oriented towards specific areas of industrial and social need.

STU grants for R&D amounted to SKr 747 million in 1984-84, more than the combined budget of all the primary research councils. Of this sum, 32% was directed to universities and colleges and a further 23% to cooperative research institutes (OECD 1987d). The STU 'Development of Knowledge' program has a budget of SKr 240 million (1985-86). Of this, SKr 20 million per annum is distributed by the Board's Technical Research Council on the recommendation of a panel of researchers. A large proportion of STU's funds thus supports longer-term research activities within the universities and as a result the Board "has had a significant effect on the nature of Swedish R&D in the natural sciences and engineering" (OECD 1987d, p 46).

The general procedure for establishing a research program starts with a "concept program": a report by an expert panel addressing international trends; reviewing the situation in Swedish industry; and assessing the success of related programs. This is submitted for comment to industrial organisations, trades unions, sectoral agencies, political parties and other interest groups. Following any necessary amendment, the program is submitted to parliament for approval, after which it may be implemented immediately (Leyten and Smits 1987).

STU is involved in the evaluation of specific areas of technological research, e.g. powder metallurgy, organic synthesis, and aeronautics (Gibbons 1985b). Evaluation groups include international experts and take a broad view of the field, not simply STU-funded research. They address the scientific aspects of the research (including its "future potential") although they may also assess how research in the higher education sector meets the needs of industry. However, Hakansson (quoted by Gibbons 1985b, p 13) notes that "the evaluations and recommendations made on the basis of industrial and social considerations ... have proved to be debatable". The evaluations seem to have been most useful for fundamental, rather than applied, research fields and where based solely on scientific considerations. Industry and other views of the research field are considered later within STU's broader planning process. A negative evaluation may lead to increased resources for an important research area, rather than the reverse.

In the view of the OECD Examiners "STU is an exceptionally well-adapted interface between science and technology, on the one hand, and industry ... on the other" (OECD 1987d, pp 82- 83). There is also a state-owned development company to "support innovations satisfying urgent needs in society and create better conditions for development and exploitation of innovations" (OECD 1987d, p 12).

Cooperative research programs

The cooperative research institutes (some of which are long-standing) and cooperative programs are joint ventures between government (usually represented by STU) and consortia of several companies to support specific R&D programs (for example, the systems technology aspects of IT). The scope of each program is determined by an elected program board, and the actual research is carried out either by industry or (more usually) the universities. Currently there are 30 cooperative research programs, over half of which involve special cooperative research institutes.

Another example of cooperative research is the joint biotechnology project involving the University of Uppsala, STU and the company Pharmacia. Here, the researchers are provided by Pharmacia, but the work is carried out within a university department. The steering committee for the project includes not only the three sponsors, but also independent representatives of industry (OECD 1987d).
PRIORITY AREAS

Since 1982, priority research fields have been defined directly by Riksdag-approved Research Policy Acts every two or three years. The role of the government and parliament is to determine the general areas receiving support and the national balance between research fields, without producing "too forceful and detailed a definition of priorities" (Swedish Cabinet Office 1987b, p 45).

The original (1982) Act set a wide range of priority research areas in the natural and social sciences and humanities. These included national concerns, such as "soil ecology in relation to agriculture, forestry and the environment", as well as research priorities in social welfare and public administration. The first long-term priority however was "research which is a precondition and consequence of the national emphasis on technical development" (OECD 1987d, p 15). This is seen as comprising both the science underlying technical development and the assessment of social and economic consequences. Industrial priority areas were electronics, computer technology, biotechnology, health and hygiene technology, materials technology, new materials, production engineering, chemical technology, energy technologies and wood technology, all technologies closely related to Sweden's industrial strengths.

The 1984 Act reasserts the priorities set in 1982 and places emphasis on environmental research, information technology, materials science and biotechnology. Cultural sciences is added to this list by the 1987 Bill. Projected increases in real funding for four priority areas for the period 1986-87 to 1989-90 are given as: cultural sciences, SKr 20 million; natural, urban and working environments, SKr 37 million; biotechnology, SKr 62 million (including capital expenses); and IT, SKr 72 million (Swedish Cabinet Office 1987b).

Although research organisations are left to determine more detailed priorities, the provisions of the Research Acts may be quite specific. The 1987 Bill, for example, announces a national information technology program along the following lines:

"Primary research in this field is to be supported, partly through the improvement of basic resources and the establishment of new professorships. Special allocations are being made to all institutes of technology and to Umeå University. The research councils - primarily the Natural Sciences Research Council - are to receive special grants for projects and equipment relating among other things to microelectronics. A centre for industrial applications of information technology is to be set up in conjunction with Linköping University. Special funds are being allocated for research into the human and social implications of information technology ... The Board for Technical Development will be allocated a further SKr 43 million for applied research" (Swedish Cabinet Office 1987a, pp 4-5).

Similarly specific budgetary and administrative initiatives are announced for the other priority areas. National programs also exist in the areas of space and "micronics" (microstructure) technologies.

CONCLUSIONS

Provision for identifying and funding national priority areas of scientific and technological research is well developed in Sweden; a national consensual process coordinated at the highest level.

Evaluation by international peer review appears endemic within the Swedish research system, but has tended to focus on post hoc assessment of specific projects or areas. Gibbons (1985b) raises the question of prospective forecasting with the assertion that "evaluation of research in Sweden is likely to become more preoccupied with identifying future developments in science as one way of ensuring that her current high international status in science is maintained" (p 27). Certainly the mechanisms exist whereby such forecasts could be rapidly integrated into the research planning system, further strengthening Sweden's national "exploitation" of her scientific and technological base.
CHAPTER 6

THE ROLE OF EVALUATION AND FORECASTING

Central to any process for the promotion of "exploitable areas" of science are mechanisms to identify those areas of basic research having potential for exploitation. But, as Rip et al (1986) remind us:

"priority setting is not the justification for allocation of resources, but one step (and not even the first step) in a process of implementation of program goals" (p 3).

Attention is also therefore turning to the effectiveness of different means for achieving particular goals in strategic research and quantification of their success.

