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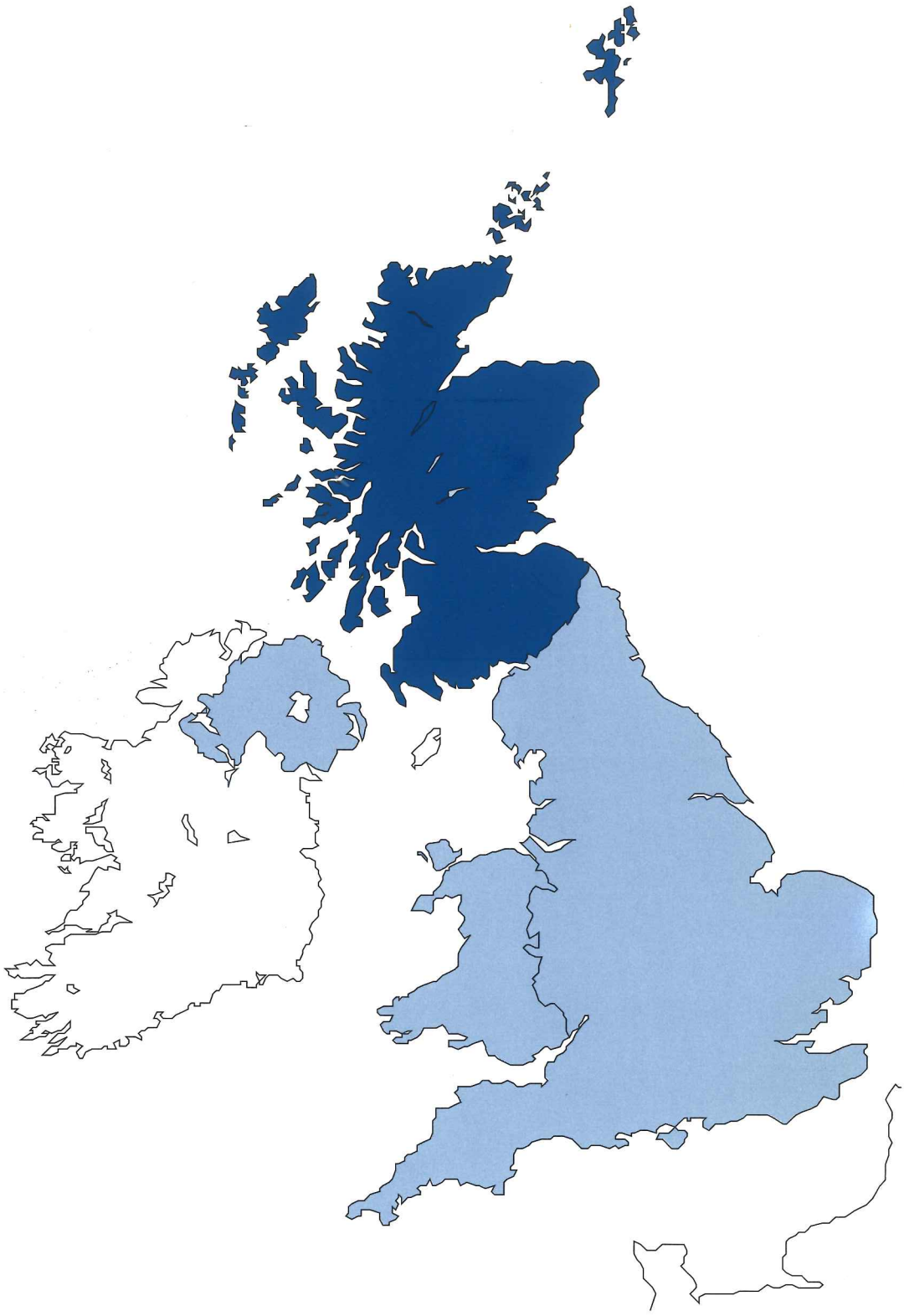
Devolution and Science

Report by a Joint Working Group of the Royal Society of London and the Royal Society of Edinburgh



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Summary

1 The publicly funded research capability in Science, Engineering and Technology (the SET base) is a vital resource for a modern society. It creates new knowledge and concepts, new products, new processes and newly trained scientists, engineers and technologists who continually regenerate the scientific capability of industry, commerce, government and of the SET base itself. Its innovations lead to improvements in the quality of life, more competitive and prosperous industries and a stronger national economy.

2 Devolution will change the patterns of responsibility for regional components of the SET base and is likely to produce regional priorities for it. This will create both risks to the effectiveness of the SET base and opportunities to increase its effectiveness. It will be important to avoid the former and exploit the latter.

3 The UK has strong basic research which has the **diversity** to permit it to adapt to innovation no matter what its source, **focus** in areas where there is the best match between scientific opportunity and potential for utility, and is **excellent** by international standards.

4 These are benefits, which Scotland shares, which flow from the large size and competitiveness of the UK basic research system. The dis-economies of small scale are severe, and barriers between Scotland and the rest of the UK would be to the great disadvantage of all. It is vital therefore that Scotland remains a well integrated part of the UK SET base.

