Policy document: 17/04

The future funding of the European science base: A Royal Society background working paper: V2.0

June 2004

(Updated version of policy document 28/03 – originally published in January 2004)

1 The creation of the concept of the European Research Area (ERA), and the target of increasing total (Gross) R&D expenditure (GERD) within the EU from 1.9% of GDP to 3% by 2010 has stimulated widespread discussion of European fundamental research, in terms of its standing against the United States, its administration and its funding arrangements. As part of this consideration there have been calls for the establishment of a European Research Council (ERC), for example in the report of the ESF high level Group, chaired by Sir Richard Sykes (ESF2003) (summary at Annex **B**), and most recently in the report of the Expert Group, chaired by Frederico Mayor. This latter group was established by the Danish Presidency and reported to the Council of Ministers in December (ERCEG 2003), and its report is the subject of another paper by the Society (RS 2004). A selection of relevant reports is listed at the start of the references.

2 The Council of the Royal Society established a small Working Group (membership at Annex **A**) to advise it on the future development of fundamental research in Europe. This group steered the production of a background working paper, published in January 2004, surveying the science base in Europe, comparing it with the situation in the US and the North American Free Trade Area, and identifying a number of problems that needed resolution. This updated version of that paper, published in June 2004, incorporates new information on the relative performance of the top research teams in Europe and the US (in paragraphs 41 to 48). A few other factual changes have been made where significant new information has become available, but the majority of figures in the text are still in terms of EU(15). A further update to the paper may be prepared if significant new information becomes available.

3 A difficulty in studying the European situation is the lack of readily available and consistent information on the detailed distribution of funding for R&D within member states of the EU below the level of detail collected for and reported by the OECD, and on the performance of individual institutions. In order to aid development of central policy, efforts need to be made to improve significantly in the information available across the EU.

4 A further problem when considering European fundamental research is the wide variation in the national level of funding of fundamental research across the EU, and also in the way that fundamental research is distributed between: universities; research council type laboratories – such as the Max Planck, CRNS and UK research council institutes; research based national collections; and government laboratories under the direct control of central or regional governments. Furthermore, even within the university systems there are differing balances between project and infrastructure funding and, particularly with the latter, different distribution mechanisms.

5 A comparison of the components of GERD for the EU(15) and the US indicate that the main EU shortfall is in research conducted in business, rather than in the public sector and in particular in universities. The US GERD in 2000 was 2.7% of GDP, and about 90% of the EU funding gap with the US comes from the business funded R&D sector. While in no way down playing the importance of fundamental research, focus on the establishment of a ERC should not be allowed to displace effort needed to encourage more directly improved innovative capacity within European business.

6 Nevertheless, fundamental research is a key component of Europe's plans for economic growth in the first part of the twenty first century at a number of different levels, and it is clear that there are many areas where Europe's performance could be improved, including:

- a Supporting networking across Member States, but only on the basis of bottom up requirements, not politically inspired top-down exercise;
- b Better organisation and possibly expansion of the strategic fundamental research within the current Framework Programmes;
- c The funding of large research infrastructure projects that are required on a European basis, such as large radiation sources, biomedical and other databases and living stock collections, and making better use of existing large facilities on a European basis;
- d The support of the very best fundamental research teams, at a level that ensures that they can compete on the world stage into the future;
- e Coordination of European input to global research programmes, although where these are science led there are already well-developed mechanisms for securing a European consensus to the development of such programmes.
- f Increasing mobility of researchers across the EU – mainly an issue of social benefits, which could be improved through better coordination by national research councils.
- g Increasing mobility of researchers between the public and business sector R&D within the EU;
- h Collection and analysis of financial and other statistical information on European research, especially at universities and research council style institutes – this may well require prior work on standardising accounting systems.

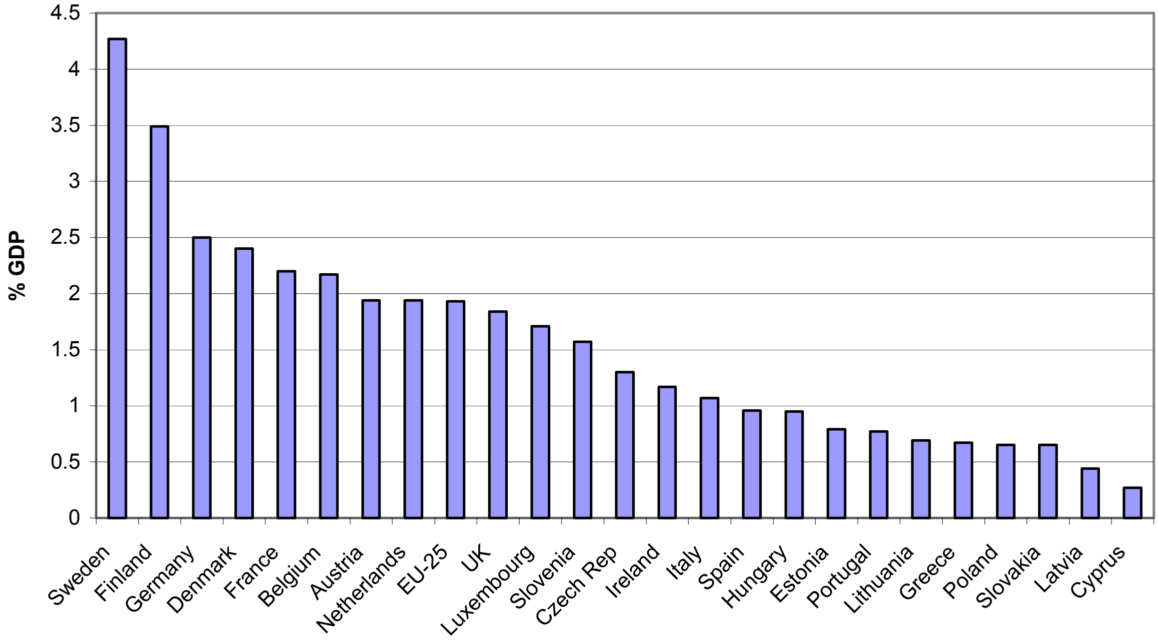
7 Many of the initiatives in these areas could be funded on an EU basis, but for some countries it would be counter productive to supplement this with a levy on existing national funding mechanisms for fundamental research, which themselves are under pressure. A possible way forward for strengthening the resourcing of most basic research at EU level may be to explore ways of coordinating the existing European funding arrangements, including relevant parts of the Framework Programme, with a view to making these more effective and dealing with the activities that are not already covered. The Mayor report published on 15 December 2003 (ERCEG 2003) suggested the establishment of a European Fund for Research Excellence to support the very highest quality European research teams (ie 6 d above). These proposals are considered in another Royal Society paper (RS2004), and it is important that the Mayor proposals and any emerging from the European Commission are scrutinised by the European scientific community.

The political background

8 The Lisbon 2000 European Council set the objective of Europe becoming "The most competitive and dynamic knowledge-based economy in the world." This led to the 2002 Barcelona European Council setting an equally ambitious and more specific quantitative target - to increase the total European research and development expenditure (OECD defined Gross Expenditure on R&D (GERD)) to 3% of GDP by 2010, from its present base of 1.9%. The Commission has indicated that to achieve this, publicly funded research needs to increase by 6% per annum and industry funded research by 9% (EU2003). To illustrate the size of the challenge, the UK's GERD in 2000 was £17.543 billion about 1.85% of GDP, and 3% of the UK's GDP in 2000 was £28.5billion, i.e. an additional £11 billion would have been required to meet the 3% target figure in that year.

9 Within the current EU(25) average figure of 1.93% of GDP there is a wide range of expenditure on R&D:

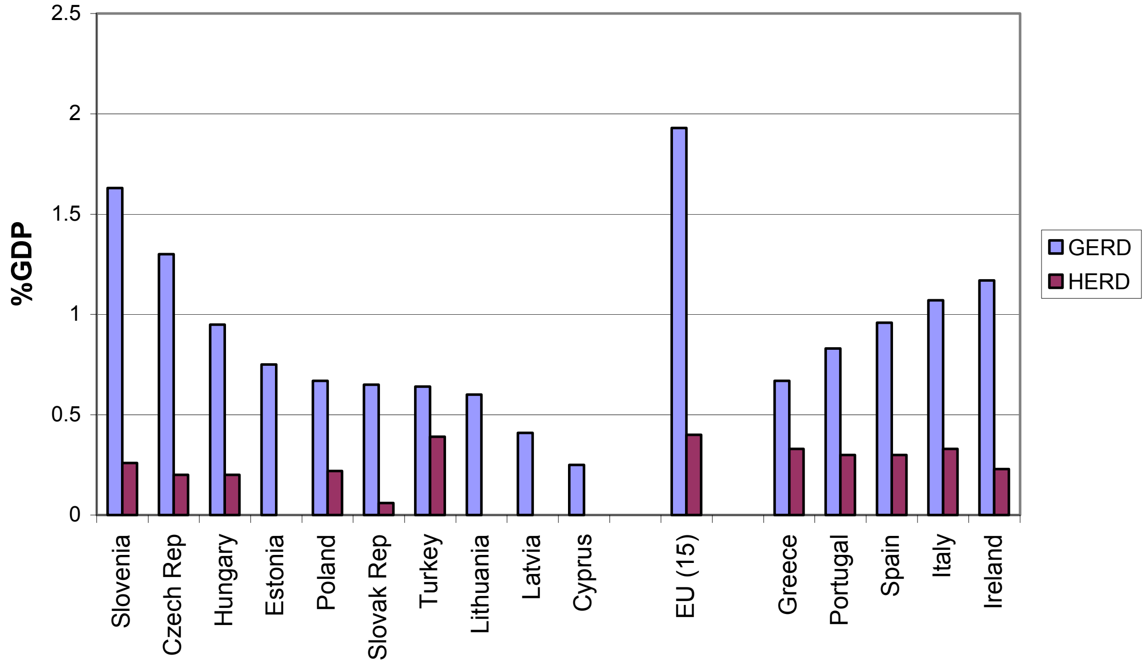
Fig 1 GERD (2001) for EU member states



Source: Key Figures 2003-2004 (excludes Malta)

10 If the EU is to achieve a total R&D expenditure of 3% of overall GDP, the larger EU states need to increase their expenditure on R&D. Some other states have an even greater gap to overcome, and enlargement of the EU has increased the difficulty of achieving 3%. Although some of the new member states, such as Slovenia and the Czech Republic, already invest more in total R&D as a percentage of GDP than some established member states, it should be noted that from the available information their expenditure on university research (HERD) is generally somewhat lower (fig 2). Clearly some special arrangements may be required to help both new and established member states increase their R&D expenditure, but this needs to be a conscious separate exercise, and this should not be attempted by distorting quality-based funding mechanisms.

Fig 2 GERD and HERD for new member states and lowest performers of the established states



Source: OECD Main S&T Indicators 2003/1 (HERD is not reported separately by all new member states, and in no case would be zero)

The overall funding context of research in Europe and the US

11 The overall R&D activity can be analysed in terms of where the activity is undertaken – higher education (HERD), government laboratories (GOVERD), business (BERD) and private non-profit (PNPRD). The differences between the EU and US in terms of expenditure within these performing areas, as percentages of GDP, are shown in fig 3A, where the much larger business involvement with R&D is apparent. Fig 3B analyses GERD in terms of funding source, where the main difference is the input from business. Apart from the contribution to R&D funding classified as from "abroad", which needs further investigation, the main difference between the EU(15) and the US is in the amount of R&D performed by business and the funding of R&D by business. The following paragraphs examine HERD and BERD in more detail.