Clearly, the choice of evaluation and other methods used in selecting priority research areas cannot be divorced from the institutional and programmatic context in which they are used, and this aspect is dealt with more fully in the final chapter. Nevertheless, it is appropriate first to consider the types of criteria necessary to identify "exploitable areas" and the extent to which existing research selection processes address, or might be modified to address, these criteria.

CRITERIA OF EVALUATION

Weinberg (1963) first proposed explicit recognition of "internal" and "external" criteria for scientific choice.

Internal criteria (sensu Weinberg) are those generated within a specific scientific field, i.e.,

- readiness of the field for exploitation (in the scientific sense);
- competence of the scientists in the field;

and external criteria are those falling outside that specific field:

- scientific merit (e.g. relevance to neighbouring fields of science or to the "unity" of science);
- technological merit,
- social merit.

Internal criteria are therefore those of efficiency, while external criteria, at least those pertaining to technological and social merit, are criteria of utility (Weinberg 1984). Most commentators (e.g. Irvine and Martin 1984b) now regard "scientific merit" as an internal criterion (i.e. intrinsic to scientific endeavour). Weinberg sees limitations of the criteria of choice arising in practice because "scientific choices at the highest level ... often become political choices" (1984, p 9). However, it may be more informative to recognise that "internal" and 'external' criteria are not mutually exclusive, and their definition is to some extent a political exercise" (Irvine and Martin 1984b, p 69).

In general, internal criteria are associated with "peer review" evaluation mechanisms used to determine priorities between research proposals in a specific field, while external criteria come to the fore in determining broad allocation of R&D resources and in technology assessment or forecasting exercises.

The development of policies for strategic research and exploitable areas of science requires that external criteria be taken into consideration at all decision making levels. This means that such criteria must be made more detailed and explicit. A closer linkage between judgements made using internal criteria and those using external criteria is also essential.
TABLE 6.1

UK ADVISORY BOARD FOR THE RESEARCH COUNCILS' CRITERIA FOR SCIENTIFIC PRIORITIES

INTERNAL

(1) timeliness - expectation of rapid scientific advance (in 5, 10 or 20 years);
(2) pervasiveness - likelihood of a wide range of links with other research;
(3) excellence.

EXTERNAL

(1) exploitability - potential for nationally profitable industrial or commercial use (in 5, 10 or 20 years);
(2) applicability - potential for uses leading to other benefits: social, environmental or related to Government policy (in 5, 10 or 20 years);
(3) significance for education and training.

(Source: ABRC 1987, p 18)

This is certainly happening. For example, the British ABRC has recently promulgated new criteria for priority setting to guide its own decisions and those of the research councils (Table 6.1). The new "common criteria" reinstate Weinberg's dichotomy and replace "scientific criteria" and "management criteria" dating from 1975 (Turney 1987b). They also place greater emphasis on external factors, particularly of course "exploitability" and "applicability". The ABRC recognises that the main scope for applying its external criteria will be in judging the relative level of support for scientific programs and fields.

The effectiveness of any criterion for scientific choice depends on the way in which it is applied in practice. It is therefore helpful to consider the kinds of evaluation procedures commonly employed and their relative merits in determining internal and external criteria.

EVALUATION MECHANISMS

Peer review

Evaluation by one's scientific peers is central to the identification of scientifically promising areas of basic scientific research. It is applied to areas where scientific excellence is the sole or prime criterion; i.e. it is concerned entirely with criteria "internal" to science. Peer review is therefore most commonly employed in evaluating research in the higher education sector (whether on a disciplinary, research group or institutional basis) to determine the allocation of research funds to specific projects or to assess the scientific worth of particular research programs. Clearly, all these types of evaluation are important in assessing the strength and direction of the "science push" side of the exploitable science equation.

A number of problems can be identified with peer review as it is usually practised (Irvine and Martin 1984b). Firstly, it is conservative. Individuals involved tend to be senior scientists from the more prestigious institutions. As a result, funding decisions may become incrementalist,
reflecting the established pattern of resource allocation. This is particularly likely to happen when concentration of research effort between institutions or within specialisms produces a shrinking pool of "peers". The same concerns apply to countries with a small population of research scientists. Similarly, when overall research resources are decreasing, scientists may abandon their "disinterestedness" and become advocates for their particular field. Because of their institutional structure, peer review bodies may be less willing to identify declining fields of science or research groups. Finally, they may also be less than ideally placed to recognise emerging research areas of importance, particularly if interdisciplinary in nature. These concerns lead Irvine and Martin to remark on "the general ineffectiveness of peer-evaluation as a mechanism for restructuring scientific activity" (1984b, p 76).

Gibbons and Georgiou (1986) suggest that strict peer review works best when the field is clearly identifiable; neither too large nor too small; and generates enough research proposals to provide a significant choice to the selectors.

Nonetheless, it is still recognised that practising scientists are best placed to judge the quality of contemporary scientific research and to anticipate likely future scientific developments. The focus of effort is therefore to strengthen and extend peer evaluation procedures and to make their output available in forms more useful for the formulation of research policy for exploitable science. Strengthening peer evaluation implics making it more both more broadly based and disinterested, for example by the inclusion of international experts and researchers from a variety of disciplines. Peer review bodies may be less than ideally placed to recognise emerging research areas of importance, particularly if interdisciplinary in nature. These concerns lead Irvine and Martin to remark on "the general ineffectiveness of peer-evaluation as a mechanism for restructuring scientific activity" (1984b, p 76).

Indirect peer review

Indirect measures of scientific worth may be obtained by tapping judgements made by the scientific community, for example by examination of refereed scientific papers or patents granted. Quantitative analyses of the scientific literature to produce bibliometric indicators are increasingly being used by evaluators, partly because a ready database exists in the "Science Citation Index". Bibliometric analyses might be expected to provide useful broadly based indicators of research performance. In fact, severe practical and theoretical problems such as comparison between specialism and journal coverage limit their utility.

