Raising EU R&D Intensity

Improving the Effectiveness of Public Support Mechanisms for Private Sector Research and Development: **Direct Measures**

Report to the European Commission from an Independent Expert Group

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Report to the European Commission
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Directorate-General for Research
Knowledge Based Society and Economy
Strategy and Policy, Investment in Research

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Foreword

The EU is currently lagging behind both the USA and Japan in terms of expenditure on R&D as a proportion of GDP, primarily due to slow relative growth in business R&D expenditure. The European Council in Barcelona set an overall target of 3% of GDP by the year 2010, with industry asked to contribute two thirds of this objective. To approach these levels, dramatic improvements are needed in the effectiveness of policies used to stimulate private sector R&D.

In order to review how progress could be made towards this goal, the Commission services set up four expert groups to explore and enhance the potential of different financial and fiscal policy instruments. These different expert groups investigated respectively: direct measures, fiscal measures, risk capital measures and loan and equity guarantee instruments. An overarching expert group, the policy mix group, was also charged with reviewing the relationships between the mechanisms dealt with by the four groups and considering how these measures might be combined most appropriately to stimulate private sector R&D.

The specific aim of this report is to offer suggestions and guidance concerning the design and implementation of direct public support measures to stimulate private investment in research. The report considers the importance of supply side measures, the growing importance and significance of demand-side measures and the role of framework conditions. After reviewing the use of these measures and the factors that affect their effectiveness, the report then presents a series of recommendations for policymakers across the EU.

I should like to thank all the experts who took part in the production of this timely report, particularly the Chairman of the expert group, Professor Georghiou. Their work contributed significantly to the Commission's own thinking and to the preparation of the Communication from the Commission: 'Investing in Research: An Action Plan for Europe'. It contains much of value to all those concerned with the formulation and delivery of effective policy mixes. As such I trust that it will stimulate the process of mutual learning needed to realise not only the 3% target for R&D, but also the target set at Lisbon of becoming the most competitive and dynamic knowledge-based economy in the world.

This report, as well as the other reports of the Expert Groups, is available on the Commission Web site http://europa.eu.int/comm/research/era/3pct.

Philippe Busquin
European Commissioner for Research

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EXECUTIVE SUMMARY

This report investigates the effectiveness of direct public support measures in stimulating private investment in research in the context of the target of raising the EU's expenditure on R&D to 3% by 2010. Direct measures were defined in the Terms of Reference of the Working Group to include subsidies and grants, including grants that are repayable in case of successful commercial exploitation (conditional loans), procurement and block funding of public institutions.

I. Summary of Conclusions and Recommendations

Direct measures encompass the great majority of the instruments used in science, technology and innovation policy. As an overall message it is important to stress that their cumulative effect is already one which raises the quantity and quality of R&D in Europe and has the potential to do more towards bringing Europe to a position of at least shared world leadership in business R&D. However, the real challenge is to create the conditions where firms recognise that R&D investment in Europe will provide them with high returns and sustained profitability.

To achieve these conditions, we argue that demand-side policies are needed to foster the lead markets for innovation that could drive the step-change needed. Supply-side policies can act as a positive supporting force while favourable framework conditions and policy coordination are critical conditions.

Supply-side

1. For grants and reimbursable loans good practice lies in their use as incentives for developing new networks and collaborative linkages. This includes setting measures in the context of a broader strategy such as the development of a cluster. Specific points on grants are:
    a. Grants should be offered as a small portfolio of flexible measures with adaptive rules.
    b. State Aids rules should be changed to allow awards up to the current maximum level of support available for any part of the R&D process where there is a clear rationale for support from public funds. The present interpretation of the additionality criterion also fails to recognise the real nature of risk and uncertainty in R&D.
    c. Grants are at their most valuable during a recession. They enable firms to rebuild their technology bases when their own revenues are stretched and they also maintain research capacity which could be easily destroyed but far less easily recreated.
2. R&D support policies are a marginal factor in the relocation of international R&D investment while in less developed regions at least equal priority should be given to the transfer of existing technologies. For cohesion and accession countries measures to promote an innovative culture are a priority. However, R&D provides a key to the absorption of technologies and must also be supported.
3. The contract research sector has a vital role in providing R&D capabilities for traditional SMEs. Government should ensure that contract research organisations maintain their scientific and technological capabilities through strategic research

programmes and that they act as a focus for networking between companies and universities.