Fig 3A Components of GERD by Performer (2000)

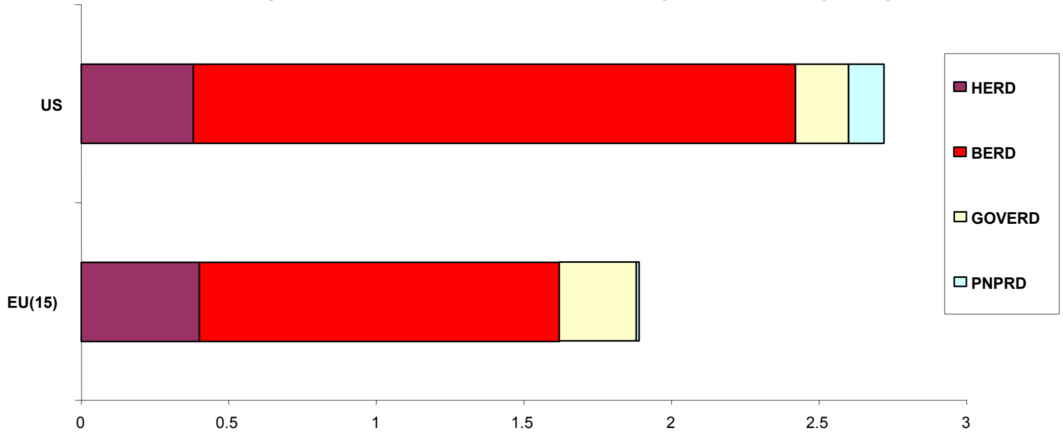
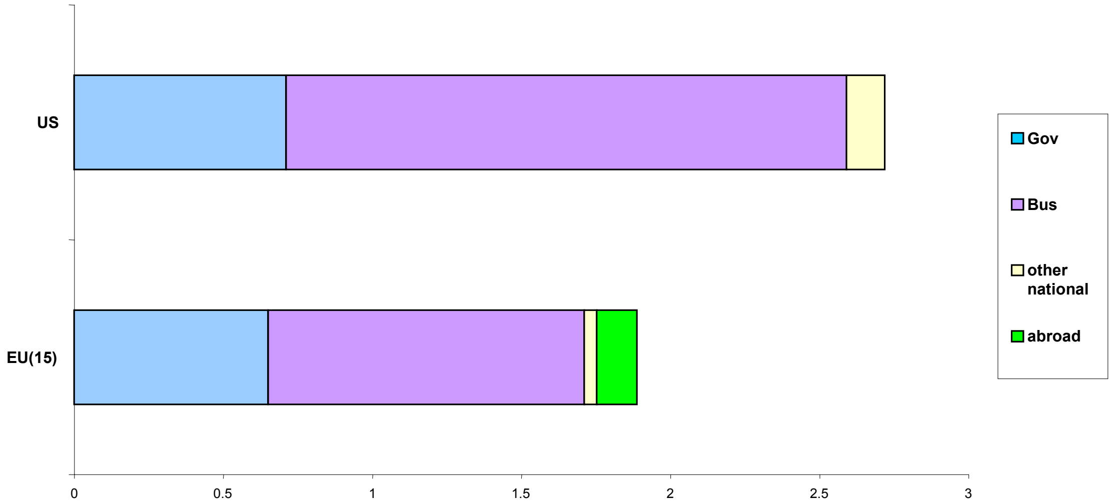


Fig 3B. Funders of GERD (2000)

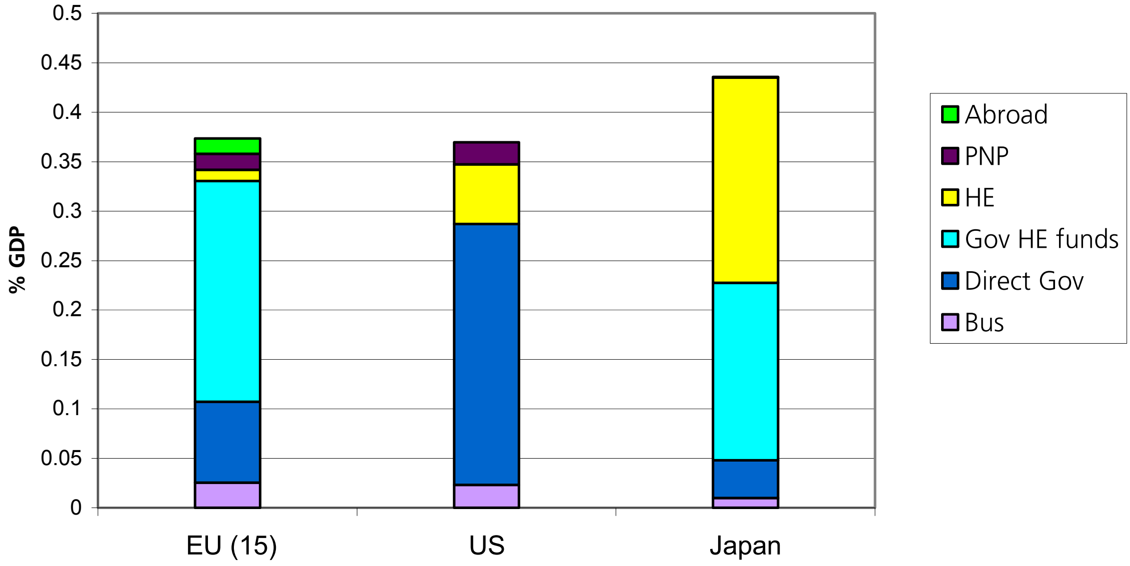


Source: OECD Basic S&T Statistics 2001

Higher Education R&D (HERD)

12 The amount of higher education research is comparable as a percentage of GDP within the EU(15) and the US. The slightly higher percentage within the EU(15) is probably more than compensated by the underestimate of US HERD, which excludes the arts and humanities. However, the sources of funding of HERD show significant differences, as can be seen from fig 4, which compares HERD in the EU, US and Japan.

Fig 4 HERD Funders 1999



Source: OECD Basic S&T Statistics 2001

13 These differences include:

- Public support appears to be greater within the EU(15), but the difference may be less as some of institution "own funds" in the US may be State funding to the institution for general purposes that the institution has used for R&D, and the US figures exclude humanities.

- The majority of public funds for HERD in the US are in the form of federal grants rather than general support for research infrastructure, although in practice some of the federal funding is for similar purposes to the Government HE funds in the EU. Furthermore there is a wide range of federal sources of funds for science and engineering research, with over 60% coming from the National Institutes of Health:

Table 1: Federal sources of funds for US university science and engineering research

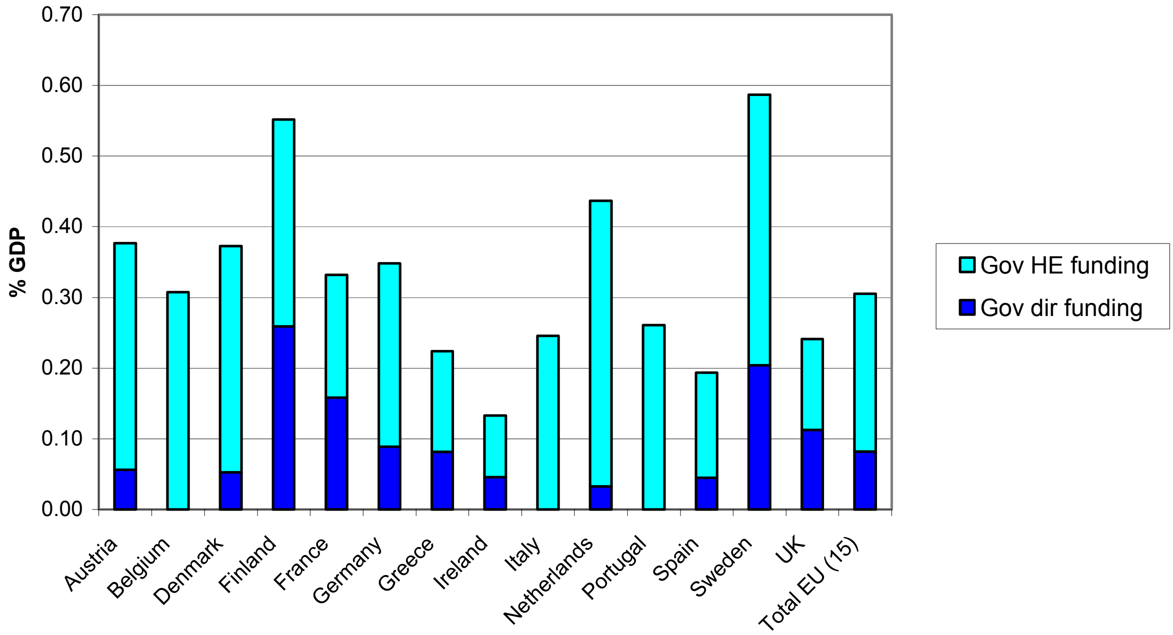
1999	Total	NIH	NSF	Dept. of Defense	NASA	Dept. Energy	Dept. Agriculture	Other Agencies
$bn	16.6	10.1	2.2	1.5	0.8	0.7	0.5	0.8
%		61	13	9	5	4	3	5

Source: NSF Science & Engineering Indicators 2002 (Volume 2)
Note that this is only funding going through university accounts, and does not include facilities provided at non-university sites.

- Business support for higher education research is slightly higher in Europe than in the US, which may reflect businesses in Europe sub-contracting more of its applied R&D to universities.

14 OECD figures for components of HERD distinguish between general support for university research (Government HE funds) and direct or grant support (fig 5). The distribution of funding between these two categories varies widely across the EU. Note that some countries only give a total figure, which is displayed as "Government HE funds". Furthermore, as discussed further in Annex **C**, EU States have widely differing distribution of R&D funding between universities and public sector research establishments. Hence, an ERC would be operating across a widely differing government funding landscape across the Union, the implications of which need further consideration.

Fig 5 Government general and direct (project) funding of university research



Source: OECD Basic S&T Statistics 2001

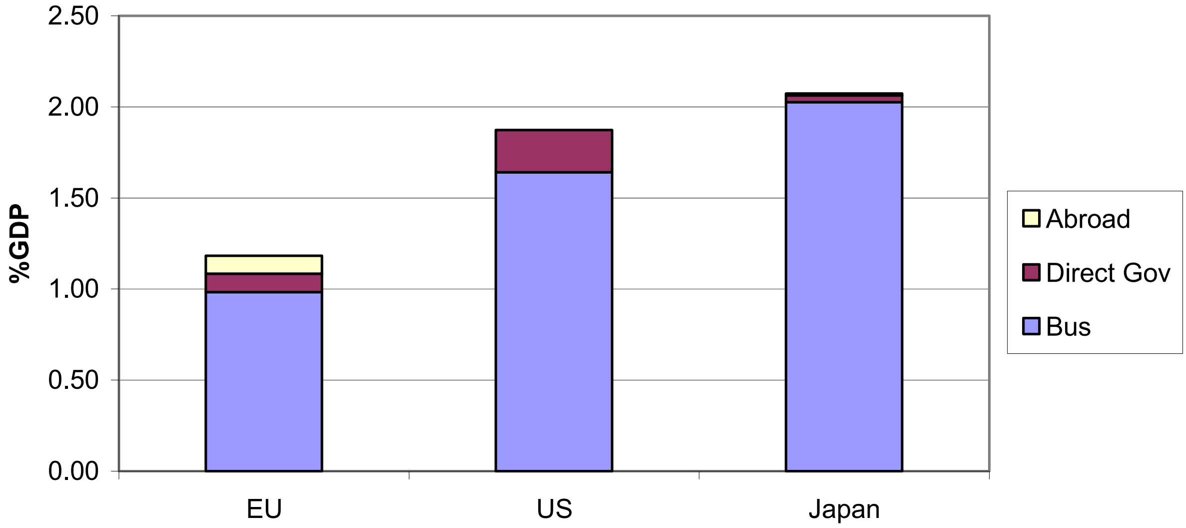
Note that Belgium, Italy and Portugal do not distinguish in their figures between the two routes for Government funding, which depresses the EU direct (project) funding.