Simple publication counts are hardly useful, but more sophisticated techniques have been developed to measure quality and linkages between publications (Gibbons and Georgiou 1986). Citation analysis, i.e. the number of citations a paper receives, provides one measure of peer approval. As an input to strategic research policy making, perhaps the most useful bibliometric measures are those that attempt to identify scientific networks, or the relationship between specialisms. Co-citation measures the strength of linkages between papers by counting the number of times they are cited together. Co-word analysis looks for common occurrence of keywords. These techniques should facilitate the identification of emerging areas of research, and the existing scientific areas on which they are based. The main problem is the time lag; the delays between research, publication, citation and publication cause citation based indicators to reflect a field of science as it was perhaps five or more years previously.

Because of their inherent limitations, the interpretation and validation of bibliometric indicators requires the judgement of experts in the research field. They are best viewed as complementary to other evaluation processes. The UK ABRC has endorsed the use of citation and co-citation methods by the research councils provided they are not used in isolation (Gibbons and Georgiou 1985).

Modified peer review

Consideration of wider external criteria requires the involvement of the potential users of research and other interest groups. This may be accomplished by including representatives on what are primarily "peer review" panels, or through a multi-stage review procedure. The former approach is common, but may lead to confusion over objectives and the weighting of different criteria, as apparently has happened in the Netherlands' "conditional financing" scheme.
The Dutch Technical Sciences Foundation (STW) provides an example of multi-stage evaluation:

"in the first round five experts selected for a specific proposal give their written opinions and comments ... (but no 'marks') ... to which additional 'counter-comments' by the applicants are attached ... Subsequently the proposal, comments and rejoinders are sent to twelve individuals - who are imagined to form a jury together, but do not know each other - who are asked to rate the proposal on a series of criteria. The board of STW sets the final priority ... but almost always obeys the outcomes of the selection procedures" (Blume et al 1985, p 27).

Medical research also provides good examples of multi-stage selection and evaluation procedures with the aim of balancing scientific, clinical and social considerations. The US National Institutes of Health (NIH) run a formal binary priority setting system for medical research grant applications based on peer review (Georghiou 1986). Applications are referred to one of many scientific review panels ("study sections") who may recommend approval, disapproval or deferral of the application. If approved, each member awards the application a priority score. The application is then referred to the appropriate Institute, together with a numerical rating derived from the panellists' scores, for review by a Council. The Councils represent both scientific and public interests and take account of the quality of the review, program priorities and the relevance of the proposed research. However, as Georghiou concludes, "in practice, councils vote en bloc to approve most study section recommendations" (1986, p 14).

Apart from bibliometric analysis, the types of evaluation described above are generally carried out ex ante, e.g. to determine allocation of research grants. However, the results of such selection procedures may be useful if available in aggregated form.

Structural evaluation

As policy inputs, ex post evaluations may be more directly relevant. These encompass reviews of academic specialisms or of broader areas of science, and of scientific programs or institutions. Again, evaluation criteria may be internal or external. Although basically historical, such surveys invariably have prospective intent and are therefore important for strategic research policies.

A common use of ex post evaluation is the survey of a scientific specialism. This may be simply an inventory of research activities in that field, but usually attempts to assess where the best research is carried out, how quality rates on an international scale, what new research themes are emerging and therefore what future developments in the field might be expected. Such conclusions are based on "internal" criteria of scientific efficiency and excellence and are best made by scientific "peers". Evaluation panels are usually broad based, drawing upon scientific expertise from within government and the private sector, as well as academia. Indirect measures such as bibliometrics may also be used to inform the survey. A good example of such evaluation is that carried out by the Dutch Verkenningscommissies. All the VCs in natural sciences have used bibliometric indicators as one input to their national surveys (Blume et al 1985).

This kind of evaluation may be broadened, both in terms of widening the area of science covered and by including the "users" of the research. The Dutch "sector councils" represent an institutionalised forum for such evaluation.

Program evaluation

Program evaluation is a form of structural evaluation focusing on the effectiveness of processes and institutions in promoting particular program goals. Such evaluations are particularly useful in the context of the exploitable areas of science because promotion of these areas of necessity involves novel arrangements and programs. As Gibbons and Georghiou note, "structural and organisational aspects of R&D are potentially transferable between programs, at least in part" (1986, p 30). In the Netherlands, evaluation of the Biotechnology IOP led to a similar program model being applied to other areas of strategic research (OECD 1987c).

The time-scale of most programs for promoting strategic research means that some concurrent evaluation is desirable. In the UK Alvey Program for IT, three groups of policy-oriented
academic evaluators were engaged to assess the structure and organisation of the program and the implementation of collaborative arrangements; its effectiveness in the context of the UK economy; and its impact on firm strategies in the software industry (L. Georgiou, pers. comm.). The evaluation has identified such problems as intellectual property rights, the form of collaborative agreements and the differing funding and administrative practices of the government agencies involved.

TECHNOLOGY ASSESSMENT AND FORECASTING

Perhaps the most daunting challenge is the development of evaluation techniques that link science, technology and the socio-economic environment, loosely termed technology assessment. Leyten and Smits (1987) recognise two elements: research into the social aspects of technological change; and institutionalised support for policy-making on S&T developments. Both aspects are incorporated in the US Congress Office of Technology Assessment (OTA). In Japan, the influential long term "visions" of MITI and STA include a significant element of technology assessment. But in other countries (e.g. the Netherlands and Sweden) technology assessment bodies appear to have little or no formal input into S&T policy decisions.

In some instances it may be feasible to set precise criteria for the evaluation of technologies. A study for the UK Department of Trade and Industry (PREST 1986) emphasises the role of the enabling knowledge base of technologies and technological performance (rather than the technology per se). Implicit in this approach is the development of future technological and economic scenarios by:

(1) identification of the range of actual and potential products and processes and relevant performance advantages over existing products;

(2) relating these advantages to economic performance in both the existing and forecast future economic environments;

(3) identification of the time-scale over which new products and processes will acquire economic weight, and their long-term market potential; and

(4) identification of the processes generating technological variety.

Clearly, the further one departs from the current scientific knowledge base, the more problematical any such assessment becomes. As the PREST study concludes:

"Obvious solutions to the analysis of technology priorities would have been developed long ago. Successful analysis of policy priorities will require a blend of science, technology, economics and other social sciences. Adequate tools to deal with matters of this complexity are only now being developed" (PREST 1986, p 2).