4. The means of measuring and supporting R&D in the service sector requires reconsideration.

Demand-side

5. In pursuing the 3% target the principal opportunity lies in the use of demand-side policies. Loss of actual and potential R&D investment from Europe has been as much driven by the attractiveness of markets elsewhere as by any factors intrinsic to the performance of research.
6. Public technology procurement is probably the policy instrument with the largest potential to contribute to the 3% target. The boost to innovation derived from defence spending in the USA could be matched in Europe by innovation-oriented procurement in sectors such as health and public security.
7. Specific measures which could be taken to promote PTP include:
    a. Requiring governments to produce a regular plan and statement on the degree of innovation and technology development involved in their procurement practices;
    b. A recognition that public services are also risk takers and hence an understanding that there is a trade-off involved which will involve some failures in procurement decisions en route to greater public service productivity;
    c. Investigation of the possibility of declaring a target for the R&D/innovation component in public procurement;
    d. Investigation of possible changes in competition regulations.
8. The defence experience clearly demonstrates the need for “smart procurement” practices involving close coordination between purchaser and innovative supplier.
9. The exclusion of SMEs from a large proportion of procurement is one reason for their low R&D intensity on Europe. Actions to remedy this include the establishment of analogues to the US SBIR.
10. Measures to increase the innovative content of private procurement by improving purchasing information and reducing risk also offer important opportunities towards creation of lead markets.
11. Technology platforms create gearing effects by combining financial support with regulatory and other policies. They also can create the scale to address critical problem areas.
12. Promotion of clusters offers a further means to maximise the effectiveness of policy combinations.

Framework conditions

13. Framework conditions determine the attractiveness of R&D investment in Europe and can only be temporarily offset by financial measures alone. The most important of them is the availability of highly skilled researchers.
14. There is a role for direct measures in rewarding the recruitment of new personnel and in promoting training of industrial personnel against a background of formal academic qualification.
15. Obstacles to mobility from the public to the private sector should be removed. These cover administrative and legal issues but also the cultural gap that exists. Measures to promote inter-sectoral mobility include financial support for secondments and

relaxation or removal of restrictions arising from the civil service status of researchers.

16. Continuing support for the science base is an essential precondition for a healthy industrial R&D culture. The science base in Europe lacks the strong concentrations of excellence which can be found in the USA. Radical restructuring is needed in some fields towards policies based upon concentration of resources and creation of well-networked "centres of excellence".
17. The relationship between an excellent science base and industrial innovation is far from automatic. Continuing emphasis upon the whole range of direct measures that exist to promote industry-science relations is needed, along with complementary measures to train students in entrepreneurial skills.

Coordination

18. Progress towards the Barcelona target requires a substantial new orientation of innovation policy in Europe towards a demand-side focus on the creation of lead markets friendly to new products, processes and services. This report has emphasised the need for coordinated policies to achieve this. At all levels of governance, the need for such coordination goes well beyond those traditionally responsible for science and technology policy. The way to achieve this depends upon the particular circumstances but in general we expect that innovation policy should have its locus at the centre of government.