Business Expenditure on R&D (BERD)

15 As has been indicated above, the main difference between EU(15) and the US is in the business R&D sector, with EU business only undertaking 60% of the US business based research as measured as a % of GDP. Both the public and private sector financing of BERD contribute to this lower investment (fig 6). The main shortfall in **public** support for R&D in the EU is in the business sector, and it is worth considering whether there are any particular reasons for this, such as the EU State Aids policy[1], or the high defence component of the public US funding of R&D. As far as the private sector funding is concerned, a recent report by the European Round Table of Industrialists (ERTI 2003) has indicated that significant additional investment was unlikely.

[1] State Aids – EU legislation controlling member state subsidies to their businesses.

Fig 6 BERD Funders 1999



Source: OECD S&T Indicators 2003/1

The Defence factor

16 A major difference between Europe and the US public expenditure on research is the proportion of the work that is classified as defence related. In Europe only 15% of research funding is classified as defence expenditure (largely in France and the UK), while in the US over half of the public R&D budget falls into this category. It is not clear however, what effect this difference has on the impact of business R&D, or on fundamental R&D. The majority of US Government expenditure on business R&D is in the defence sector, which may be more targeted on specific products than civil research. In the UK, over 75% of the MOD R&D budget is classed as experimental development, and it only supports about £17million of R&D at universities (less than 0.5% of HERD). On the other hand, in the US the Department of Defense grants to universities account for about 9% of Federal grant support for university R&D (4.5% of US HERD).

17 The difference in US and European support for non-university R&D, particularly the defence component, would repay further study. The impact of US defence R&D and procurement expenditure on overall economic development, including its impact on the civil private sector, has been recognised for many years. One European response was the EUREKA programme (www.eureka.be). While this has had some impact, it hardly competes with the size of the defence procurement in the US.

Definition of Fundamental Research

18 The terms basic and applied research, together with the related experimental development, are defined by OECD in its Frascati Book (OECD 1993):

- **basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view;

- **applied research** is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective; and

- **experimental development** is systematic work drawing on existing knowledge gained from research and practical experience that is directed to producing new materials, products or devices; to installing new processes, systems or services; or to improving substantially those already produced or installed.

Identifying the boundary between basic and applied aspects of R&D is often difficult and subjective. Much university research is classified as applied since there is often at least a long-term practical aim, especially in medical and environmental research.

19 **Fundamental research** can be defined as basic and applied research, where the resulting information is ordinarily published and shared broadly within the scientific community. Such research can be distinguished from **proprietary research** and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary reasons or specific national security reasons. While universities are encouraged to ensure that they protect their intellectual property, the expectation is that the findings will be published, and hence the remainder of this paper centres on fundamental research.

The purpose of fundamental research

20 Fundamental research is largely supported by public funds because of a breakdown in the market economy in this area, the research having such long payback times that an individual firm is unlikely to get a sufficient return to justify its investment. However, since most research is done in other countries – this is true even of the US - it is important to consider why individual states invest in fundamental research. Recently a number of commentators supporting the pooling of resources have said that it is paradoxical that national states are unwilling to pool their funds for fundamental research as this would make the production of new knowledge more efficient.

21 However, there are six overlapping reasons for funding fundamental research:

i. to maintain and develop knowledge, skills, and long-term research infrastructure, for unforeseen eventualities and also a capacity to keep in touch with and understand developments occurring elsewhere in the world;
ii. to solve problems – eg to underpin solutions to societal problems such as those in the health, social, economic, environmental areas;
iii. to fuel economic activity, new and better/cheaper products and new and better/more efficient services;
iv. to train PhDs and post docs and to provide within universities an exciting and challenging learning environment for first degree and masters students
v. to retain existing expertise and to attract inward migration of skilled people;
vi. to retain existing business investment, and to attract "foreign" companies/capital.

Implicit in many of these are the key roles that fundamental research plays in maintaining culture and a community's standing within the world.

22 From these it can be seen that there are significant localised benefits from fundamental research activity including:

- maintaining expertise across a wide range of disciplines, with people able to pick up and run with new ideas wherever they are generated – includes being available to provide advice to regional and national governments;
- providing the entry ticket to the international research community, sometimes through formal collaborations, but at other times just through attendance at conferences and informal contacts;
- maintaining an interface between universities and the business and wider community;
- educational benefits.

23 The arguments for and against member states contributing to an ERC, as opposed to EU funding are likely to centre on the balance accorded to the various benefits from fundamental research, and the balance between European, national and more local economic development. While not belittling the importance of the primary research findings and their exploitation, arguably the most important output from the science base is people – graduates at all levels and post doctoral researchers who leave the system and also the maintenance of the pool of expertise retained within the higher education system.

The Structure of Fundamental Research in Europe

24 Fundamental research is undertaken mainly in universities and public sector laboratories, but the distribution varies widely within different countries. In the UK, for example, like the US, the research is largely carried out in the universities, with some specialist institutes and units managed by the Research Councils some of which are located on university campuses. On the other hand, in France and Germany a significant proportion of the research is undertaken at publicly funded laboratories. Annex **C** considers three estimates of the funding of fundamental research in Europe.

Shortcoming with the existing support arrangements

25 No system is perfect, and it is important to consider the various problems or shortcomings of the existing arrangements raised in the Sykes report and by other proponents of an ERC:

a Lack of resources for fundamental research:
  - i Funding
  - ii Equipment and facilities
  - iii Researchers

b Effectiveness of the use of resources (possible duplication of effort and the existence of sub-optimal competence structures);

c The need to create and maintain more centres of excellence that can compete on the world stage;

d The need to improve the ability of national research councils to identify world-class research standards;

e The need to improve the quantity and quality of outputs from European research:

i Publications
ii PhD students;

f Difficulties in quickly achieving critical mass in emerging new areas, and or in interdisciplinary topics;

g Obstacles to researcher mobility;

h Problems of establishing European and inter-continental facilities;

i Need for a European input to global research projects;

j it has been suggested that a European wide funding body would be better able to improve the knowledge transfer from universities to European firms.

26 A crucial issue that arises from many of the above points is the level at which decisions are best made. Potentially, this can be anywhere from the institutional level, through region, state to a central European body. Another important factor to be considered is the degree of central steering of fundamental research that is appropriate.

Analysis of Shortcomings

a ***Lack of resources for fundamental research:***

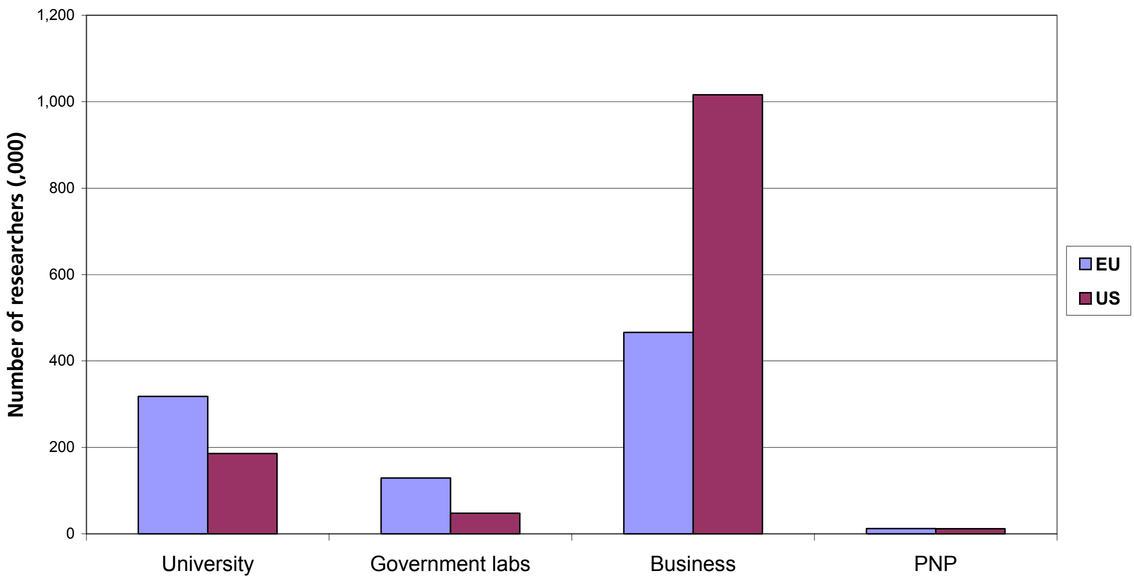
27 Resources cover both funding and numbers of researchers:

i **Funding** - there are always more good science projects than can be funded under any realistic funding scenario, and hence the introduction of a genuine new funding stream (as opposed to re-orienting existing levels of funding) is therefore an attractive proposition. Comparisons with the US indicate that higher education and government research laboratories are funded at similar levels in terms of GDP and the EU now publishes more papers than the US. However, as will be discussed in more detail later, there is a shortage of the top research teams in Europe when compared with the US.

ii **Equipment and facilities** – many areas of fundamental research depend crucially on the availability of state of the art facilities. For the most expensive equipment, depending on the capital and/or running costs the provision of regional, national or international resources is essential. With increasing cooperation between member states, it is not clear that there is a problem, except at the level of EU wide or world centres, where further action is required.

iii **Researchers** - OECD FTE reported figures indicate that there are significantly more university and government researchers in the EU(15) than in the US (fig 7)

Fig 7. Researchers (,000) in the EU and US 1999



Source: OECD S&T Indicators 2003/1

The exclusion of researchers in the arts and humanities in the US figures and inconsistent estimation of FTE numbers for university researchers may explain some of the difference in this sector. The Government laboratory figures for the US exclude any military personnel.

However, the difference in the number of business researchers between the EU and US reflects the differences in overall funding of business research, and illustrates the major potential shortfall in appropriate staff if European business research were to expand to meet its share of the 3% of GDP GERD target. A communication from the commission (EU 2003) estimates that 700 000 additional FTE researchers will be needed if the 3% target is to be reached.

b *Effectiveness of the use of resources (possible duplication of effort and the existence of sub-optimal competence structures)* –

28 It is possible that the wide range of national motives for supporting fundamental research may lead some national research funding systems to be less selective than a centralised system, provided decisions with the latter are based purely on quality grounds alone. While the UK funding is highly selective, there is insufficient evidence to comment on the overall selectivity within the EU. It is arguable that decisions on the level of selectivity should be left, at least for the majority of funding, to member states or, as in the UK, partly to devolved administrations within member states. National priorities may, however, lead to a less than optimal number of quality research teams within the EU, and resolving this might justify central resources.

29 It is not clear whether there is un-coordinated duplication within Europe, or if there is, whether such duplication is above the level that provides the localised benefits set out in paragraph 17 and 18, or indeed retains the essential degree of competition that keeps

fundamental research alive. Science has traditionally progressed though competing research programmes, with teams nevertheless keeping in touch with each other.

30 Increasingly, networks of collaborating research teams have grown up to take forward the research quicker and to rationalise on the use of resources, with the dispersed members of the network still maintaining their expertise and professional standing. While there may be scope for subsidising the costs of such networking, it is important to stress that this must not be imposed top down. Such collaborations should always be because the potential partners want such a network and that it is seen to be in the interest of all concerned.