The US OTA also finds strictly quantitative approaches to research planning and evaluation unsatisfactory. OTA concludes that, "the metaphor of research funding as an investment, while valid conceptually, does not provide a useful practical guide to improving Federal research decision making" (OTA 1986, p 9). However, it recognises the utility of bibliometric and other science indicators in research program evaluation and recommends that these be employed more widely.

Attention has therefore turned to "macro-level" S&T forecasting initiatives, particularly those of the Japanese STA and MITI (Chapter 3). These are attempts to integrate the expert judgements and sectoral forecasts of research scientists, industrialists, interest groups and policy-makers on a national scale. Irvine and Martin's analysis of the Japanese experience in identifying exploitable areas of research reveals five essential aspects of the process:

(1) it is informed by up-to-date information on international research trends across the academic, governmental and industrial sectors;
(2) it integrates "science-push" and "demand-pull" perspectives by involving active researchers from both academia and industry;

(3) priority setting is by a "bottom-up" process providing a framework for the incorporation of a wide range of interests, including those of the scientific community and industry;

(4) the role of government agencies is to identify broad trends only, leaving the forecasting of commercial applications to industrial associations and individual firms; and

(5) perhaps the main benefit derives from the forecasting process, rather than the forecasts themselves.

This forecasting process is characterised alliteratively as comprising "communication, concentration on the future, coordination, creation of consensus, and commitment" (Irvine and Martin 1984a, p 144).

CONCLUSIONS

The successful identification and promotion of the exploitable areas of science must draw on a range of evaluation and forecasting techniques designed to assess:

- the quality of scientific research;
- the effectiveness of strategic research programs and of policy to promote strategic research in specific areas of science; and
- future economic and social conditions.

Integrating these diverse aims is a novel task. It presumes greater interaction than commonly exists between the peer-review oriented "gatekeepers" of basic scientific research and those charged with the implementation and evaluation of technological, industrial, economic and social policy. But, as the diversity of national approaches shows, there is no universal mechanism by which these goals can be achieved. As Gibbons and Gourghiu (1986) emphasise, "the purpose of evaluations and the methods and criteria applied to them have their bases in the socio-economic context of each country" (p 97). The role of evaluation and forecasting must therefore be viewed against the background of national S&T research and policy infrastructures.
CHAPTER 7  
DIRECTIONS AND DETERMINANTS

The final Chapter of this study attempts to identify common directions in public policy for the exploitable areas of science and to assess their determinants. Can essential policy elements be defined, and to what extent are the ways in which these elements are addressed, in terms of the organisation of public support for R&D, generally applicable throughout the countries studied?

ELEMENTS OF A POLICY

As noted in Chapter 2, the British ACARD has proposed four elements of a process for "exploiting" science:

- information gathering and communication;
- identification of exploitable scientific areas;
- allocation of resources to the priority areas; and
- commitment to exploiting the results.

While these are appropriate "goals" of a policy, ACARD was deliberately imprecise about the mechanisms by which they might be achieved within the national R&D and socio-economic infrastructure.

In a 1982 review Stankiewicz identifies three critical factors lacking in Swedish support for "basic technologies", namely:

1. adequate provision for basic technological research fields, which were being squeezed between expanding budgets for fundamental sciences and for short term development work;
2. the appropriate organisational forms for the support of basic technologies; and
3. the appropriate mechanisms for setting priorities in basic technology.

By slight extension, these may also be considered necessary conditions for a successful process for the "exploitable areas of science" (indeed the Japanese would recognise little difference between that term and their "base technologies"). The conditions thus become:

- specific provision for strategic research in the priority areas;
- new or adapted structures or institutions required to fund, perform and exploit the results of research; and
- the national forecasting, planning and coordination mechanisms that direct or facilitate the process.

The scientific and technological infrastructure of many countries is indeed moving towards fulfilling these conditions. Blume (1986) sees three essential features of public science policy in the 1980s: looking ahead (i.e. forecasting and strategic planning); new approaches to decision-making; and the establishment of new forms of relationship between universities and industry.

Each of these trends is clearly relevant to the "exploitation" of science. Indeed, "exploitability" may be seen as the most significant of the driving forces behind all these changes in as far as they reflect closer links between science policy and industry policy. They address the mechanisms needed to identify the "exploitable areas"; to allocate resources specifically for strategic research; and to implement programs of strategic research in the selected priority areas.

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Using these headings, it is possible to see how science policy in the countries under study is being directed towards meeting the goals elaborated by ACARD and the conditions set out by Stankiewicz, and how the common types of approach identified by Blume have arisen.

THE IDENTIFICATION OF EXPLOITABLE AREAS

What types of inputs are required to identify "exploitable areas" of science and who provides them? Chapter 6 has discussed the necessity for incorporating criteria both "internal" and "external" to research in identifying nationally exploitable areas of science and suggested that integration of different approaches into a "forecasting" process is the most notable way in which this has been achieved.

As a corollary, there must be some formal or informal institutional mechanism for addressing questions of social and economic choice in R&D. It is unlikely that bodies such as research councils by themselves can themselves adequately address these "external" criteria in identification of priority areas (the role of research councils is discussed below). If an avenue does not exist, it must be created. The UK CEST is an example where a body has been created to redress what ACARD describes as the "lack of forum".

The breadth of participation in such forums varies considerably between countries. In Japan, strategic research priorities are very strongly influenced by industry and the industry associations, but it is nevertheless a "bottom-up" consensus-building process with input from the academic research community as well.

In Sweden, for example, there is a high level of technological awareness among the population and a tradition of negotiation and consensus. As a result, the Swedish approach to the development of new technology within their society is neither laissez faire nor merely reactive. Rather, as Leyten and Smits (1987, p 8) remark, Sweden uses "technology assessment as [an] instrument of public policy". By this they mean that the key question to be considered is a particular technology's role in either the origin or resolution of social (including economic) problems.

Similarly, in the Netherlands, as Blume remarks, "the broadly consultative, consensual approach to policy-making and coordination ... seems a feature of Dutch social processes" (1986, p 75) and this is reflected in the belief that priority setting must also have a network-like, consultative and non-hierarchical character. Sector councils provide a means for industry and other research users to influence public sector research priorities. The role of the VCs has changed from a primarily academic assessment of research to an important priority setting input to policy.