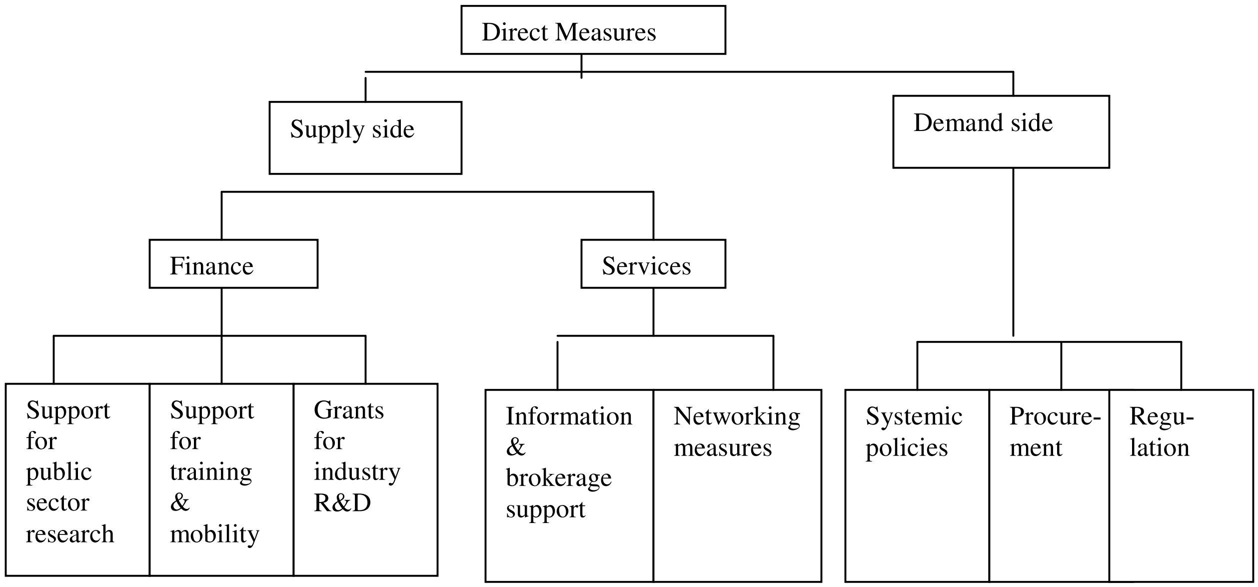
II. Summary of Supporting Evidence

Stimulation of private investment in R&D includes:

- Encouraging existing R&D performing firms to spend more or to relocate R&D into Europe from other regions;
- Encouraging firms which do not perform R&D to begin to do so or to outsource more technology from external suppliers who perform R&D;
- Encouraging the formation and growth of new firms which perform R&D;
- Increasing the scope of what we understand as R&D, particularly in non-technological innovation.

Given the dynamic situation in which business R&D operates, the study has also considered measures to prevent or minimise cuts.

The classification system developed for this study divides Direct Measures as follows:



Framework Conditions: Human resources, Science base, Regulatory framework (including State Aid, Competition & IPR, General fiscal environment

Investment in Industrial R&D in Europe

Without substantial leverage of business R&D, it would take an order of magnitude increase in public funding to have a significant impact upon the 3% target. Between 1991 and 1999 there was a fall of five percentage points in the proportion of BERD financed by government in the EU. This has been driven mainly by cutbacks in defence R&D and by an increase in business expenditure during that period.

There is a case for reconsideration of what we define as the creation of new knowledge by industry as a first step to understanding the conditions and policies which could stimulate its growth. The service sector exhibited strong growth in its R&D during the 1990s. However, service R&D is largely not recognised or addressed by current policy measures. There is at least a risk that the total amount of R&D being performed in Europe is constrained by the definitions in the Frascati Manual.

The principal motivations for location of internationally mobile R&D are market-related (adaptation and learning from lead markets or lead customers). The next most important factors are knowledge-augmenting – access to scientific talent and networks. Public policies for R&D are only a tertiary factor in most circumstances. An investigation of the role of international R&D investment in contributing to the 3% goal shows that there is a range from 5% to 60% in the weight of foreign manufacturing R&D in Member States. The relative attractiveness of Europe as a location for foreign companies has declined, with the share of foreign-controlled manufacturing R&D in the USA increasing from 45.3% in 1991 to 55.5% in 1998.

Both the cohesion and the accession countries still face the need to formulate clear national innovation policies and ensure support for more effective efforts at national and regional level to support the development of innovation in local industries and SMEs. In both cases, though to different extents, there is lack of a well - defined national innovation system and of involvement of industry in priority setting, lack of coordination between institutions and ministries, bureaucracy of RTD administration, and problems in addressing regional disparities.

There is a need for complementary actions to make firms aware of the opportunities and threats, but also the necessity, of innovation and going 'international' and of measures to encourage their entrance to new, more innovation-demanding markets. Without these, direct R&D-supporting measures to encourage them to be involved in R&D and innovation, collaborate with research organisations, and the like, or indirect measures such as tax incentives, may still have limited results in terms of increasing the private investments in R&D.