31 While a central funding scheme might be able to spot and reduce un-necessary duplication of research activities, national funding agencies should also ensure that their peer review bodies had a better knowledge of the European scene.

c ***Benefits to be achieved from creating centres of excellence that can compete on the world stage,***

32 The issue of critical mass is complex. It can for example be considered in terms of making the best use of capital equipment, or in terms of the minimum size of the intellectual community required to provide a stimulating environment for the highest quality research. Both of these are highly subject specific. Where little equipment is required, the intellectual critical mass dominates, but through networking, the use of email and facilities for sharing and discussing data etc, even quite small groups at isolated institutions may be able to undertake excellent research. With increasing cost of research facilities in some disciplines, full utilisation of the investment becomes of increasing importance, but there is a discontinuity when the equipment facilities are so expensive that they are best provided on a regional, national or international basis. Furthermore this also affects the intellectual critical mass, as this may be provided by visits to the centre. In the UK, for example, some high quality research teams in astronomy are small and in relatively low research-intensive universities. The question of the effect of size on research performance in the UK was the subject of a recent report by the Science Policy Research Unit, University of Sussex (SPRU2003).

33 In certain areas, it is appropriate to establish a centre or centres of excellence to drive forward the research. It is usual for these to be fairly widely distributed, although some argue that it is necessary to establish major research universities with centres of excellence in many subjects if Europe is to compete with the powerhouses in the US.

34 It is true that the top US universities in terms of total R&D spend have higher R&D budgets than European universities as illustrated by the comparison of the top 10 US and UK universities set out in Table 2A and 2B. However, total size of R&D income is clearly not crucial since there are many US universities with a high research reputation and relatively low total research income. For example, the California Institute of Technology and Princeton, with R&D incomes of about £136 and £82million respectively, are only 42nd and 80th in the US list, and below the top four and top ten UK universities respectively (table 2B). Neither of these institutions, however, has a medical school, and life sciences represents a relatively low proportion of the R&D expenditure (under 20%) compared with over the 60% average over the top 100 universities.

Table 2A Top 10 US Universities by Total Research Income (2001)

			£million
1.	Johns Hopkins*	Private	640
2.	University of California Los Angeles	Public	444
3.	University of Wisconsin-Madison	Public	387
4.	University of Michigan	Public	384
5.	University of Washington-Seattle	Public	377
6.	University of California -San Diego	Public	356
7.	University of California - San Francisco	Public	336
8.	Stanford	Private	309
9.	University of Pennsylvania	Private	301
10.	University of Minnesota	Public	296

Source NSF 2001 report on R&D expenditures

* over half of this expenditure is at the Federally funded Applied Physics Lab.

A full list of the top 100 US universities (1999 figures) is included as table 3 in annex D

Table 2B Top 10 UK Universities (2000)

		£million
1.	University of Oxford	206
2.	University College London	204
3.	Imperial College of Science, Technology and Medicine	202
4.	University of Cambridge	189
5.	King's College London	124
6.	University of Edinburgh	111
7.	University of Manchester	101
8.	University of Birmingham	91
9.	University of Leeds	89
10.	University of Glasgow	87

35 All comparisons with the US should take account of the impact of the large budgets for the National Institutes for Health, and the major contributions that the medical schools make to the research total at some universities (over 50% at Johns Hopkins- excluding the Applied Physics Laboratory) and the University of Pennsylvania and 40% at Stanford.)

36 It is more difficult to get consistent information on the situation at universities elsewhere in Europe. The latest (3rd) European Report on S&T indicators lists the 20 top research organisations in the larger EU states and 10 in the smaller states and the list of those publishing at least 8,000 papers over a four year period are set out in annex **D**.

37 As the US statistics illustrate, while there is probably a certain minimum level of research funding for an institution, total R&D funding is less important than being able to attract a group of very talented researchers producing high quality research.

38 Hence, while it may well be important for Europe to have some high quality research powerhouses that can rival the US, whether this means matching total R&D income is debatable. Furthermore, as discussed in paragraphs 20-23, high impact research is only part of the story, and it is also important to maintain high quality research in other institutions. Since many of these reasons are based on local criteria, this element in the selection process must not be jeopardised. The question is whether national funding

arrangements can continue to fund an appropriate mixture of the powerhouses and other centres, or whether new funding sources are required.

d The ability of national research councils to identify world-class research standards

39 It is quite possible for national bodies to include experts from other member states and elsewhere as referees and members on their peer review bodies, and this is increasingly common throughout the EU. Nevertheless, there are advantages in some of the research funding being competed for on a wider geographical basis than at present.

e The need to improve the quantity and quality of outputs from European research:

40 Outputs can be considered in terms of publications and their impact, and output of trained people.

i Publications

41 EU(15) now publishes more papers than the US. The overall impact of these papers is probably less, although individual member states vary widely in their impact. The latter may be because of language problems and insular citation behaviour of large countries. Nevertheless, impact rather than publication volume is probably a more important factor in attracting business and investment into Europe, and hence needs to be taken seriously.

42 While there is significant information on individual member states, there is less reliable information on the impact of EU research as a whole, because of the need to correct for shared international papers within national figures. Using the technique used in the NSF Science and Engineering Indicators of assigning fractions of papers where authorship spans two or more countries the EU output of publications in 1999 compared with the US (US=100) in terms of numbers, and numbers divided by population, GDP and HERD is as follows:

	Publication	Publication/pop	Publication/GDP	Publication/HERD
EU Publications (US=100)	106	77	115	111

The picture is not so satisfactory when comparing the top 1% of cited papers as shown below. Although this is for a different journal set, this is unlikely to explain the difference, nor is the national size effect on citations:

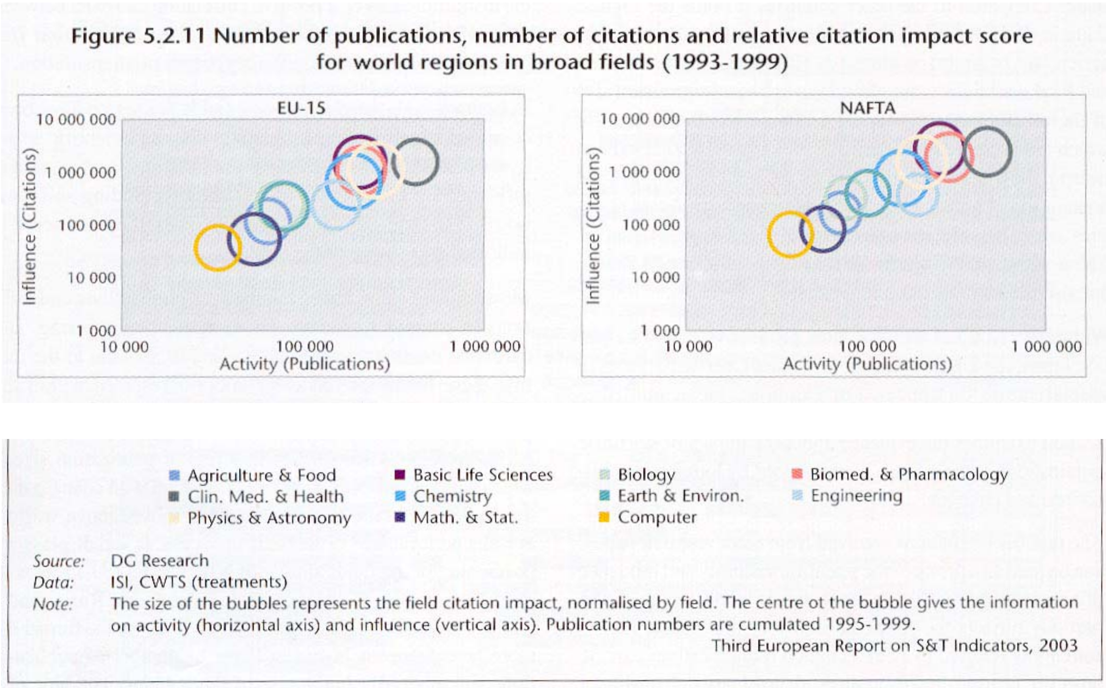
	Publication	Publication/pop	Publication/GDP	Publication/HERD
EU top 1% cited Publications (US=100)	59	42	64	62

Based on information in a private communication, Jonathan Adams, Evidence Ltd, Leeds, based on ISI database

This warrants further investigation, but strongly suggests that there are fewer of the very top research teams within Europe compared with the US. This is in accord with other measures of esteem such as Nobel and other significant prizes.

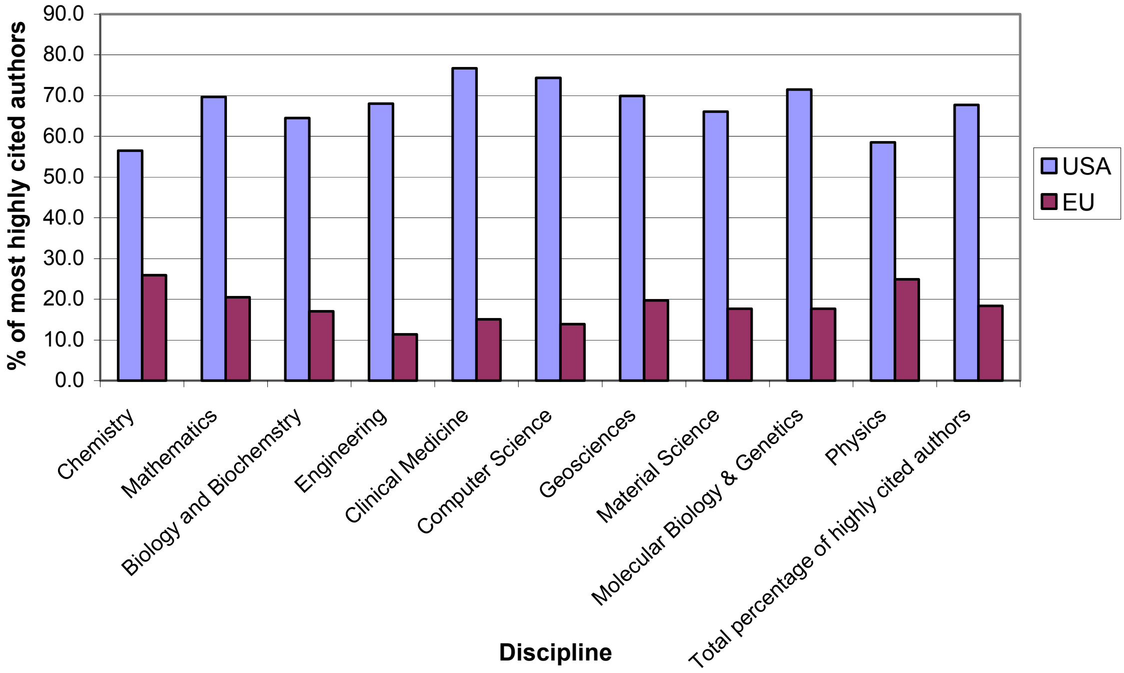
43 The EU 3rd European Report on S&T Indicators has a composite indicator comparing the number of publications, number of citations and relative citation impact score for 11 broad fields for the EU(15) and the North America Free Trade Association (NAFTA) (fig 8). This shows the similar publication pattern of the two areas, but while the EU performance is close to world average in all of these areas, NAFTA performs above average in 5 areas – physics, clinical medicine, biomedicine, chemistry and basic life sciences.

Fig 8 – Comparison of number of publications, citation and relative citation impact scores in 11 broad fields between the EU(15) and the North Atlantic Free Trade Area



44 The percentage of the most highly cited authors, in ten disciplines, who are located in the US and the EU is shown in Fig 9. Part of the significant difference between the US and Europe can be explained by the national citation bias of large countries and the bias against publications in languages other than English. Furthermore, several permanent members of the same team with a large number of highly cited papers may be included in the list. If the highly cited teams in the US have more permanent members, this will increase the number of US entries. However, it seems unlikely that these will explain the full extent of the difference.