In Britain, Yoxen (1984) notes that while the Government clearly has a policy for the development of biotechnology, important questions have not been fully or publicly considered. In particular,

"technology assessment has been absent here from the process of building up a consensus behind a set of policies for technological innovation" (p 219).

While CEST is a significant move to bring the industrial and commercial sector into this process, there appears to be little attempt to initiate a wider community or even parliamentary debate on national scientific R&D policies and priorities.

The scope of the priority areas

The scope of the selected priority areas reflects to no small degree the breadth of the consultative process employed in their selection. While this study has not attempted to catalogue all "exploitable areas" identified by each country, similarities are obvious. All emphasise aspects of the "generic" or "basic" technologies; namely information technology, biotechnology and materials technologies. But it is also interesting to see where national priorities lie outside these areas.
Britain's priorities lie squarely in existing industrial sectors like manufacturing engineering and marine technologies, and (in SERC priorities at least) in traditionally strong scientific research areas.

While also focusing on the "base technologies", the Japanese' research priorities indicate concern with wider social problems such as the biological ageing process, disaster prevention and the development of pollution-free industrial processes.

Similarly, the Dutch IOPs include in their current or proposed programs R&D into building construction, equipment for the handicapped, metal recycling and noise control. Sweden's existing industrial strengths are represented in the emphasis on health, chemical and wood technologies. Environmental research is also accorded priority and special provision is made for research into the cultural and social aspects of technology, for example the implications for employment.

Two lines of argument appear to justify choice of priority areas. Firstly, to be sustainable, exploitable science must draw upon some national comparative advantage, be it by virtue of basic scientific research strength, industrial or commercial expertise or social or cultural advantage. This logic implies a "niche strategy" for selecting S&T priorities. Secondly, to remain (or become) an advanced industrial nation, one must excel in or at least remain abreast of those areas of science which are likely to form the basis of widely applicable developing technologies. This may be termed the "generic technology" approach.

Both arguments have validity. Interestingly, the choice of priority areas by the countries in this study suggests that it is possible, even for the smaller economies, to pursue both strategies simultaneously.

**High level coordination**

The availability of expert advice from the generators and users of research is insufficient in itself to promote the "exploitable areas of science" (e.g. see ASTEC 1981). As Irvine and Martin (1984a) emphasise, priority setting must go beyond simply identifying new research areas of potential long-term social significance. It must ensure that researchers and policy-makers in industry, government and elsewhere act upon this information when research resources are allocated, and that somebody has responsibility for resolving divergent or even conflicting lines of advice. To Blume, the "lessons" of strategic planning,

"imply something more than the existence of a small planning and forecasting unit somewhere in government. To the contrary, they imply something of a transformation in the way priorities (part of the essence of science policy after all) are established" (1986, p 58).

Again this implies a closer link between the research and the policy-making processes. It requires both information networks and a commitment to the priorities so identified. This is seen as the Japanese success: the process for identification of research priorities is cooperative and consensual, thus assuring some measure of implementation.

While such broad consensus (as in Japan and also Sweden) is certainly important, a trend towards more powerful national S&T policy coordination and decision-making bodies closely linked to the political process is also identifiable. In some countries, such bodies have been the prime movers in reorienting R&D policy towards "exploitability". Blume explains this in terms of the relative failure of higher education and industry ministries to come to grips with planning for strategic research: "In the UK, for example, it was ACARD (and no ministry) which thrust the 1980s on government" (1986 p 73).

The establishment of the Prime Ministerial ACOST in the UK, and similar proposals in the Netherlands, reflect this trend. The Swedes' Research Advisory Board, chaired by the Prime Minister, may be taken as a long-standing model for these high level advisory bodies; but the extent of the Swedish Parliament's involvement in determination of research priorities is perhaps unique.
These high level bodies also act as arbitrators: for example between ministries responsible for higher education sector research interests and those primarily concerned with industrial and technological R&D. Even in consensual Japan, the CST seems to be adopting a more active role in selection of priority research areas and this must partly be due to the rivalry between Monbusho, MITI and the STA. By contrast, policy direction in the Netherlands appears relatively weak in the absence of a high level body to coordinate the various public R&D sectors.

THE ORGANISATION OF STRATEGIC RESEARCH

Reversing "sectorisation"

Blume (1986) makes the point that the decision-making structures of the 1970s may be inadequate to cope with the challenges of the 1980s and beyond. This partly explains the emergence of the more powerful executive bodies mentioned above. Specifically, he regards countries like Britain and Sweden as having gone too far in the direction of short-term "demand pull" or sectorisation. As we have seen in previous chapters, the recent history of both countries' science policy reflects a substantial reversal of this trend.

In Britain, the establishment of CEST and the abolition of the DTI's sectoral Research Requirement Boards reflects a more integrated approach to industry and public research needs. It is perhaps also significant that the Medical Research Council, which strongly promotes R&D in biotechnology, was one of the first governmental bodies in Britain to abandon the strait-jacket of the Rothschild customer/contractor arrangements.

Recent organisational changes in Dutch R&D are aimed at greater coordination between public research institutes. In Sweden the unique research coordinating council, FRN, and formal inputs by sectoral research bodies (including STU) and UHA into the national Research Bill process achieve a long-term, coordinated view of research needs.

Strategic research in the higher education sector

In all countries studied, research within the higher education sector is a significant contributor to the national R&D effort (Figure A.1), particularly in basic and strategic research, and all are moving to marshal this potentially "exploitable" resource.

Two main strategies may be noted. Firstly, all countries, except (at least until recently) Japan, are planning university research more explicitly, for example by reducing the level of general university funding compared with what Martin and Irvine term academic, separately budgeted research (e.g. research project and program funding) (see Figure A.2) although none yet approaches the US level of ASBR; and by concentrating research into special centres dedicated to the priority areas. Secondly is the trend towards collaborative programs of strategic research, often involving the higher education research sector and the commercial sector. As Blume notes, the "renewed attention to links between universities and industry is one of the most striking aspects of science policy today", (1986, p 61).