5 Devolution also creates an opportunity to use the science base more effectively to support distinctive Scottish priorities

- in promoting wealth creation and the quality of life
- in policies for health, education, agriculture, fisheries and the environment
- in supporting the new Parliament in its scrutiny of policy and legislation

6 Amongst the report's recommendations are

- that the Parliament adopts an explicit policy to sustain Scotland's role in the UK SET base whilst promoting greater regional efforts to benefit from it;
- that a senior minister is appointed with principal responsibility for SET in Scotland, supported by a Science Policy Advisory Board with high level representation from the research and industrial sectors and chaired by a senior scientist;
- that a senior scientist of international standing is appointed to ensure a strong, functional focus for SET in Scotland, with responsibility for SET advice to ministers, for liaison with UK science policy bodies, and for day-to-day implementation of SET policy. This post should be embedded as a cross-Departmental function within the Scottish Civil Service;
- that the new Parliament takes steps to ensure that it has access to sources of authoritative and independent scientific advice to underpin its scrutinising and legislative roles.

1 Rationale for this Report

1 An important part of the publicly funded UK capacity in Science, Engineering and Technology (the SET base) is located in Scotland and is an asset to Scotland and to the UK as a whole. Scotland will continue to need a vigorous SET base after devolution, because it provides :

- an important contribution to a wide range of policy decisions relating to the economy, health, education, agriculture, fisheries, energy and the environment;
- people educated and trained in SET who are a vital resource in both public and private sectors of society;
- the foundations for new insights, more effective policies designed to improve the quality of life, more competitive and prosperous industries and a stronger national economy.

2 These are issues to which the new Scottish Parliament is likely to accord a high priority. The transfer to it of responsibility for a significant proportion of Scotland's SET base will require it to determine priorities and decide how the diverse functions of the SET base should be managed efficiently. This will be both a challenge and an opportunity; the Parliament will need to develop distinctive policies for the SET base which take advantage of existing linkages with the rest of the UK whilst adapting it to the special needs of Scotland.

3 The UK has a world-leading SET base. Amongst developed countries it has the largest output of published papers at the lowest unit cost.[1] The cumulative impact of devolution in Scotland, Wales and Northern Ireland poses a challenge for the UK SET base as whole; both to maintain its leading position and to ensure that its excellence can be used to support the regional benefits which devolution is designed to bring.

4 The Royal Society, as the UK's Academy of Sciences, and the Royal Society of Edinburgh as Scotland's Academy of Science and Letters, are respected sources of expert advice in matters relating to the SET base. The Councils of both

Research income in universities 1996-97 (£1000s) Source: HESA

	Scotland		Rest of UK	
	Total	Per FTE Researcher	Total	Per FTE Researcher
Funding Councils	102 000	7.5	679 339	7.0
Research Councils	65 943	4.9	459 200	4.7
Government Department	37 367	2.8	259 368	2.7
European Union	18 593	1.4	139 089	1.4
Charities	42 477	3.1	321 883	3.3
Industry	23 955	1.8	164 105	1.7

Research and development expenditure 1996 (£m) Source: ONS

	Business		Government		Universities		Total
	Total	%	Total	%	Total	%	Total
England	8 743	1.4	1 852	0.3	2 282	0.4	12 877
Wales	117	0.4	32	0.1	105	0.3	254
Scotland	357	0.6	163	0.3	348	0.5	868
Northern Ireland	83	0.5	23	0.1	57	0.3	163
UK Total	**9 300**		**2 070**		**2 792**		**14 162**

Societies decided to carry out this joint study into the effect of devolution on the SET base, recognising that it is a complex issue with both UK and distinctively regional aspects. Although this report focuses primarily on issues for Scotland after devolution, the issues which it highlights are relevant to devolution in Wales and Northern Ireland, and of importance for the whole of the UK SET base.

2 Purposes of Government Funding of Science, Engineering and Technology

5 The Science Engineering and Technology (SET) Base consists of scientists and the physical plant needed to support their work, located primarily in universities, Research Council laboratories and the research laboratories of Government Departments and of Government-funded agencies. Its output is new knowledge and concepts, new products, new processes and newly trained scientists, engineers and technologists who continually regenerate the scientific capability of industry, commerce, government and of the SET base itself.

6 It is right for the Scottish Executive and UK Government to invest substantial resources in funding SET because they are responsible for public health, safety and well being, and for the care and sustainable development of the environment. Scientific knowledge is an essential basis for standards and measures in all these fields, although it is not sufficient on its own; economic understanding, social values and political judgements all interact to determine final policy.[2] The Governments are responsible for education, at school and university level, and hence for the maintenance of curricular content and standards. Governments in all developed countries have traditionally been the funders of basic research which, while it is vital to the success of industry and commerce in the long term, is unlikely to be financed by the private sector because it is not usually driven by immediate market needs.

7 The increasing rate at which scientific innovation is exploited to create useful and marketable technologies reflects the central role of SET in the development of a knowledge-based economy. Econometric research indicates a high rate of return from investment in scientific research by governments, and suggests that it may be as high as 28%.[3]

8 The seeds of tomorrow's capabilities need to be sown now. An efficient modern SET base must be the equivalent of an investment portfolio comprising a range of investments from short term, with a predictable return, to longer term, more speculative components, from which the key capabilities of tomorrow's SET will be generated.