Fig 9 Highly cited authors



Source: This data is based on between 219 and 250 of the most highly cited authors as identified by ISI and on the ISIHighlyCited.com website as collated in March 2004.

45 As would be expected, the performance of individual EU member states varies. The analysis in terms of publications and top 1% publications is as follows, but the individual countries totals are not corrected for international authorship.

Table 3 Various statistics on S&E total papers and top 1% cited papers (US=100)

	All publications			Top 1% of cited papers		
	No	No/population	No/gdp	No	No/population	No/GDP
Austria	3	90	115	2	55	70
Belgium	4	101	138	3	72	98
Denmark	3	152	184	2	124	150
Finland	3	145	202	2	93	129
France	18	83	120	11	50	71
Germany	25	84	115	17	56	76
Greece	2	45	99	0.5	12	27
Ireland	1	73	91	0.8	60	75
Italy	12	55	77	7	33	45
Netherlands	7	126	161	6	105	133
Portugal	1	30	58	0.4	11	22
Spain	8	56	100	3	23	40
Sweden	6	179	256	4	122	174
UK	27	125	180	20	94	136
EU	106	76	115	59	42	64

Based on information from Evidence Ltd, Leeds based on ISI database

46 These figures would indicate that within Europe there is some strength in depth that needs to be nurtured. However, further work is clearly required on the impact of EU research relative to the US. On a world stage, the overall impact of European research is highly dependent on the relative quality of the best teams in each field, and it would be helpful to have citation data on a European basis, for example on the number of papers in total and on a discipline basis that are in the top 0.1% of cited papers. Certainly the evidence on the number of Nobel Prizes awarded over the past two decades to European researchers who undertook their research while working in Europe would indicate a major problem with European research impact compared with the US.

47 Assuming that the majority of publications arise from the HE, Government institutes or public-non-profit laboratories, the US is no longer the lead player in terms of $m spent on the science base.

Table 4: some selected indicators per R&D expenditure on the science base (SBRD)

	Pub/$m SBRD	**Total Citations /$m SBRD**	**Highly cited papers/$bn SBRD**
UK	8.33	**26.65**	**224.39**
Sweden	7.51	23.90	202.97
US	4.16	20.19	165.07
Denmark	6.20	19.54	188.61
Netherlands	4.79	17.61	166.13
Ireland	**8.34**	17.55	213.24
Belgium	6.27	16.91	177.30
Finland	5.53	16.67	130.36
Spain	7.56	13.94	75.36
Austria	5.62	12.98	96.80
Germany	4.31	12.86	107.14
France	4.12	11.73	96.97
Italy	4.90	11.35	85.14
Greece	7.38	8.00	50.28
Japan	3.06	7.20	40.19
Portugal	3.41	3.31	24.00

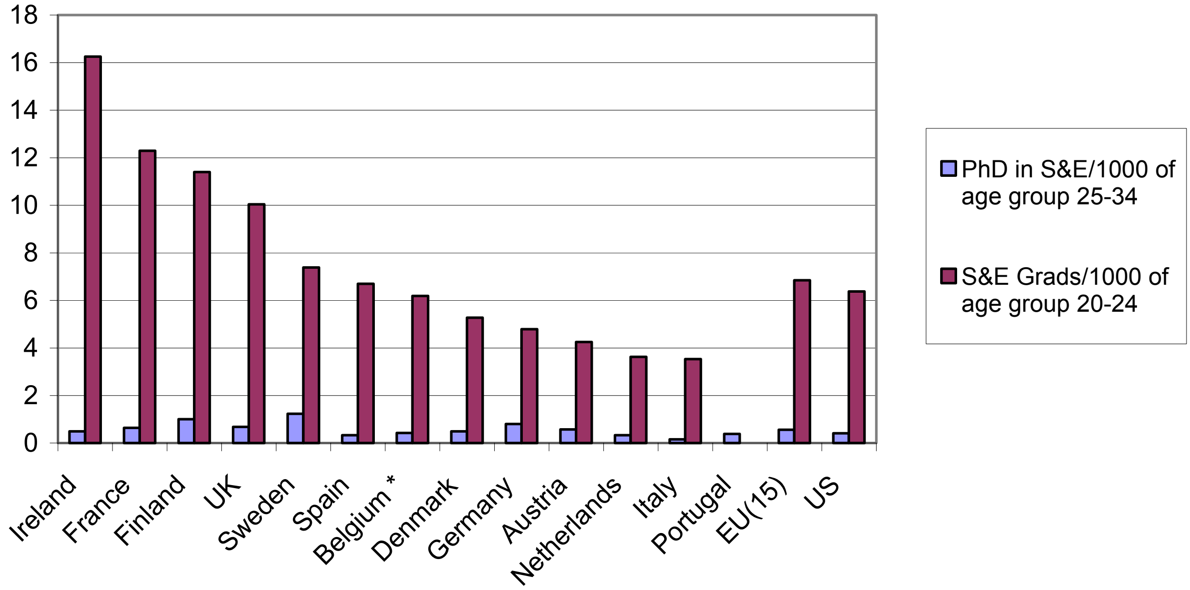
Source: EU Key figures and OECD Main S&T indicators 2002/2

48 This would indicate that potentially at least some European States are more effective in their use of resources than the US, but if it is the very highest quality research teams that are important, this further analysis also has to be recalculated using the figures for the top 0.1% cited papers.

ii Trained people

49 EU(15) produces more S&T graduates and PhDs than the US as shown by the figure below. What is less certain is whether these trained people go into research and how many of the latter stay in Europe or whether they are attracted to the US.

Fig 10. Output of Graduates and PhDs as % of relevant age population



Source: Third European Report on S&T indicators 2003

50 The potential large number of business researchers, and other trained staff, that would be required were the EU to achieve its target for increasing GERD to 3% of GDP by 2010 was raised in paragraph 27(iii) above. The US certainly relies on importing trained staff. In 1999 27% of the doctorate holders in the US were foreign born. Many of these came to the US to undertake a PhD study and stayed on afterwards. For recipients of 1992-93 doctorates in science and engineering with temporary visas 53% were still in the US in 1997. With its lower level of "foreign" researchers, there may well be a case for the EU maintaining its current higher level of output of PhDs. However, it is also important to consider the proportions across the disciplines as the total figures hide structural differences between the EU and US, as shown below.

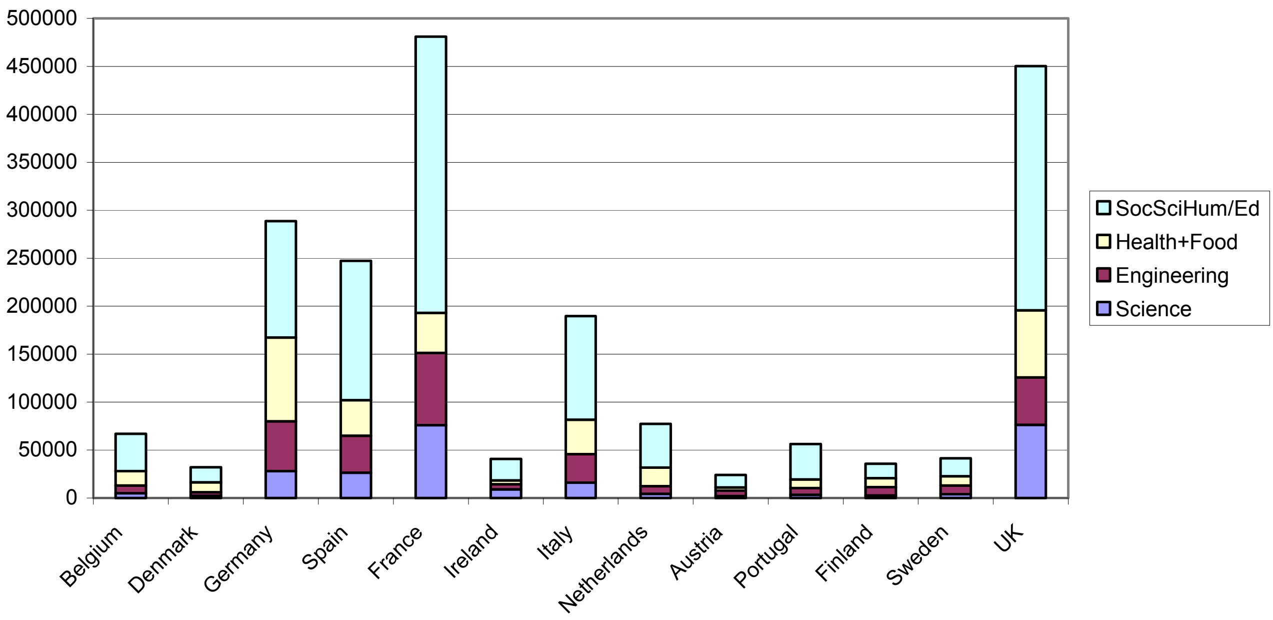
Table 5: Graduates in fields of study EU and US

	Total	Science	Engineering	Total S+E	Health & Food	Social Science/ Humanities/Educ
EU 2000	2,143,500	255,172	300,475	555,647	351,814	1,123,519
US 1998	2,066,595	169,311	179,328	348,549	322,758	1,301,199

Source European Report on S&T indicators 2003

51 There are also structural differences between member states:

Fig 11. Graduates by fields of study 2000



Source European Report on S&T indicators 2003

The differences between the numbers of science and engineering graduates in member states may have an impact on their fundamental research programmes. Unlike the UK, most member states have more engineering than science graduates.

A report on increasing human resources for science and technology in Europe (Gago 2004) suggests that Europe's strength is in its younger fraction of the population trained in science and technology, but new human resources will not be attracted at the level required to meet the 3% target unless new jobs are created and career prospects are improved.

f Difficulties in quickly achieving critical mass in emerging new areas, and or in interdisciplinary topics –

52 It is not clear that there have been problems in organising the fundamental research community, what is much more problematical is the organisation of business to exploit these new areas.

g Obstacles to researcher mobility

53 This is clearly a problem, but not just between countries, there are still problems of mobility between the main research sectors, especially between academia and business within many if not all EU countries. There have been a number of EU based initiatives to improve mobility, but as the Sykes report points out many of the problems are due to incompatibility and non-transferability of social benefits rights etc, which require concerted action by national governments.

54 Increased mobility of researchers should aid the dissemination within Europe of the tacit knowledge, experience and personal networks of contacts possessed by the individuals

and hence enhance the overall research base of the EU.

55 There have been a number of successful EU programmes to encourage the mobility of students and young researchers. However, there remain significant barriers at later stages in researchers careers, largely due to differing institutional career structures and national cultural and social security/pension issues, and these need to be addressed by member states.

h Problems of establishing European-wide and intercontinental facilities –

56 It has sometimes proved a lengthy process to set up a large international facility, but nevertheless Europe has many examples of world leading facilities, which have flourished once they have been established, and there may be a need for coordination of national funding bodies to facilitate decisions on such centres.

i Need for a European input to global research projects.

57 It is not clear that there are problems securing a European input to global research projects.

j Improving knowledge transfer from the science base

56 The Lambert Review of UK university-business collaboration (Lambert 2003) did not raise any significant area where an ERC would make any material difference.

57 The UK Research Councils have experimented with varying amounts of "directed" research, where specific budgets are set aside for particular topics, but in all cases, researchers were free to formulate their own research proposals. However, EPSRC has significantly reduced its directed programmes in recent years. It is important to be vigilant that a centralised body is not tempted to be more dirigiste.

58 On the other hand, there may be a case for the funding within the Framework Programme that is directed at strategic areas of S&T being allocated on a different basis, with a less bureaucratic system.