In Britain, UGC policy is to provide general university funds for research on a more critical and selective basis, with separate allocation of the research component. Research funding is also being concentrated into fewer universities and departments. SERC is reducing the proportion of "proposal driven" funding in favour of priority programs, particularly within the IRCs. Unlike the Netherlands, however, the British Government is attempting to reform the university research system against a background of declining real public support for basic and strategic scientific research in this sector.

The Dutch are trying to reduce the level of general university funding for research (which is the highest proportion of any country studied) by increasing separately budgeted research funds and through the "conditional financing" program. The criteria for funding under this program encompass the national and social relevance of the research.
With few government research institutions, Sweden is more heavily reliant on the higher education research sector than the other countries studied. In consequence, this sector is very well coordinated and is closely attuned to national priorities. The UHA consults with sectoral research bodies and feeds the results of this and its own evaluations of university science into the consensual Research Bill process.

The Japanese universities appear to be led in their research, rather than national leaders. There is little formal sign of concentration of R&D funding in Japanese universities. It is STA and MITI (through the AISIT) rather than Monbusho that are becoming increasingly involved in setting strategic and even basic research priorities out of a concern for the need to strengthen Japan's research base.

IMPLEMENTATION OF POLICIES AND PROGRAMS FOR THE EXPLOITABLE AREAS OF SCIENCE

The changing role of Research Councils

A recent paper by van Rossum (1986) on the changing role of research councils in several countries attempts to explain why councils have adopted differing roles in the implementation of policies for exploitable science.

Van Rossum notes that research councils were originally established to separate decision-making on the level of research funding from that of the allocation of funds over various fields. Assessment of research using "internal" criteria and peer review was the norm. The emerging emphasis on priority setting for strategic research has encouraged research councils to become, in van Rossum's words, more "programmatic" and led to new demands on the structure of councils.

Van Rossum classifies research councils as either "brokers" or "gatekeepers". Brokers are oriented more towards the environment of scientific research and concerned with achieving linkages between the producers and the users of research. Gatekeepers are more inwardly focused on the science system and, by controlling the purse strings, are guarantors of the quality of research. In classifying a specific research council, van Rossum considers the extent to which organisations outside the research sphere are involved in the council's deliberations; and also how its research priorities are set. For example, is the process "bottom up" (solely research driven) or does it involve an "eclectic combination of bottom-up and top-down procedures in choosing among scientific fields" (1986, p. 4). Van Rossum thus categorises the British research councils as "brokers", while the Swedish and Dutch councils conform more to the "gatekeeper" model. Brokers are often regarded as the vehicle by which government scientific research priorities can be implemented, whilst gatekeepers may be seen as the main obstacle in their resistance to policies for strategic science.

Governments have therefore adopted different strategies to implement policies for the exploitable areas of science depending in part on the structure and attitudes of the existing research councils. Van Rossum recognises three main strategies:

1. Establishment of new bodies to choose and implement research priorities. Here, existing research councils are not formally involved, although they may assist with evaluations etc. In this case national priorities are determined outside the research council system;

2. Adaptation of existing structures and procedures. This approach requires research councils explicitly to choose and implement national priorities, i.e. the process is essentially assimilated within their existing evaluation and selection mechanisms; and

3. Establishment of new organisations, but formally linking them with the research councils. This leaves the research councils' existing procedures unchanged but involves the councils formally in the determination and/or implementation of national priorities.
As van Rossum points out, the differences observed between countries' response to the exploitation of scientific research are a product of the extent of government involvement in funding research; the structure of the research system; and the political structure of the country.

In the Netherlands, ZWO is seen more as a quality control mechanism for pure scientific research (although Blume even doubts its capacity here). Although ZWO is starting to support more research in priority areas, the implementation of priority programs of strategic research is usually carried out elsewhere: through STW, IOPs or government research institutions, for example. The STW was set up in 1981 specifically to stimulate technological research by linking the research base with industry users. This organisational dichotomy leads to some discontinuity in the linkages between basic, strategic and applied research.

In Japan the universities are involved in collaborative strategic research programs, but these are more likely be directed from MITI or the STA than the Science Council.

The second option, admitting "external" criteria for research priority formulation within the research councils, engenders change in the internal structure of the councils and their external links, as "each priority involves different organizations and agencies" (van Rossum 1986, p 13). This implies a wider "brokerage" role and greater flexibility in the council's organisation. Councils may implement programs of strategic research directly by indicating priority areas and funding them accordingly, or indirectly by reallocation of resources away from general funding programs. In the case of the British SERC, for example, this trend is reflected in the setting up of Directorates and SPPs in areas of 'perceived national need'. Even so, evaluation within SERC remains primarily 'peer review' with industrial relevance becoming an ancillary criterion of choice in some cases.

The Swedish research councils and executive boards (like UHA) are strong, as are the universities themselves, and the university research sector performs much of the country's strategic research. Sweden has therefore adopted the third strategy. Although the research councils supply only 10% of university funds, they are influential not only in ensuring scientific quality, but also in determining broader national research needs.

The "traditional" research councils, especially NFR, do attempt to address future priorities, but largely though peer review mechanisms. The Council for Planning and Coordination of Research (FRN) is a unique quasi-research council enjoying a significant advisory and coordinating role in the determination of research priorities and overseeing collaborative programs in priority interdisciplinary areas. It is not closely involved with the implementation of the research: the responsibility for this lies with the other research councils or with the National Board for Technical Development (STU). Priority programs are executed via normal research council procedures; i.e. soliciting of proposals, and their evaluation by peer review. In the case of the microelectronics program, a forerunner to the current national information technology program, basic/strategic research was handled by NFR and the technology development side by STU. A special committee was set up to solicit proposals, but these were then evaluated through normal NFR channels.

Van Rossum suggests that this type of procedure may create some discrepancy between the objectives of the priority program, and its elaboration within the research council. This source of potential conflict is not confined to Sweden of course:

"One of the grey areas of science and technology policy concerns the relationship between priorities and the development of policies which effectively can co-ordinate action aimed at attaining them" (OECD 1984, p 42).