For countries with a low starting base, intermediary targets are needed both for measures to stimulate private investment in R&D and for removal of wider barriers inhibiting innovation. The target of 3% GERD/GDP (and the origination of 2/3 of it from industry) seems to be a target 'too distant' to comprehend and to design appropriate measures for achieving it. Promotion of cultural changes to favour innovation can precede more costly direct support measures.

Supply-side policy measures

While finance is the motor for grant-based policy measures, good practice policies appear to be founded in the "behavioural additionality" rationale and in particular in using grants to provide incentives for developing new networks and collaborative linkages. Effects of this type are more likely to persist beyond the immediate funding period. This includes setting measures in the context of a broader strategy such as the development of a cluster. These approaches create cumulative technological assets which in the longer run enable firms to increase their returns on R&D and in turn their investment in it.

The value of grant schemes can be diminished when there are too many of them, each trying to focus on a narrow objective and possibly at a sub-critical level. This can be confusing to firms seeking support and favours "regular users" who have developed skills in navigating the funding infrastructure. **On the other hand there is also a risk in creating large and inflexible instruments which do not adapt to individual circumstances or to changing technological priorities over time.** The right mix would appear to be a small portfolio of flexible measures with adaptive rules. There is also a need for policy coordination to ensure that addressing one deficit in the system does not create a bottleneck elsewhere.

Conditional reimbursable loans have a niche for application in support of smaller firms operating nearer the market.

Demand-side policy measures

Public technology procurement (PTP) occurs when a government agency places an order for goods or services that do not yet exist and hence R&D and innovation have to take place before delivery. The financial security of the order reduces the uncertainty for the supplier and thus encourages R&D investment. The potential of this policy instrument is very large – EU governments spend €720 billion annually. Within this a greater emphasis upon innovative products could attract significant new resources for R&D. There are historical success cases but also dangers if the policy is used to support ailing national champions. PTP depends upon close relations between the buyer and seller and hence is inhibited by EU internal market regulations. Experience in the defence sector has shown that "smart procurement" produces a more satisfactory outcome for public expenditure than does full competition at all stages.

There is an opportunity for Europe to develop a common procurement base in civil public goods, for example healthcare and security. The USA receives a major boost to its technological capabilities from defence spending, especially from the technologically oriented DARPA. It is unlikely, even with common procurement, that Europe could match this input within defence alone.

The stimulation of private procurement in support of innovation is a further policy option. The aim is to promote buyer-seller interactions via the build-up of competences and communication networks among buyers and sellers, through education, conferences, prize contests, grants, associations, campaigns at universities, media support etc. and to encourage better use of information technology.

Systemic policies

Networking has become a key aspect of company strategy. More and more key innovations and related global businesses are developed and dominated not by single companies but by market oriented, value-chain based networks. In their role as facilitator, governments have adopted the innovation systems approach to support such networking. This sees the firm's innovation environment as a system of actors, interactions and framework conditions and directs policies towards identifying systemic failures such as insufficient industry-science linkages.

Cluster policies offer a systemic approach to market interactions among concentrations of firms supporting each other. They provide a framework for designing policy mixes. Governments can create the framework conditions for clusters and incentivise and facilitate the building up of collaboration. The policy can be used at national, regional, inter-firm or industry-science levels. It provides a natural platform for combining foresight and strategic elements with direct measures.

Regulation and standards can be combined with direct measures and with other policies to create public-private partnerships or technology platforms in a further measure to help create and structure lead markets for innovative firms and hence reduce the risk of R&D investment.

Framework conditions

European science is characterised by "islands of excellence" but is at present unable to match the high *volume* of excellence achieved by leading US institutions. Lack of economies of scale in equipment and of the critical mass needed for interdisciplinarity are accompanied by a fragmented interface with industry. Excellence is a key driver for competitiveness, and supports the provision of trained people, as well as the other points of contact between industry and science.

The contract research sector in Europe is heavily oriented towards applied research and many laboratories exist to perform R&D and other technical services for SMEs and traditional firms. Outsourcing in general has trebled in recent years. Research centres can also provide central facilities such as research equipment, databases or pilot plant. The sector can also act as a bridge between industry and the science base.