3 The drivers for change in Scotland

9 Scotland is a very small country. Its ability to sustain a competitive, healthy society in the competitive global economy will depend upon the development of the skills and knowledge of its people and their innovative application in industry, in health and in environmental quality. The SET base is critical to this enterprise. The drivers of decisions for change in the SET base in Scotland will be the needs of the economy, of Government, of Parliament and of civil society. These are expressed below in bold type, followed by important issues associated with them in each case.

Economic needs

10 There will be a need to manage (and to be seen to manage) the Scottish economy, including its employment base. In the complex knowledge-driven economy envisaged in the 1998 White Paper on competitiveness, the influence of science, engineering and technology on the economic health of the nation will be pervasive. Unless there is a healthy SET base and appropriate two-way linkages with industry, many sectors of the Scottish economy are likely to fail the test of international competitiveness. Equally, without an internationally-competitive economy, the quality of life for Scottish citizens will deteriorate in wealth, health and culture. Science, engineering and technology have too direct an impact on the economy of Scotland for a laissez-faire policy to be acceptable.

11 Economic imperatives require the best use to be made of available Scottish resources, through co-ordination of relevant activities of five major players - Scottish higher and further education, the departments and associated laboratories of the Scottish Executive, Scottish Enterprise, UK Research Council Institutes and industry - to prevent the dissipation of resource through fragmentation of effort. This will require the roles of individual groups to be defined and structures or policies to be put in place which will facilitate more extensive, more innovative, and more productive interactions. There will be a strategic need to achieve successful integration of the links in the chain of innovation, from basic research to exploitation, with the needs of users playing an integral part.

12 There will be a natural tendency to focus attention on enhanced economic exploitation of the existing, internationally competitive SET base in Scotland. If it is insensitively exploited, there is a risk not only that the creativity and excellence of the science base will deteriorate, but that the economic benefits which it currently brings to Scotland will decrease. It is important

therefore that the SET base is exploited sustainably, that enhanced economic benefits are reaped from it whilst maintaining its breadth, its capacity for creativity and innovation and its attractiveness to scientists of the highest calibre. The market for the good scientists is competitive and international, and they can easily be lost from a badly managed system. It will be vital to achieve an appropriate balance of resourcing between basic science and the promotion of application, with mechanisms to sustain both.

13 Scottish industry currently suffers from very low levels of investment in research and development (see box, p.2). For instance, the multinational companies that dominate one of the most important of its industrial sectors, the information and communications industry, have hitherto done virtually no research, design or even development work in Scotland, limiting interaction with universities to the provision of trained manpower. As a consequence, industry cannot pull through or exploit science base innovation as effectively as in other economies with a more mature industrial base. In the new field of biotechnology for example, although the UK is a clear second to the USA in the authorship of cited research papers, it is poor third to the USA and Japan in owning the patents.

14 A country of Scotland's size cannot be internationally competitive in all possible sectors of SET-based industry. There is a risk that it may not be able to respond quickly and flexibly to new technological and market opportunities, producing significant economic and social damage if existing technologies become rapidly redundant.

15 A rapidly evolving knowledge based economy depends upon skilled people and perennial up-dating of the skills base. It is not obvious however that a greater degree of strategic manpower planning in higher and further education by their funding agencies is the correct response. The rapid rate of technological change, often in unforeseen directions, and the rapid obsolescence of existing technologies argue for an education which inculcates a capacity for broad scientific understanding coupled with on-the-job specific training as the most flexible approach to training.

The needs of Government

16 The needs of Government are for advice to support evidence-based policies for improvement of the quality of life, science and technology to support regulation and standard setting and monitoring to assess the effectiveness of policies, for instance in health, natural resources and the environment.

17 Many modern science based issues have proved politically intractable because scientific information is inevitably incomplete on any issue at a given time, and because Governments have found it difficult to come to terms with scientific uncertainty, both in formulating policy and in communicating it to the public. The SET resources of the Scottish Civil Service will be limited in comparison with the diversity of scientific knowledge relevant to important issues of public policy. It will be important therefore to make use of the wider SET base in gleaning policy advice. Over-compartmentalisation between government departments and between scientific disciplines, and lack of co-ordination across the wider SET base tend to frustrate an effective, integrated use of the science base in policy formulation. Further problems arise because Government itself has often been reluctant to fund the science and technology which it needs to support evidence-based policies.

The needs of Parliament

18 The role of Parliaments in introducing and scrutinising legislation and overseeing the operation of government has been made difficult by the burgeoning scientific and technical complexity of many aspects of contemporary life. In order to fulfil their constitutional roles in relation to such issues, many Parliaments (eg. UK, Denmark, Germany, the Netherlands, USA) have sought to establish independent, authoritative sources of advice and information, not influenced by party-political considerations. The Scottish parliament will have a similar need.

19 The Parliament could depend for its advice on Government Departments, or contract the function to learned societies or to University consortia, or to the Westminster Parliament's Parliamentary Office of Science and Technology (POST), or to a body of its own creation. Experience elsewhere suggests that whatever the Parliament's choice, the source should have a primary loyalty to the Parliament; it should be independent; and it must not be seen merely as a lobby for science.

The needs of civil society

20 Increasing public concerns about many current science-based issues make it important that means are found to increase public understanding of the underlying scientific and technological issues and of the limitations of scientific understanding. Information must be seen as independent, authoritative and unconstrained by party politics.