Research councils are well placed to assist in recognising exploitable areas of science, to evaluate the excellence of research programs within such areas and to facilitate their implementation within the higher education research sector. Certainly, the active participation of research councils should lead to a better concordance between basic research and national priorities. Van Rossum appears correct in suggesting that most councils are moving towards a more active
"brokerage" role in this regard. But he also cautions against excessive government direction of research council programs:

"strategic scientific research directed towards future technological applications does not work efficiently with a top-down approach" (1986, p 5)

Too great an emphasis on "top-down" government control, van Rossum argues, can endanger the brokerage role of the research council, and that role is essential in linking scientific institutions with other agencies in the society and economy.

Collaborative programs of strategic research

All the countries in this study have established separate collaborative (industry/public sector) programs to promote longer-term research in some "exploitable areas" of science. Except in Japan, these are run with some involvement by the relevant research council and/or the scientific academies.

In the UK, SERC was involved in the Alvey IT program and is also a partner in most of the programs under the DTI's new LINK scheme. DTI has indicated that its R&D funding will in future be largely restricted to such collaborative ventures.

The collaborative program seems the prime mechanism for strategic research in Japan, with ERATO and the NGBT scheme in particular linking industrial, government and university research.

The IOPs in the Netherlands appear to be very effective in promoting excellent strategic research in the national priority areas by bringing together universities, government research institutes and industry. Universities contribute 50% of the cost of the program, but there is surprisingly little financial support from industry despite their influence over the direction of the IOP.

In Sweden, collaborative R&D appears more institutionalised and there is perhaps less need for specific collaborative programs. The Government (through STU), universities and the private sector are cooperating in joint R&D in areas such as biotechnology and IT.

In countries where a significant proportion of R&D is carried out by government research institutions, these bodies can be expected to participate in, or even initiate, national programs of strategic research. The Dutch Organisation for Applied Research (TNO) is becoming increasingly involved in strategic research themes. In the UK, the Ministry of Defence is a significant contributor to the Alvey program, but there is less sign of involvement in strategic research by civil ministries.

As Rip et al (1986) point out, the establishment of new, structured programs for the priority areas avoids problems of ad hocism, but the programs themselves may become institutionalised and, eventually, perhaps inappropriate. Many such programs therefore are specifically established for a limited duration.

CONCLUSIONS

As suggested in Chapter 1, the definition of national "exploitable areas" of scientific research is largely a political exercise. The methods of selection employed and the scope of scientific priorities chosen reflect the dominant policy-making models within the country and diverge quite considerably between the countries studied.

While all countries have chosen a similar core of "exploitable areas" related to the emerging "generic" technologies, they place differing emphasis on other areas of relevance to existing national scientific, industrial or even cultural strengths.

Implementation of the chosen research priorities also varies between countries. Here, the focus is determined by the relative importance of the academic, government and industrial research
sectors, and by the national S&T policy and funding structures. To a degree, implementation does require new models of research coordination and funding; however, the more successful may be viewed as means of facilitating research collaboration in priority areas rather than directing it.

The UK, for example, is moving decisively away from the trichotomy of academic, sectoral public and private sector R&D. Despite some successes, notably the Alvey program, a broadly based structure for determining and implementing research priorities has been put in place only recently. The success of the Government’s 1987 policy changes may turn on whether the public research sector can adequately respond given a declining level of civil research resources that are already proportionately the lowest of the countries studied.

The Netherlands has developed some elements of the “exploitable areas” process well (e.g. the IOPs and the VCs and Sector Councils). Rather surprisingly, collaboration within the public research sector and between it and industry does not appear as well developed. There appears to be a lack of national coordination and goals. The inertia of the independent university sector and of the large government research institutions in the face of reform may also be a factor.

Sweden and Japan emerge as the countries with the most comprehensive national “vision” of science and technology’s role in their society and the more effective means of channelling R&D resources towards national goals.

A cause of potential conflict is that the development of policy tools appropriate to what Blume (1986) terms “the new strategic thinking” have had selective application to specific fields deemed of importance (e.g. biotechnology or IT related areas of science). Blume cautions that,

"there are grave dangers attaching to excessive emphasis upon what appear to be the 'relevant' sciences" (p 62),

because,

"intellectually, we have to remember that 'relevance' in research is a concept which has changed its meaning; there is no inevitable one-to-one correlation with the notion that the customer knows best. Science can be - and sciences are - relevant in different ways" (p 76).

Ultimately, it is impossible to gauge which scientific skills future society will require. For this reason we may agree with Irvine and Martin (1984a) that “a modern industrial state needs to support a balanced portfolio of basic research interests”. Only a limited proportion of the national R&D resource can sensibly be directed to what are currently determined potentially "exploitable areas", but there is no clear consensus what proportion this might reasonably be. Significantly, countries like Japan and Sweden that appear to have the most advanced strategic planning systems for S&T are also those that are increasingly emphasising the importance of basic research as a foundation for their long-term technological, economic and social development.

The experience of these countries provides lessons for developing public policies for exploitation of Australian scientific research, provided we understand why and how particular policies and administrative mechanisms have come to be chosen. The present study has attempted to illuminate that understanding.
APPENDIX

THE RESEARCH ENVIRONMENT: INTERCOUNTRY COMPARISONS

As a backdrop to examining national research policies in detail, it is appropriate to consider gross differences in the level and distribution of R&D that may affect the development of policies for exploitable scientific research.

Figure A.1 shows the R&D intensity (expressed as a percentage of national GDP) for the four countries under study (the US and Australia are added for comparison). All four have a high level of R&D expenditure by OECD standards and in all cases the majority is performed by the business enterprise sector. Most significant are the differences in the relative and absolute contribution of the three major sectors (business, government and higher education) between countries. Significant differences also occur in sources of research funding and in the contribution of military research (see OECD 1987b).

FIGURE A.1

R&D EXPENDITURE BY SECTOR OF PERFORMANCE IN SIX OECD MEMBER COUNTRIES, 1985

BERD is business enterprise R&D (including public enterprises); PNP is private, non-profit sector R&D (small in all countries); HERD is higher education sector R&D (figure for Japan is adjusted by OECD for comparability). Sources: OECD 1987b; Jones 1986 (Australia).