59 An important mechanism of knowledge transfer is via the education and training of young people who are then employed by business, by training courses for business staff within universities and the transfer of more senior staff between the sectors. As indicated above, however, in most if not all member states there appear to be significantly greater barriers to mobility between the private and public R&D sectors than in the US.

Conclusions

60 Fundamental research is a key component of the EU's plans for economic growth in the first part of the twenty first century at a number of different levels. However, there appear to be major gaps in the published information on the detailed structure and funding of research below the aggregate information provided to OECD, except for the UK and possibly the Netherlands and some smaller Member States. In order to aid development of central policy, efforts need to be made to improve significantly the information available across the EU.

61 Another problem facing any centrally administered policies within the EU for university research is the widely differing structure of universities across Europe, including the balance between publicly funded general funds and project based grant funding. Over time these differences may be reduced, possibly as a result of the attempts to clarify equivalent qualifications across the EU (the Bologna process).

62 While in no way down playing the importance of fundamental research, there is a danger that focus on the establishment of a European Research Council would displace effort that would be better used to encourage more directly improved innovative capacity within European business, which except for the pharmaceutical and aerospace industries is where the main shortfall compared with the US resides. Within the business innovation agenda there is a significant role for fundamental research and this needs to be included in the plans.

63 Nevertheless the above analysis has identified the following issues where better coordination of some kind may be helpful:

- a Supporting networking across Member States, but only on the basis of bottom up requirements, not politically inspired top-down exercises;
- b Better organisation and possibly expansion of the strategic underpinning research within the current Framework Programmes;
- c The funding of large research infrastructure projects that are required on a European basis, such as large radiation sources, biomedical and other databases and living stock collections, and making better use of existing large facilities on a European basis;
- d The support of the very best fundamental research teams, at a level that ensures that they can compete on the world stage into the future.
- e Coordination of European input to global research programmes, although where these are science led there are already well-developed mechanisms for securing a European consensus to the development of such programmes;
- f Increasing mobility of researchers across the EU – mainly an issue of social benefits, which could be improved through better coordination by national research councils;
- g. Increasing mobility of researchers between the public and business sector R&D within the EU;
- h Collection and analysis of financial and other statistical information on European research, especially at universities and research council style institutes – this may well require prior work on standardising accounting systems.

64 The most appropriate way forward with many of these may be to explore mechanisms for coordinating the existing European arrangements or developing existing components of the Framework Programme in these areas with a view to making these more effective and dealing with the activities that are not already covered. Our views on the proposals in the Mayor report (Mayor 2003), which largely address item 4 in paragraph 63, are in a separate note (Royal Society 2004).

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Annex A

Royal Society Working Group on fundamental research in Europe

Professor Julia Higgins FRS (Chairman)	Foreign Secretary and Vice President
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Sir Brian Fender CMG	Formerly Chief Executive HEFCE
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Points made in the Sykes Report (ESF 2003) on "New structures for the support of high-quality research in Europe"

Underlying Weaknesses in European Research

1 The report claims that the underlying problem is that, at present, there is no clear European mechanism to support fundamental research on a broad front and existing European support for such research suffers from particular handicaps such as:

- difficulties in mobilising funds rapidly to support emerging sectors and new research teams;
- difficulties in initiating interdisciplinary approaches;
- obstacles to the mobility of researchers, such as incompatibility and non-transferability of social benefits, rights and procedures;
- duplication of efforts between countries and the existence of sub-optimal competence structures.

Possible Activities on an ERC

2 The report lists on page 7 the following candidate activities of an ERC:

- Setting priorities in trans-disciplinary research, and providing incentives for initiating new areas of innovative science and scholarship.
- Adding a clear European dimension to the competition for some of the most prestigious grants and awards.
- Establishing leading-edge collaborative research centres of appropriate size in basic and strategic research areas that call for integrative approaches from different disciplines.
- Making better use of existing large facilities by providing improved support for trans-national access to them.
- Offering additional funding opportunities and new career structures for young postdoctoral researchers, and thus enabling them to pursue their own ideas in an internationally supported, highly stimulating environment.
- Providing the focal point and support for European participation in large international programmes of global dimension and dealing with global problems so avoiding current difficulties where the European "voice" is dispersed and lacks a commonality of position.

3 The report stresses that the key point is that the ERC must focus on excellence as the basis for its funding decisions, aiming for high potential, high science-gain endeavours that

- are scientifically excellent;
- have a European dimension;

- develop long-term perspectives for funding science;
- encourage bottom-up approaches;
- give priority to emerging areas, new teams, and multidisciplinary research;
- are able to cover the whole research spectrum, including the humanities;
- have transparency in their decision-making processes;
- stimulate multi-partner multinational collaborative approaches;
- stimulate capacity building.

The funding of Fundamental Research

1. Information on the funding of fundamental research is not collected on a international basis, and there is no internationally agreed definition of grouping referred to in the UK as the Science Base. One approximation is to use the OECD HERD figures, but this excludes the fundamental research undertaken in freestanding research council and government laboratories and hence is a lower bound. An upper bound can be estimated by adding either (1) HERD + PNPRD + GOVRD or (2) HERD + PNPRD + (Gov and PNP funded)GOVRD (2). The Comparative figures for the EU, US and Japan are:

Table B1 HERD and the two "Science base" estimates

1999	EU		US		Japan	
	$m	% GDP	$m	% GDP	$m	% GDP
HERD	32,779	0.38	34,060	0.37	13,769	0.44
"Science Base" 1	56,991	0.65	61,877	0.63	26,999	0.85
"Science Base" 2	53,914	0.62	61,877	0.63	26,998	0.85

Source OECD Basic S&T Statistics 2001

From the above it can be seen that the EU expenditure on HERD and approximations to the Science Base is not very much lower than the US expenditure in $M and is comparable as a percentage of GDP. Note that the US figures exclude expenditure on university arts and humanities research.

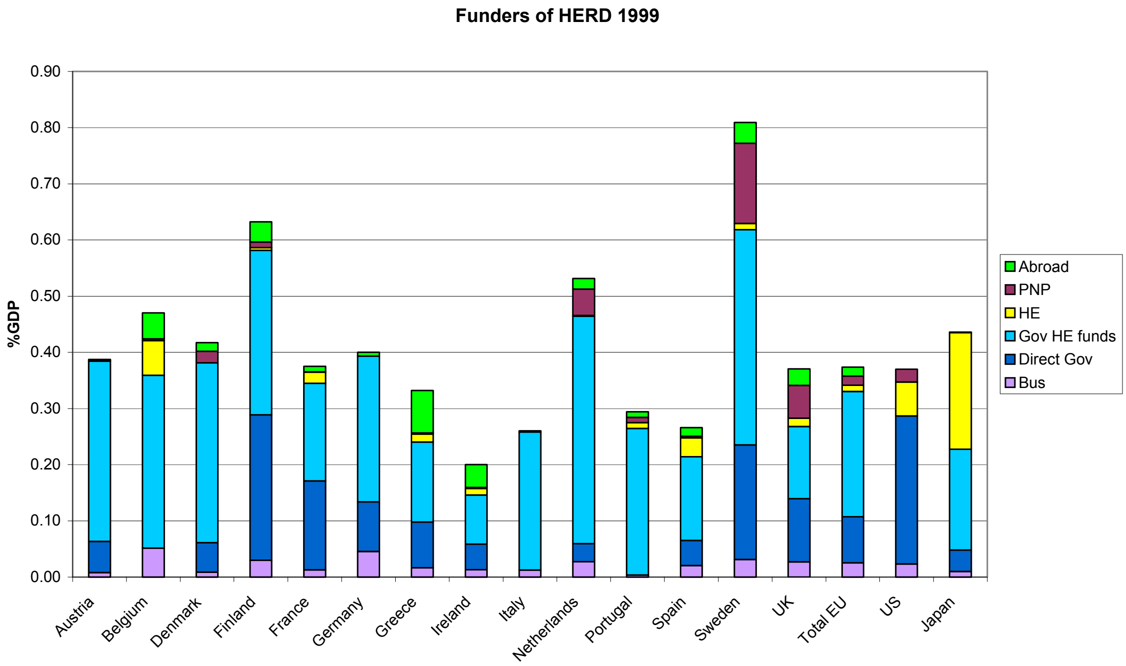
2. It does, of course, vary quite considerably across the EU as shown below.

Table B2 Individual Country's expenditure on HERD and "Science Base" 1999

	HERD		**Science Base 1**		**Science Base 2**	
	$m	% GDP	$m	% GDP	$m	% GDP
Austria	984	0.47	1,219	0.59	1,189	0.57
Belgium	1,186	0.47	1,410	0.56	1,395	0.55
Denmark	623	0.42	1,124	0.76	1,058	0.72
Finland	765	0.63	1,236	1.02	1142	0.94
France	5,225	0.38	11,210	0.80	10,333	0.74
Germany	8,099	0.40	14,869	0.73	14,577	0.72
Greece	553	0.33	799	0.48	716	0.43
Ireland	194	0.20	272	0.28	257	0.26
Italy	3594	0.26	6,742	0.49	6,502	0.47
Netherlands	2,228	0.53	3,708	0.88	3,275	0.76
Portugal	499	0.29	1,000	0.59	974	0.57
Spain	2,006	0.27	3,198	0.42	3,018	0.40
Sweden	1,683	0.81	1,956	0.95	1,935	0.93
UK	5,140	0.37	8,249	0.59	7,545	0.54
EU	32,779	0.38	56,991	0.65	53,914	0.62
US	34,080	0.37	61,877	0.67	61.877	0.67
Japan	13,769	0.44	26,999	0.85	26,998	0.85

Source OECD Basic S&T Statistics 2001

3. It is also instructive to analyse the source of funding for higher education R&D – as % of GDP



Source OECD Basic S&T Statistics 2001

Table B3 Country based analysis of the inputs to HERD

Country	Gov HE	Gov direct	Total Gov	HE	PNP	Business	Abroad	Total
Austria	0.32	0.06	0.38	0	0	0.01	0	0.47
Belgium	0.31	0	0.31	0.06	0	0.05	0.05	0.47
Denmark	0.32	0.05	0.37	0	0.02	0.01	0.02	0.42
Finland	0.29	0.26	0.55	0	0.01	0.03	0.04	0.63
France	0.17	0.16	0.33	0.02	0	0.01	0.01	0.38
Germany	0.26	0.09	0.35	0	0	0.05	0.01	0.04
Greece	0.14	0.08	0.22	0.01	0	0.02	0.06	0.33
Ireland	0.09	0.05	0.14	0.01	0	0.01	0.04	0.20
Italy	0.25	0	0.25	0	0	0.01	0	0.26
Netherlands	0.40	0.03	0.43	0	0.05	0.03	0.02	0.53
Portugal	0.26	0	0.26	0.01	0.01	0	0.01	0.29
Spain	0.15	0.04	0.19	0.01	0	0.02	0.02	0.27
Sweden	0.38	0.20	0.58	0.03	0.14	0.03	0.04	0.81
UK	0.13	0.11	0.24	0.02	0.06	0.03	0.03	0.37
EU	0.22	0.08	0.30	0.01	0.02	0.03	0.02	0.38
US	0	0.26	0.26	0.06	0.02	0.02	0	0.37
Japan	0.04	0.18	0.22	0.21	0	0.01	0	0.44

Source OECD Basic S&T statistics

Annex D

Universities in Europe and the US

1. There is no comprehensive study of the universities in Europe, in terms of their funding. The 3rd European Report on S&T Indicators has a table showing the top 20 research performers in the largest EU states and the top 10 in the smaller states, choosing first the top publishing institutions during the period 1996-1999 in each of 11 disciplines, and then the second performer until 20 or 10 had been identified. A threshold number of 60 papers was used. It is unfortunate that London is treated as a single institution. The list contains research council institutes, government laboratories as well as universities. From these lists the 50 universities with over 8,000 publications in the four-year period, ordered in terms of decreasing field norm citation score are:

Table 1

University	Country	Publications	Citations	Field norm citations score
Cambridge	UK	26486	197887	1.55
Oxford	UK	25416	190619	1.48
Tech University of Munich	Germany	10736	55317	1.4
Edinburgh	UK	13818	89077	1.35
University of Freiburg	Germany	9476	63142	1.34
University of Strasbourg	France	9758	63951	1.32
Erasmus University	Netherlands	8995	65171	1.32
University of London	UK	85182	550278	1.29
University of Helsinki	Finland	13446	81531	1.29
Leiden University	Netherlands	12585	86682	1.25
Karolinska Institute	Sweden	15434	116900	1.22
Univ Amsterdam	Netherlands	12851	51638	1.22
Free Univ of Amsterdam	Netherlands	8689	51638	1.22
State Univ Groningen	Netherlands	10257	57480	1.18
University of Bristol	UK	9861	47904	1.18
Wageningen University	Netherlands	9556	40850	1.17
Univ Paris 5 R Decartes	France	10508	74222	1.16
Glasgow	UK	11876	62404	1.14
University of Utrecht	Netherlands	14942	80846	1.11
University of Wurburg	Germany	9210	49742	1.11
University of Arhus	Denmank	8245	43295	1.09
Univ Uppsala	Sweden	13438	70035	1.08
University of Gothenburg	Sweden	10791	56675	1.08
University of Lund	Sweden	16341	83179	1.07
KUL Kath Univ Leuven	Belgium	15420	68876	1.07
Univ Erlanggen Nurnberg	Germany	12737	52355	1.07
Free Univ Brussels	Belgium	10538	53564	1.07
Univ Paris 11 South	France	16265	75822	1.06
University of Sheffield	UK	9700	40768	1.06
University of Munich	Germany	16208	83477	1.05
Catholic Univ Nijmegen	Netherlands	9648	50840	1.05
University of Stockholm	Sweden	8588	43391	1.05
University of Padua	Italy	10501	49658	1.04
University of Leeds	UK	9637	37592	1.04
University of Florence	Italy	8209	35149	1.04
University of Manchester	UK	16816	76277	1.03
University of Nottingham	UK	8685	36079	1.03
University of Southampton	UK	9336	38746	1.03

University of Copenhagen	Denmark	11667	63432	1.02
University of Milan	Italy	16972	81963	1.01
Humbolt University	Germany	8947	31676	1.01
Free Univ of Berlin	Germany	10830	55210	1
Univ Paris 6 P&M Curie	France	13438	100372	0.98
University of Vienna	Austria	12485	50255	0.92
University of Bologna	Italy	10962	42161	0.92
Wales	UK	14029	49505	0.9
University of Barcelona	Spain	9678	33705	0.84
University of Rome 1	Italy	13402	47422	0.81
University of Naples	Italy	9789	32813	0.74
Univ Complutense Madrid	Spain	8274	22444	0.7

Sources 3rd European report on S&T indicators.

1. publications in the period 1996-1999
2. citations to these papers.

2. Note that in France, Italy and Spain publications have been credited to the research council and this explains the relatively low number of university entries for these countries. For this and other reasons this is an incomplete and unsatisfactory list, but is probably the best available at present. It is clearly important to get a better picture of university research in Europe.

The top research council/government laboratories, with over 1,000 publications are shown the next table.

Table 2

Institute	Country	Publications	Citations	Field norm citations score
Riso National Lab	Denmark	1,987	8,991	1.53
RAL	UK	3723	18673	1.42
Niels Bohr Inst	Denmark	1,311	7,193	1.42
Inst Pasteur	France	7,249	79,379	1.39
Res Centre Julich	Germany	6,301	28,812	1.34
NERC	UK	1809	10,378	1.33
Natl Public Health Inst	Finland	2,349	16,035	1.33
MPI Extraterrestrial Physics	Germany	1,831	12,693	1.3
GSI Centre for heavy ion research	Germany	1,657	6,926	1.28
CEA	France	14,782	72,269	1.21
CNRS	France	23,784	130,105	1.19
INSERM	France	6,851	55,774	1.17
INFN	Italy	9,199	38,311	1.17
GSF-Res Centre for Env and Health	Germany	2529	13,619	1.16
Inst Natl Super Health	Italy	2,767	15,362	1.06
TNO	Netherlands	3,097	17,709	1.05
INFM	Italy	2,525	4,697	1.04
Royal Inst Tech	Sweden	5041	14,218	1.02
DLR	Germany	1,707	4,252	1
Observatoire Paris	France	2,594	12,301	0.94
INRA	France	11,428	42,148	0.86
CSIC	Spain	16,133	50,681	0.86
CNR	Italy	18,833	66,626	0.85
IRCCS	Italy	4,005	15271	0.8
ENEA	Italy	1,313	2,400	0.62
INSA	France	2,598	4,560	0.59

There are clearly anomalies in these tables, and further work clearly needs to be done at this level.

Table 3 **The top 100 US universities in terms of S&E R&D funding (1999)**

Source Appendix table 5-4.from NSF Annual Survey

Expenditures on science and engineering R&D at the top 100 academic institutions, by source of funds: 1999 (Millions of current dollars)

(

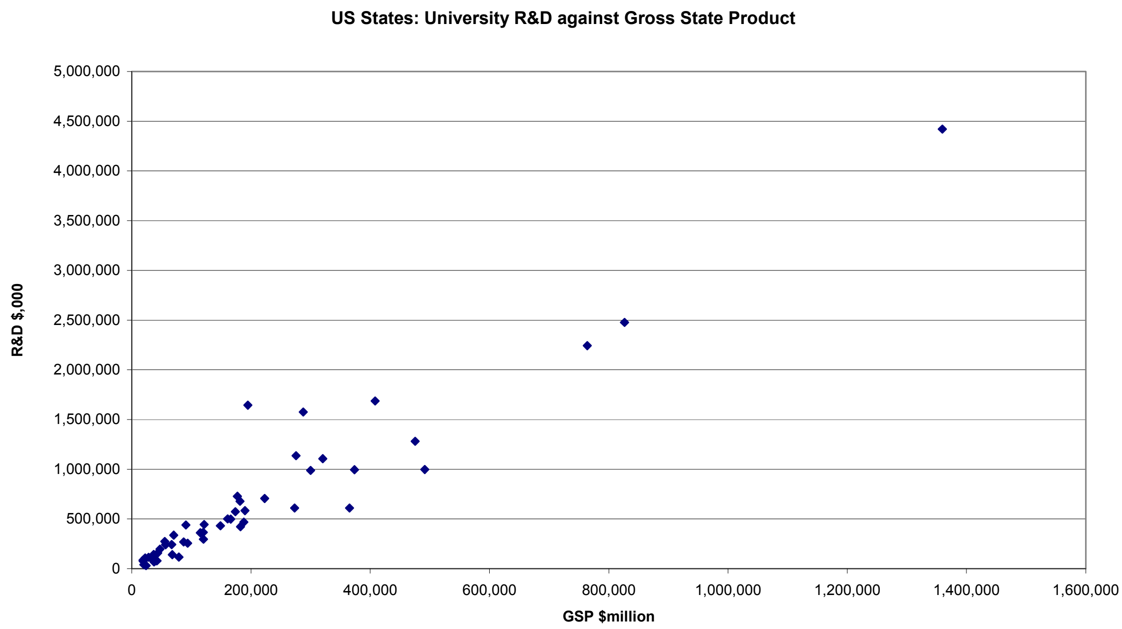
		Source of funds					
Rank and academic institution	Institution type	Total	Federal Government	State/ local government	Industry	Academic institutions	All other sources
All institutions		**27,489**	**16,047**	**2,028**	**2,048**	**5,366**	**2,000**
1 University of Michigan, all campuses	Public	509	334	5	34	103	32
2 University of Washington-Seattle	Public	483	368	12	51	43	9
3 University of California-Los Angeles	Public	478	252	10	34	108	73
4 University of Wisconsin-Madison	Public	463	250	39	14	102	57
5 University of California-San Diego	Public	462	292	22	31	72	45
6 University of California-Berkeley	Public	452	191	48	22	149	42
7 Johns Hopkins Univ[a]	Private	439	352	1	15	26	44
8 Johns Hopkins Applied Physics Lab	Private	436	419	0	0	17	0
9 Stanford University	Private	427	354	3	32	19	19
10 MIT	Private	420	309	—	75	13	23
Top 10 institutions		**4,566**	**3,121**	**140**	**310**	**652**	**344**
11 Univ of California-San Francisco	Public	417	233	19	37	72	56
12 Texas A&M University, all campuses	Public	402	149	95	35	115	9
13 Cornell University, all campuses	Private	396	235	38	12	75	36
14 University of Pennsylvania	Private	384	279	2	30	33	39
15 Pennsylvania State University, all campuses	Public	379	199	16	66	99	0
16 University of Minnesota, all campuses	Public	371	208	49	24	62	29
17 Univ of Illinois at Urbana-Champaign	Public	358	186	38	13	107	15
18 Duke University	Private	348	187	6	122	14	20
19 Harvard University	Private	326	266	2	12	0	46
20 Ohio State University, all campuses	Public	323	135	50	52	59	27
Top 20 institutions		**8,271**	**5,198**	**454**	**712**	**1,288**	**619**
21 University of Arizona	Public	320	178	8	17	104	13
22 University of Colorado, all campuses	Public	319	245	6	10	25	33
23 Washington University	Private	316	219	7	20	35	35
24 University of California-Davis	Public	308	124	22	16	120	25
25 University of Florida	Public	304	122	66	28	78	10
26 University of Southern California	Private	281	200	9	23	49	0
27 Columbia University in the City of New York	Private	280	240	1	3	11	25
28 Yale University	Private	274	213	—	15	17	28
29 Baylor College of Medicine	Private	272	141	2	19	39	70
30 North Carolina State Univ at Raleigh	Public	271	66	97	31	75	—
Top 30 institutions		**11,215**	**6,946**	**673**	**894**	**1,842**	**858**
31 Georgia Institute of Technology, all campuses	Public	264	113	14	63	74	0
32 University of Texas at Austin	Public	258	165	18	40	31	5
33 Univ of Maryland at College Park	Public	258	145	45	3	57	8
34 Univ of North Carolina at Chapel Hill	Public	253	183	15	6	49	0
35 University of Pittsburgh, all campuses	Public	249	195	1	13	22	18
36 University of Georgia	Public	237	56	47	11	122	2
37 Northwestern University	Private	234	133	4	14	58	25
38 Univ of Alabama at Birmingham	Public	232	165	1	10	18	37
39 Purdue University, all campuses	Public	226	96	26	29	76	—
40 Louisiana State University, all campuses	Public	226	76	69	13	54	14
Top 40 institutions		**13,652**	**8,272**	**913**	**1,096**	**2,403**	**967**
41 Rutgers the State University of New Jersey, all campuses	Public	214	76	25	10	85	18