21 Recent crises such as BSE and the debate about genetically-modified foods demonstrate how difficult it is to secure

public confidence in 'official' scientific advice or in government's custodianship of public welfare. Without an understanding of the nature of scientific advice, the distinction between such advice and the formulation of policy and means of reflecting public values in policy, public confidence in the political judgement of the Scottish Parliament itself could be put at risk.

4 Principles for Organisation of the SET Base in Scotland

22 There is a spectrum of SET activity ranging from research undertaken to acquire knowledge for its own sake to research directed towards immediate practical ends. Three categories are commonly recognised within this spectrum :

- Basic research : experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and of observable facts.
- Strategic research : original investigation undertaken to acquire new knowledge to form the basis of solutions to actual or future practical problems.
- Applied research and development : systematic work drawing on existing knowledge gained from research to produce new materials, products, devices, processes, systems or services, or to improving those already produced.

23 If the SET base is to respond in a sustained way to the needs set out in the preceding section it must be characterised by

- a strong capability in basic research
- excellent strategic and applied research
- efficient flows of knowledge and expertise from the SET base to users

This section sets out principles for the development of these attributes, and describes how they are embodied in the current UK SET base of the UK and of a number of other European countries, with a view to identifying models for Scotland after devolution.

Maintaining basic research

24 Basic research is the bedrock on which the ability of the SET base to address immediate and long term needs rests. It must be characterised by **focus** in areas of science opportunity and need, and **diversity** which gives flexibility to address new opportunities. The infrastructure costs of modern science are very large, and it would be prohibitively expensive even in a relatively substantial economy like that of the UK to maintain a world-class capability across all fields. Decisions therefore have to be made about investment priorities. While intellectual curiosity will always be a driving stimulus to science, a SET base which paid no regard to need would be an unaffordable luxury. Driving the SET base to address problems based on need alone, without heed to their tractability, is a recipe for waste. Priorities should therefore be set in areas where there is a conjunction of tractability and need. However, although investment choices must be made, they must not lead to over-specialisation which reduces the capacity to exploit unexpected innovations. The key to retaining the flexibility to exploit such opportunities lies in maintaining a broad capability in basic science which continuously re-synthesises specific knowledge in the form of general understanding with broad applicability.

25 The SET base must aspire to **excellence** by international standards. Liberalisation of global markets requires that successful business should be internationally competitive. It is increasingly free to locate itself where circumstances are favourable. For knowledge-based industries, this means in locations where there is an excellent SET base and a technically highly skilled population, which itself is part of the output of the SET base. Excellence, recognised by peer review judged against international standards, is therefore a prerequisite of an effective SET base. There is an analogous requirement for excellence in the SET which underpins Government policy, where public scrutiny is so great that only excellence is acceptable. There is no trade off between relevance and excellence. Only excellent SET is relevant.

26 There is a minimum efficient scale of scientific community and of resourcing below which it is difficult to sustain an internationally competitive basic research capability. This is because:

- a large scale research system has a greater capacity to maintain research diversity, and thereby the flexibility to pursue new directions;
- in a small scale system, it is difficult to achieve focus, for example in response to economic and policy imperatives, without losing diversity and difficult to allocate large sums from a relatively small resource to fund major facilities;
- excellence in basic research arises from its competitiveness. Driven partly by funding, partly by individual satisfaction and partly by the desire for esteem, it thrives in the greater competition and wider horizons that larger systems offer.

27 It is therefore important that devolution does not lead to fragmentation of basic research in the UK, and that basic SET in Scotland remains well integrated within the UK system as part of an evolving European SET base. It is important that the Research Councils, which are reserved UK institutions in the Scotland Act, retain a UK-wide remit

and that Scotland continues to compete UK-wide for funding. The Scottish Higher Education Funding Council also has a key role to play in maintaining the competitiveness of Scottish institutions, and enabling them to continue attracting and retaining outstanding scientists.

Efficient application of the SET base

28 A strong "pull" from users is the best means of ensuring that the SET base is effectively exploited. It is important that scientists are aware of the needs of users, and users are aware of the potential of the science base. This applies to the outputs from all the streams of knowledge and expertise from the SET base in supporting and promoting industrial and economic development, in supporting government policies in health, education, environment, etc, and in providing SET-related advice to legislators and citizens.

29 It might seem attractive only to maintain applied SET capabilities which directly underpin current needs. This is not a viable option. The technologies which underlie most daily life that are at the heart of economic competitiveness, medical care, natural resource use and environmental protection are increasingly driven by scientific innovation. The time taken to pull innovation in basic science through into application in new technologies appears to getting shorter, producing shorter term interdependence of basic, strategic and applied research. This trend is led by the USA where the citation of basic research papers in patents is growing in all sectors.4 Basic research is increasingly likely to be the engine of strategic and applied research in developing new technologies, and must be maintained if only to support them. Moreover, knowledge developed elsewhere which may create new technologies is not automatically made available to another country. Effort and deep understanding are needed to acquire it and harness it to meet domestic needs. A domestic capacity to absorb foreign knowledge requires a domestic capacity to perform research at high, internationally competitive levels.5 A productive and robust modern economy cannot depend largely upon scientific output from elsewhere.