Ideally, R&D statistics to inform policy development for exploitable areas of science would include a breakdown by research category (basic, strategic etc), scientific discipline (or technological area), sector or sub-sector of performance, and source of funds. Martin and Irvine (1986) have attempted to improve upon OECD statistics for publicly funded academic and related
R&D by enhancing comparability between countries and providing greater disaggregation of research fields and funding channels.

Figure A.2 gives their aggregated results for the UK, Japan and the Netherlands, with US figures for comparison. The different emphases given to various channels of funding and types of research institution are clear. Also significant in Martin and Irvine's data are the differences in level of support of specialisms between countries, and the variation in type of support given to different specialisms within countries. However, they do not attempt to distinguish between basic, strategic and applied research or development except in the case of "academically related" research.

**FIGURE A.2**

**GOVERNMENT FUNDING OF ACADEMIC AND ACADEMICALLY RELATED RESEARCH IN NATURAL SCIENCES AND ENGINEERING IN THE U.S., U.K., JAPAN AND NETHERLANDS, 1982.**

GUF is academic R&D financed by general university funds; ASBR is academic, separately budgeted R&D (e.g. research council grants); ARR is academically related research carried out either in central facilities for academic researchers or in government laboratories performing "longer-term and more basic research indistinguishable from that found in academic institutions". 

Source: Martin and Irvine 1986.

Readily available R&D statistics therefore provide useful indicators of the broad R&D environment of the countries in this study. However, the level of emphasis on priority areas of strategic research can be gauged only by considering the specific research policies of each country. Even then, statistics on the level of strategic research within industry, for example, are virtually non-existent.
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### ABBREVIATIONS AND ACRONYMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ABRC</td>
<td>Advisory Board for the Research Councils (UK)</td>
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<td>ACARD</td>
<td>Advisory Council for Applied Research and Development (UK)</td>
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<tr>
<td>ACOST</td>
<td>Advisory Council on Science and Technology (UK)</td>
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<tr>
<td>AFRC</td>
<td>Agricultural and Food Research Council (UK)</td>
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<td>AIST</td>
<td>Agency of Industrial Science and Technology (MITI, Japan)</td>
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<tr>
<td>ARC</td>
<td>Australian Research Council</td>
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<td>ASIETC</td>
<td>Australian Science and Technology Council</td>
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<tr>
<td>BCCJ</td>
<td>British Chamber of Commerce in Japan</td>
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<tr>
<td>CERN</td>
<td>European Organisation for Nuclear Research</td>
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<tr>
<td>CEST</td>
<td>Centre for Exploitation of Science and Technology (UK)</td>
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<tr>
<td>CST</td>
<td>Council for Science and Technology (Japan)</td>
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<td>DTI</td>
<td>Department of Trade and Industry (UK)</td>
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<td>EC</td>
<td>European Community</td>
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<td>EFTA</td>
<td>European Free Trade Association</td>
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<td>ERATO</td>
<td>Program for Exploratory Research in Advanced Technologies (STA, Japan)</td>
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<tr>
<td>FRN</td>
<td>Council for Planning and Coordination of Research (Sweden)</td>
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<tr>
<td>GERD</td>
<td>gross [national] expenditure on R&amp;D</td>
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<td>GUF</td>
<td>general university funds [or funding]</td>
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<tr>
<td>HERD</td>
<td>higher education [sector] R&amp;D</td>
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<tr>
<td>ICOT</td>
<td>Institute for New Generation Computer Technology (Japan)</td>
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<tr>
<td>INSP</td>
<td>Informatics Stimulation Plan (Netherlands)</td>
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<td>IOP</td>
<td>Innovation-Oriented Research Program (Netherlands)</td>
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<tr>
<td>IRC</td>
<td>Interdisciplinary Research Centre (UK)</td>
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<td>IT</td>
<td>information technology</td>
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<tr>
<td>KNAW</td>
<td>Royal Netherlands Academy of Arts and Sciences</td>
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<tr>
<td>MITI</td>
<td>Ministry for International Trade and Industry (Japan)</td>
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<tr>
<td>MoD</td>
<td>Ministry of Defence (UK)</td>
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<tr>
<td>MRC</td>
<td>Medical Research Council (UK)</td>
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<td>NFR</td>
<td>Natural Sciences Research Council (Sweden)</td>
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<td>Abbreviation</td>
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<tr>
<td>NGBT</td>
<td>Next Generation Base Technologies Development Program (AIST, Japan)</td>
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<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
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<tr>
<td>OTA</td>
<td>Office of Technology Assessment (Congress, USA)</td>
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<tr>
<td>PREST</td>
<td>Programme of Policy Research in Engineering, Science and Technology (University of Manchester)</td>
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<tr>
<td>R&amp;D</td>
<td>research and development</td>
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<td>RAWB</td>
<td>Advisory Council for Science Policy (Netherlands)</td>
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<tr>
<td>S&amp;T</td>
<td>science and technology, scientific and technological</td>
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<tr>
<td>SERC</td>
<td>Science and Engineering Research Council (UK)</td>
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<tr>
<td>SPP</td>
<td>Specially Promoted Programme (SERC, UK)</td>
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<td>STA</td>
<td>Science and Technology Agency (Japan)</td>
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<tr>
<td>STU</td>
<td>National Board for Technical Development (Sweden)</td>
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<tr>
<td>STW</td>
<td>Technical Sciences Foundation (Netherlands)</td>
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<tr>
<td>TNC</td>
<td>transnational company [or corporation]</td>
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<tr>
<td>TNO</td>
<td>Organisation for Applied Scientific Research (Netherlands)</td>
</tr>
<tr>
<td>UFC</td>
<td>University Funding Council (UK)</td>
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<tr>
<td>UGC</td>
<td>University Grants Committee (UK)</td>
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<tr>
<td>UHA</td>
<td>National Board of Universities and Colleges (Sweden)</td>
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<tr>
<td>VC</td>
<td>Exploratory Commission (Netherlands)</td>
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<tr>
<td>VLSI</td>
<td>very large-scale integration [or integrated] [circuit]</td>
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<tr>
<td>ZWO</td>
<td>Organisation for the Advancement of Pure Research (Netherlands)</td>
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