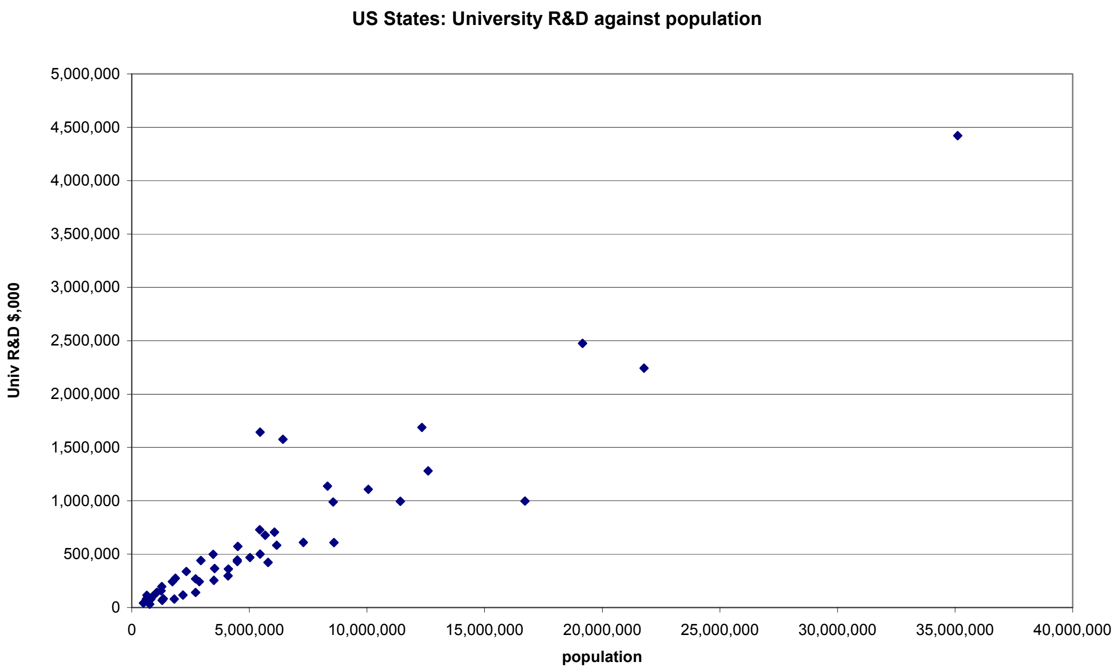
42 California Institute of Technology	Private	212	195	—	6	8	2
43 Michigan State University	Public	208	90	37	8	65	8
44 University of Iowa	Public	207	123	5	21	48	10
45 Indiana University, all campuses	Public	195	102	2	5	69	17
46 Emory University	Private	189	133	4	8	19	26
47 Case Western Reserve University	Private	182	140	3	6	17	16
48 University of Rochester	Private	177	133	8	18	7	11
49 University of Illinois at Chicago	Public	175	86	6	10	59	15
50 University of Kentucky, all campuses	Public	174	66	11	15	79	3
Top 50 institutions		**15,586**	**9,416**	**1,015**	**1,203**	**2,858**	**1,092**
51 Virginia Polytechnic Institute and State University	Public	169	75	37	13	40	4
52 New York University	Private	167	111	1	8	18	30
53 SUNY at Buffalo, all campuses	Public	167	85	5	5	42	29
54 University of Texas Southwestern Medical Center Dallas	Public	166	102	5	16	1	41
55 University of Chicago	Private	163	136	—	2	9	16
56 Iowa State University	Public	161	54	48	15	41	3
57 University of Tennessee system	Public	159	70	29	15	30	14
58 University of Virginia, all campuses	Public	157	108	6	13	16	14
59 University of Hawaii at Manoa	Public	157	93	35	13	15	0
60 University of Texas M.D. Anderson Cancer Center	Public	155	69	0	0	51	35
Top 60 institutions		**17,207**	**10,322**	**1,182**	**1,303**	**3,121**	**1,277**
61 University of Utah	Public	154	112	2	9	23	8
62 Univ of Cincinnati, all campuses	Public	153	100	4	6	33	10
63 Colorado State University	Public	150	92	17	7	34	—
64 Vanderbilt University	Private	150	117	—	4	15	14
65 University of Missouri, Columbia	Public	149	54	17	4	68	7
66 SUNY at Stony Brook, all campuses	Public	149	94	3	7	38	6
67 Wayne State University	Public	147	58	13	11	49	17
68 Carnegie Mellon University	Private	142	90	18	18	9	7
69 Univ of Oklahoma, all campuses	Public	142	58	16	8	45	16
70 University of California-Irvine	Public	142	76	4	17	28	17
Top 70 institutions		**18,685**	**11,172**	**1,276**	**1,393**	**3,464**	**1,379**
71 Boston University	Private	141	123	1	8	0	9
72 University of Maryland at Baltimore	Public	141	85	24	12	9	11
73 University of Miami	Private	140	102	1	16	6	14
74 Oregon State University	Public	139	82	29	—	24	4
75 Univ of Connecticut, all campuses	Public	135	55	10	10	48	11
76 University of Kansas, all campuses	Public	133	57	11	14	36	13
77 University of Nebraska at Lincoln	Public	131	37	4	5	78	7
78 Mount Sinai School of Medicine	Private	128	85	3	9	16	15
79 University of Medicine and Dentistry of New Jersey	Public	126	62	8	11	35	10
80 Princeton University	Private	124	73	2	6	29	14
Top 80 institutions		**20,023**	**11,932**	**1,370**	**1,484**	**3,746**	**1,488**
81 University of South Florida	Public	124	42	7	6	57	11
82 Rockefeller University	Private	122	45	2	3	40	31
83 Univ of New Mexico, all campuses	Public	116	85	2	3	22	4
84 Oregon Health Sciences University	Public	112	76	3	8	15	9
85 Yeshiva University	Private	112	90	0	0	21	1
86 Georgetown University	Private	111	84	—	8	12	7
87 Mississippi State University	Public	111	47	26	8	30	0
88 Arizona State University	Public	107	54	2	4	44	3
89 University of South Carolina	Public	106	48	4	2	47	4
90 University of Texas Health Science Center Houston	Public	105	71	2	13	6	13
Top 90 institutions		**21,149**	**12,574**	**1,420**	**1,539**	**4,041**	**1,572**
91 University California-Santa Barbara	Public	105	74	2	5	16	8
92 Tufts University	Private	102	64	—	7	20	10
93 Clemson University	Public	99	27	21	8	38	4
94 Florida State University	Public	98	56	2	1	37	2
95 Washington State University	Public	97	45	4	3	35	11
96 Utah State University	Public	95	54	17	4	17	4
97 University of Texas Medical Branch at Galveston	Public	94	55	10	6	11	11
98 University of Alaska Fairbanks	Public	89	35	4	19	31	—
99 University of Texas Health Science Center San Antonio	Public	88	57	7	11	8	6

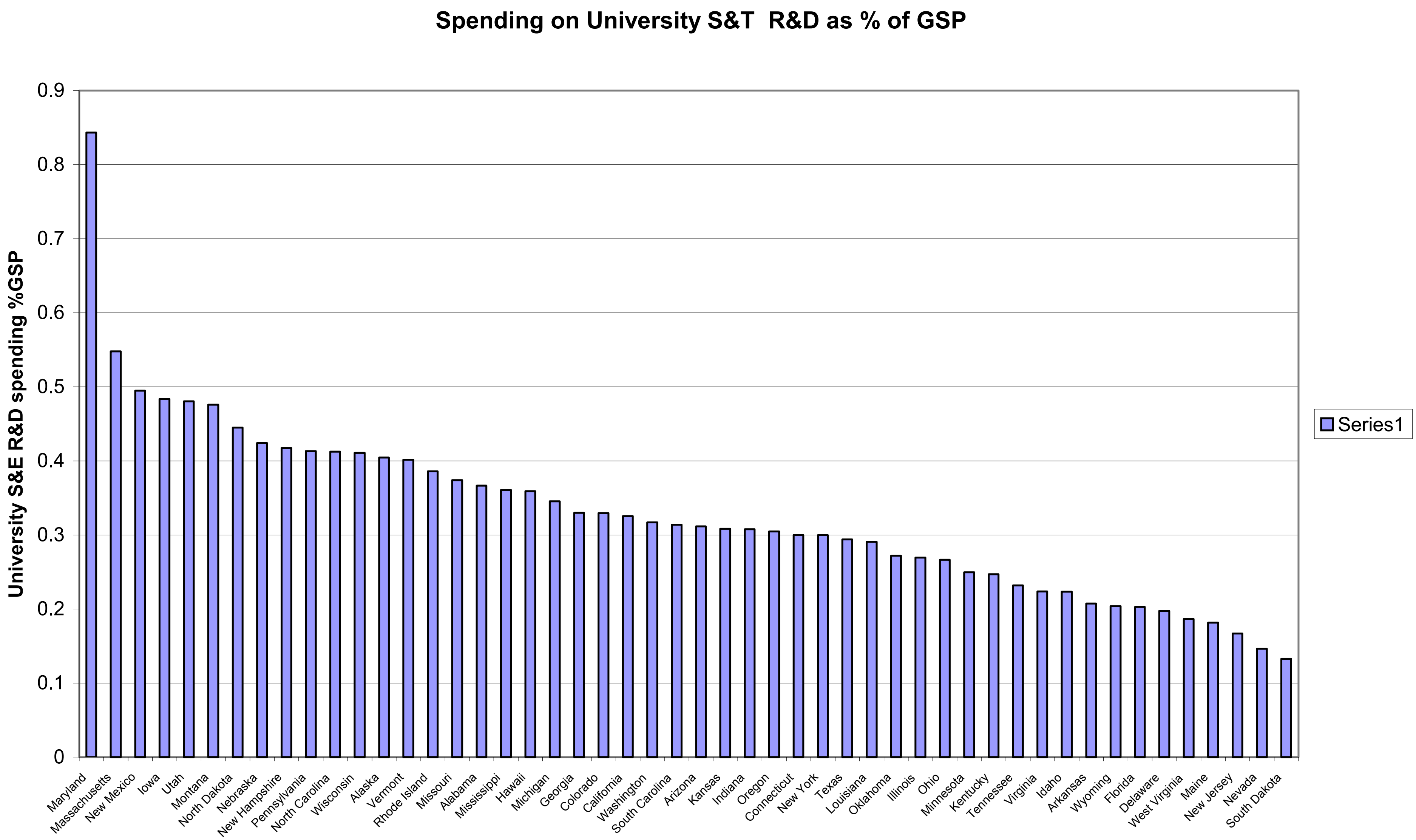
100 Tulane University	Private	87	51	3	12	18	4
Top 100 institutions		**22,102**	**13,091**	**1,488**	**1,616**	**4,271**	**1,632**

Distribution of funding for university R&D across the States of the US.

Generally there is a relatively even distribution of total university science and engineering R&D funding for science and engineering across the States of the US as shown by the following plots of expenditure against both Gross State Product and population. The States conspicuously above the trend in increasing order of both GSP and population are Maryland and Massachusetts. Florida with an expenditure of about £1 billion is one of the States below the trend. The university research expenditure of each state in science and engineering as a percentage of gross state product is illustrated on the next page.


US States: University R&D against Gross State Product
R&D $,000
GSP $million
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
1,400,000
1,600,000


US States: University R&D against population
Univ R&D $,000
population
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
5,000,000
10,000,000
15,000,000
20,000,000
25,000,000
30,000,000
35,000,000
40,000,000


Spending on University S&T R&D as % of GSP
University S&E R&D spending %GSP
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Series1
Maryland
Massachusetts
New Mexico
Iowa
Utah
Montana
North Dakota
Nebraska
New Hampshire
Pennsylvania
North Carolina
Wisconsin
Alaska
Vermont
Rhode Island
Missouri
Alabama
Mississippi
Hawaii
Michigan
Georgia
Colorado
California
Washington
South Carolina
Arizona
Kansas
Indiana
Oregon
Connecticut
New York
Texas
Louisiana
Oklahoma
Illinois
Ohio
Minnesota
Kentucky
Tennessee
Virginia
Idaho
Arkansas
Wyoming
Florida
Delaware
West Virginia
Maine
New Jersey
Nevada
South Dakota