30 Strong interaction is crucial in linking strategic and applied research to its industrial application. The success of Japanese industry in marketing new technology through the 1980s is believed to reflect their capacity to mobilise two-way flows of information between R&D and production divisions in vertically well-integrated company structures. A Scottish Government should take steps to ensure that the many routes by which the public purse funds the SET base and its exploitation are managed in such a way as to maximise opportunities for efficient vertical integration, and that public/private partnerships are facilitated. The recent White Paper on competitiveness emphasised the importance of regional partnerships between the SET base, industry and statutory agencies. For these to be effective, there must be mutual understanding of the objectives and strategies of partners in the region, and they must be aware of national and European policies and opportunities. It is also important to create an environment which encourages entreprenurial attitudes, and which is able to provide finance to support those who see opportunities for the development of innovative technologies.

31 The point along the basic-applied research spectrum at which public funding is replaced by private funding is a key policy issue. A helpful model of the role of public sector intervention is provided by recent developments in the microelectronics industry in Scotland. Microelectronic manufacturing, largely by inwardly investing companies, has become a major industrial sector in Scotland. It has not however included a significant R&D capability, and has not been able either to respond to technological change, unless the overseas parent companies decide to implement innovations in Scotland, or to interact with the SET base. During the last two years, a US company, Cadence, decided, because of the excellence of microelectronics and computer science research in Scotland, to invest in a significant R&D capability in Scotland, and to link its development with training and research within the universities. It is now hoped that other companies will do likewise as part of the Scottish Enterprise Project Alba, and that home-grown service companies will develop to broaden R&D based activity and pull more strongly on the SET base. This hoped for pattern of closely knit activity involving different types of companies, the SET base and government agencies is the essence of the Scottish Enterprise 'cluster strategy'. The challenge now is to create analogous development in other areas such as biotechnology, biomedicine, wider dimensions of information technology, optoelectronics, chemistry, etc., where there is also great strength in the SET base in Scotland.

32 The advice which will be needed by the Scottish Executive to support the development of policy, and by the Parliament in its scrutinising role, will be increasingly difficult to provide from within the governmental SET establishment. New means of tapping the expertise of the SET base outside government should be explored, recognising that Parliament will require independent sources of advice.

The current UK SET base (details in annex 2)

33 In the basic research component of the SET base, diversity is maintained primarily in the university sector, through

funding from the University Funding Councils and from the Research Councils of unsolicited proposals in any field of research, judged only on criteria of excellence. Focus is largely achieved through analysis of the current needs of users and by "foresight" processes, which inform the creation of Research Council directed programmes in universities and Research Council institutes and the SET activity of government departments. Excellence in university research is assured through a 4-5 yearly Research Assessment Exercise, in which research is assessed against international comparators, and the results used to determine Funding Council allocations for research to individual universities.

34 The application of scientific knowledge in industry and society is primarily through the flow of trained people from the SET base. Research is "pulled" into application by contracts from industry and government departments and "pushed" towards application through a range of government schemes to promote technology transfer and commercialisation of the SET base. The recent White Paper on competitiveness, Building the Knowledge Driven Economy, stressed the importance of regional partnerships between the SET base, industry and publicly funded development agencies and enterprise companies in promoting economic development.

35 SET advice to Government is channelled through its Chief Scientific Adviser (CSA) and through the SET arms of government departments. Coordination of the SET base is through the Office of Science and Technology (OST), headed by the CSA. The Council for Science and Technology provides advice to ministers on the balance of SET activities. The needs of Parliament for independent advice on SET related issues are provided for by the Parliamentary Office for Science and Technology (POST) and by the Select Committees on Science and Technology of both Houses of Parliament which conduct investigations into current SET related issues.

Examples of SET bases in other European countries

36 To place the issues facing the Scottish Parliament into a wider perspective, it is instructive to review the situation in two other countries roughly equivalent in size to Scotland (Denmark and Norway) and in provinces in a federal system (the German Länder). Details are contained in annex 3. All three countries recognise the importance of an SET base and the need to find an effective relationship basic research and strategic, applied and developmental work. Norway has chosen to concentrate its effort in strategic and applied research, with little underpinning by basic research, but this does not seem to have had the desired result of stimulating industry, and there are signs that its policy is unsustainable in the long term. Denmark has chosen to focus its basic research in niche areas, but risks a lack of flexibility in responding to unforeseen opportunities. In Germany basic and strategic research in the Länder benefit from being parts of a strongly interactive Federal system whilst having strategic and applied capabilities which are parts of regional alliances with industry and Länder governments. Fraunhofer Institutes, core funded by Federal and Länder governments, specifically address applied research objectives. This combination ensures that basic, strategic, and applied research are well developed and interact effectively with users, a process immensely enhanced by strong R&D investment from the private sector.

5 Policy Objectives for SET in Scotland following Devolution

37 Scotland has an opportunity to develop distinctive solutions to the management of its science base. With a population similar in size to Denmark and Norway, it will be fortunate in having an SET base which is an important and integral part of the larger, world class, UK SET base. Application of the principle of subsidiarity, in which decisions and actions are taken at the level at which they can be most effective, will be vital to the successful operation of the SET base in a devolved Scotland.

38 At the Scottish level, a devolved responsibility will facilitate

- greater support from the SET base for issues that are specific to the region in health, education, agriculture, fisheries and the environment;
- promoting wealth creation and the quality of life through greater co-ordination and shared strategies between key players (universities, colleges, research institutes, enterprise companies, industry, finance and government) in ways such as those proposed in the recent Scottish Office report Scotland: Towards the Knowledge Economy; and through enhanced investment in R&D intensive industry;
- a better reflection of public values in Scotland in the creation of public policy in such areas as the environment (eg. issues such as Brent Spar, genetically modified crops, wind and nuclear energy or hydroelectric schemes) involving innovative methods of public consultation and participation;
- support of policy formulation and scrutiny by the new Parliament and executive.

39 At the UK level, the Scottish SET base must remain an integral part of the UK system of basic research. Its scale benefits Scotland and the other regions of the UK by stimulating international competitiveness, through the inherent flexibility of a large system to adapt to change

whilst focusing major efforts in areas of current need and the capacity to attract and retain scientists of international calibre. Scotland should remain a committed part of the UK Research Council system, continue to be assessed through a UK-wide RAE system of peer review and ensure that financial and organisational barriers to full integration in the UK SET base are minimised.

40 At the European level, UK scientists benefit from the Framework Research Programmes which fund joint work between European scientists and have enabled world class groups to be created. The European Union has major responsibilities for policy for economic competition and regulation in many areas of science-led policy in member states. Although a well articulated European science base does not yet exist, engagement with evolving European institutions should continue to be a high priority.

41 Realising these objectives will require enhanced co-ordination both within Scotland and with the rest of the UK.

6 UK Implications

42 An important conclusion of this report is applicable to all the regions of the UK during the current process of devolution; that the Science, Engineering and Technology Base should remain well integrated on a UK level with as few internal barriers as possible. The Research Councils, which are a reserved UK function, and which should remain so, and the devolved Higher Education Funding Councils should recognise their important roles in maintaining the UK SET base. At the same time, devolved powers can be a basis for more effective application of the SET base through the creation of regional alliances, as advocated in the 1998 White Paper on Building the Knowledge Driven Economy. The means whereby these latter objectives are attained will vary from region to region, depending upon the nature of devolved responsibilities. It is important that, as constitutional arrangements become more complex, means of coordination of the UK SET base appropriate to the new arrangements are developed. The principle of regional representation should be applied, however, only to such coordinating bodies. Members of other advisory bodies should continue to be chosen on a personal basis.

7 Recommendations

43 An explicit policy for SET should be adopted by the Parliament designed to maintain the reputation and output of the Scottish SET base and to address the objectives in 37-41.

44 In view of its vital importance in a devolved Scotland, there is a strong case that a senior minister should have primary responsibility for SET.

45 The large scale strategic issues identified in this report require high level oversight. A science led Science Policy Advisory Board should be set up whose remit would be to advise Scottish ministers on strategies for

- the effective integration of research within Scotland as part of the UK SET base, as the means of maintaining excellence, diversity and focus;
- the efficient exploitation of the SET base to the benefit of society;
- the balance of the two activities.

It should have high level representation from industry, the universities, research institutes, the Royal Society of Edinburgh and Scottish Enterprise. It should have a formal link to the UK Council for Science and Technology.

46 Responsibilities should be embedded within the Scottish Civil Service which should permit the following functions to be discharged

- day-to-day implementation of the strategy of the Scottish Executive and the Science Policy Advisory Board for the SET base;
- co-ordination of SET advice to ministers;
- representation of Scottish interests on UK coordinating bodies and relevant DTI / OST committees such as the Science and Engineering Base Co-ordinating Committee; and in the EU arena;
- a trans-Departmental remit for SET within the Scottish Civil Service to ensure best use of resources and the cross-disciplinary and cross-sector integration of research and advice when appropriate.

These functions should be managed in such a way as to command professional credibility within the UK SET community, with users and with the public, by creating an appropriate post to be filled by a scientist of international repute. The relationship of this post to the UK Chief Scientific Adviser and to those within the Scottish Civil Service will need careful delineation.

47 Given the importance of SET to Scotland's future well-being and prosperity, it will be essential that good, high quality advice is readily available to Scottish Ministers and senior civil servants. Faced with the vast burgeoning of scientific knowledge and technology, however, the resources directly available to a Scottish Executive alone cannot reasonably be expected to fulfil this role. It is important therefore

- that the Scottish Executive does not seek unnecessarily to recreate existing UK capabilities in Scotland. It should seek

advice of the best quality irrespective of its location, should use the wider resources of the UK and international SET base, making full use of UK committees and Royal Commissions and influence their agendas;

- that contracts for research in support of evidence-based policies should be placed wherever it can be done best, and that the research should be subjected to high standards of peer review;
- that the policy making process is separated from the scientific evidence which is taken into account in formulating it, and that the evidence should, for important issues, be made publicly available in plain English;
- that procedures are adopted which ensure that public values are taken into account during in the stage of policy formulation[2];
- that a process of foresight is promoted which identifies difficult science-based issues before they become matters of acute controversy (eg. nuclear waste, over-use of antibiotics), so that authoritative evaluations of the underlying science and its uncertainties can be published in plain English, to avoid hurried policy decisions being made at times of acute controversy;
- that the social sciences are employed to understand better how business, universities, government agencies and research institutions can interact more effectively and how public values can be included in the formation and implementation of policy.

48 MSPs should consider how they might provide themselves with independent sources of advice on SET issues. A model is suggested whereby a small, professional secretariat, housed in the Parliament, acts as an interface with the science community and harvests material relevant to the work of MSPs, including reports of UK and overseas advisory bodies. The National Academies, such as the Royal Society and the Royal Society of Edinburgh, regularly provide advice to the Westminster Parliament, particularly through submissions to Select Committees, and this role will continue. The Scottish Parliament, given its unicameral structure and its commitment to an open, inclusive style of operation, is expected to consult widely. It would be natural for it to look to the Royal Society of Edinburgh, as Scotland's National Academy, as a leading source of independent advice, particularly on matters concerned with Scottish interests. The RSE, through its Fellowship, is willing to nominate a series of contact persons covering the whole of SET, the Social Sciences and the Arts, who could efficiently provide a parliamentary office and MSPs with advice and information.

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Annex 1

Academic units of assessment in the set base and their results in the 1996 Research Assessment Exercise

1996 RAE		Number of Units		4-5* Ratings	
Unit of Assessment		UK	Scotland	UK	Scotland
1	Clinical Laboratory Science	32	4	17	3
2	Community based Clinical Subjects	35	4	13	1
3	Hospital based Clinical Subjects	34	4	19	2
4	Clinical Dentistry	15	2	7	0
5	Pre-Clinical Studies	10	0	0	0
6	Anatomy	11	3	7	1
7	Physiology	15	3	8	0
8	Pharmacology	15	2	11	2
9	Pharmacy	16	2	8	1
10	Nursing	36	4	3	0
11	Other / Allied to Medicine	68	7	18	3
12	Biochemistry	17	4	13	2
13	Psychology	75	10	30	5
14	Biological Sciences	82	10	38	5
15	Agriculture	21	3	11	3
16	Food Science & Technology	15	2	6	1
17	Veterinary Science	6	2	6	2
18	Chemistry	62	8	25	3
19	Physics	56	7	39	5
20	Earth Sciences	33	4	17	1
21	Environmental Sciences	38	6	7	1
22	Pure Mathematics	45	5	27	3
23	Applied Mathematics	65	12	31	6
24	Statistics & Operational Res.	55	9	25	4
25	Computer Science	89	13	40	6
26	General Engineering	37	7	14	2
27	Chemical Engineering	21	4	8	0
28	Civil Engineering	43	9	22	5
29	Electrical Electronic Engineering	65	8	27	4
30	Mechanical, Aeronautical & Manufacturing Eng.	57	5	23	2
31	Mineral & Mining Engineering	14	5	6	2
Totals		**1183**	**168**	**526**	**75**

Annex 2

Funding of the UK set base

1. **Sources of funding (gross expenditure) for UK civil and defence R&D** (1996) †

	Civil		Defence	
	£m	%	£m	%
Government Departments	1 103	9	1 342	64
Research Councils	1 092	9	-	-
Higher Education Funding Councils	1 027	8	-	-
Higher Education Institutions	120	1	-	-
Business Enterprise	6 355	53	431	21
Private non-profit	546	4	0	-
Abroad	2 011	16	312	15
Total	12 254	100	2 085	100

2. **Performers of civil and defence R&D in the UK** (1996) †

	Civil	Defence
	£m	£m
Government Departments	768	727
Research Councils	570	5
Higher Education	2 732	60
Business Enterprise	8 007	1 294
Private non-profit	177	-
Total	12 254	2 085

3. **Analysis of net Government R&D expenditure by type of research activity** (1996-97) ‡

	Civil	Defence	Research Council
	%	%	%
Basic pure	3.0	-	20.4
Basic oriented	2.8	-	38.9
Applied strategic	39.8	7.5	33.6
Applied specific	45.3	25.4	6.4
Experimental Developmental	9.2	67.2	0.7
	100	100	100

Most funding from Research Councils, Higher Education Funding Councils, HE Institutions and Private Charities supports basic science and most funding from the other sources supports strategic and applied science.

† Table 6.1 SET Statistics 1998 ‡ Table 3.4 SET Statistics 1998 (includes NHS)

Annex 3

Comparisons between UK, Danish, Norwegian and German set bases

Denmark has a population of 5.3 million and an economy which is shifting emphasis from one based on agriculture and food production to the knowledge-based industries. The basic structure of its SET base is similar to the UK, with a Ministry of Research and Information Technology (MRIT) which provides competitive project funding through Research Councils; core funding for university research is provided by the Ministry of Education; and Government ministries operate their own laboratories and fund applied research in their areas of responsibility. MRIT is refocusing national research strategy to emphasise goal oriented research and to make funded projects more responsive to national goals, which emphasise the quality of life. Funding is concentrated in four broad strategic areas : science and technology; culture and communication; health; climate and environment. Industry is highly competitive in several niche areas. The Government's goal is to allow Denmark to remain competitive against much larger rivals by focusing on well chosen areas that can pay off in economic and employment terms and its research plan calls for greater interaction between researchers funded by it and the private sector. This emphasis has been accompanied by the growth of privately owned science parks which are expected to fulfil the role of transferring knowledge to industry and to foster the creation of start up companies. These policies of concentration have been criticised as being inflexible in the face of an uncertain future. Denmark has an ageing population of researchers with student numbers declining in engineering. A major challenge facing the Danish SET base is the recruitment of the next generation of scientists and engineers.

Norway has a population of 4.3 million and an economy based on exploitation of natural resources (oil and gas, timber pulp, paper, metals, chemicals, fishing) and more recently telecommunications. The Research Council of Norway (NFR) distributes research funds, provides advice to government on scientific and technical matters and promotes international co-operation in R&D. Most basic research is carried out in the higher education sector which receives core funding directly from the Government and project based funding through the Research Council of Norway. There are about 100 research institutes which receive direct funding from Government and from NFR. Institute research is applied, technological and often carried out under contract. NFR also receives funding from the other ministries such as industry, agriculture, health and environment in pursuit of their policy roles. Disciplinary distinctions in NFR research have largely disappeared, having been replaced by six divisions which are goal and task oriented [25% industry and energy; 21% science and technology; 17% bio-production and processing; 12% culture and society (12%); 10% environment and development; 6% medicine and health]. Government policy has been to reduce research activity, reflecting the relative lack of outlets for the products of research and a decision by government not to expand its budget during the years when it enjoys high revenues from oil and gas production. Norway is struggling to find a research policy that permits it to retain competitiveness in a rapidly changing world and notwithstanding its small size. Its industrial research is widely viewed as weak and it directs a large share of government research funds towards applied strategic programmes. Funds for modernising research equipment are scarce and salaries are said to be too low to attract the best young researchers. All of these factors have put Norwegian science under great stress. The NFR has recognised the need for the rejuvenation of Norway's research system and the looming problem created by retirement of older researchers.

German Länder (provinces), some of which have a population similar to that of Scotland, operate within a federal system. The Länder are the primary political entities from which the Federal Government derives its powers. The funding of non-commercial research is regarded as a social and governmental duty. This is complemented by a high level of industrial R&D. Germany's 89 universities are the backbone of the German SET base and are the responsibility of the Länder. However, key technologies are concentrated in well funded institutes. The Max Planck Institutes concentrate on basic research in carefully selected fields. The Hermann von Helmholtz Research Centres concentrate on basic and strategic research and receive 90% Federal and 10% Land funding. The Fraunhofer Institutes concentrate on strategic and applied research, contract research and information services related to new technologies and processes, and receive 90% Federal and 10% Land core funding. The Blue List research institutions concentrate mission oriented research at regional level with equal funding from Federal and Land sources. Research is highly decentralised, with strong emphasis on scientific autonomy and a market economy which encourages public and private initiatives and leaves little scope for centralised direction. There is a Science Council which advises Federal and Länder governments on all aspects of research policy, but principally on the structural development of the SET base.

1995	Denmark	Germany	Norway	UK
1 Gross Expenditure R&D				
GERD (million current PPP$) †(2)	2 149.9	38 497.5	1 697.6	21 148.4
GERD per Capita population (current PPP$) †(4)	411.2	471.4	390.4	360.9
2 Percentage GERD financed by :				
Industry †(13)	46.7	61.1	49.9	48.0
Government †(14)	39.2	36.8	44.0	33.2
Other national sources †(15)	4.1	0.3	1.2	4.4
Abroad †(16)	9.9	1.8	4.9	14.4
3 Percentage R&D performed by :				
Business Enterprise Sector †(17)	57.4	66.4	56.7	65.3
HEI Sector †(18)	24.5	18.1	26.0	19.0
Government Sector †(19)	17.0	15.4	17.3	14.4
Private non-profit sector †(20)	1.1	-	-	1.3
GERD as percentage of GDP †(5)	**1.91**	**2.30**	**1.71**	**2.02**
BERD as percentage of GDP †(25)	1.10	1.53	0.97	1.32
HERD as percentage of GDP †(47)	0.47	0.42	0.45	0.38
GOVERD as percentage GDP †(56)	0.33	0.35	0.30	0.29
National Patent applications †(71)	48 136	109 621	21 494	97 040
Number of Scientific Publications ‡(A.5.1)	5 846	45 903	3 546	54 781
Number of Citations 1993 ‡(A.5.3)	25 289	179 847	11 127	224 990

4 Government R&D appropriations by socio-economic objective in 1996 ‡(A.1.1)
(Million 1990 Purchasing Power Standard)

	%		%		%		%	
Human and social objectives	113	18	1 300	11	150	18	1 395	20
Technological objectives	104	16	2 854	24	174	21	569	8
Agriculture	45	7	307	3	83	10	349	5
Research funded from GUF	244	38	4 467	37	316	37	1 262	18
Non-oriented research	126	20	1 786	15	78	9	810	12
Other civil research	-	-	89	1	-	-	31	-
Defence	3	-	1 180	10	42	5	2 493	36

(Table numbers given in brackets)
† OECD Main Science and Technology Indicators 1998/2
‡ Second European Report on Science and Technology Indicators 1997 (Appendix)

Abbreviations

BERD Expenditure on R& D in the Business Enterprise Sector
FTE Full-time Equivalent (on R&D)
GERD Gross Domestic Expenditure on R&D
GOVERD Government Intramural Expenditure on R&D
GUF General University Funds
HEI Higher Education Institution
HERD Expenditure on R& D in the Higher Education Sector
GDP Gross Domestic Product
PPP Purchasing Power Parities

Annex 4

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