Failure to address the supply of human resources would prevent achievement of growth targets for R&D. There are significant national disparities in the intensity and distribution of human resources for R&D. The supply is affected by issues of pay and other incentives and by the ability to train them. Key issues include recruitment of postgraduates in science and engineering, of PhDs to industry and improving the attractiveness of careers in science for women.

Policy measures to promote the development of firms' internal human resource capabilities include provision of industrial input to doctoral training, academic registration of researchers in industry and provision of business and management skills training for scientists and engineers. Barriers to intersectoral mobility include removing pension and other obstacles arising from the civil service status of public researchers and subsidies for secondments.

Direct measures can contribute by enhancing firm's and scientific institutions' capabilities in intellectual property management through training and brokerage and through providing stable and fair conditions in public programmes. Intellectual property policy has a powerful influence upon the rate of innovation.

EU rules for State Aid for R&D are necessary to prevent distortions of competition. However, their present interpretation unnecessarily inhibits support for R&D and innovation by identify separate percentage limits for different stages of R&D. This does not correspond to the reality of technological development and fails to recognise that all these stages carry similar levels of risk and uncertainty.

The concept of additionality is a further problem when used to prevent support for R&D in firms' core activity. The concept of what is core is unstable and in any event may be as risky as other activities. In general State Aid regulations need to be formulated in the context of an understanding of dynamic competition rather than of static efficiency.

Policy mix, governance and delivery

Direct measures can interact positively or negatively with each other and with other policy measures within and outside the R&D domain. Furthermore they originate at multiple levels of governance and as a consequence of the multiple roles of government.

They are then implemented through a variety of linkages with agents and end-users. Policies also show evidence of historical accumulation.

Learning from experience

Evaluations of direct measures, though numerous, have placed excessive emphasis upon participants in programmes and paid insufficient attention to the surrounding innovation **environment**. **Nonetheless a number of good practice and bad practice elements may be derived from experience with direct measures. The former focus on scale, flexibility and gearing, while the latter engage with high administrative overheads, over-zealous accountability, lack of critical mass in programmes and barriers for SME participation.**

REPORT

1 Introduction

This is the Final Report to the European Commission of the Direct Measures Group and of the study contract on this topic held by PREST (Policy Research in Engineering, Science and Technology) of the University of Manchester. The group has been charged with investigating the effectiveness of direct public support measures in stimulating private investment in research in the context of the target of raising the EU's expenditure on R&D to 3% by 2010. This remit includes measures which involve a transfer from the public to the private sector. Direct measures were defined in the Terms of Reference to include subsidies and grants, including grants that are repayable in case of successful commercial exploitation (conditional loans), procurement and block funding of public institutions.

We have interpreted the stimulation of private investment in R&D as encompassing:

- Encouraging existing R&D performing firms to spend more or to relocate R&D into Europe from other regions;
- Encouraging firms which do not perform R&D to begin to do so or to outsource more technology from external suppliers who perform R&D;
- Encouraging the formation and growth of new firms which perform R&D;
- Increasing the scope of what we understand as R&D, particularly in non-technological innovation.

Given the dynamic situation in which business R&D operates, the study has also considered measures to prevent or minimise cuts in R&D[1]. These might be different from measures to stimulate new R&D. Also recognised are tendencies that work to reduce R&D spend. Firms may reduce expenditure on R&D as a result of competitive pressures resulting from deregulation and liberalisation (a clear tendency in privatised utilities for example), through productivity gains in R&D as a process (for example the increased use of automated processes in biosciences and of simulation techniques in all areas), and finally, reduction of duplication, either through the market or through policy-led rationalisation. In the absence of data on the elasticities involved we operate on the assumption that the more productive R&D in Europe becomes, the greater is the incentive to invest in it.

The report was prepared during five meetings of the Expert Panel at which topics were discussed and evidence heard from external experts. The Direct Measures group was composed of experts from industry, academia and government. It operated on an interactive basis with the Policy Mix Working Group in which the combination of Direct Measures with Indirect Measures, Loan Guarantees for innovation and Risk Capital was considered. Between meetings members of the group prepared study papers on specific topics. The overall report was prepared by the Chairman and Rapporteur on the basis of the above evidence.

[1] We note for example that according to the Stifterverband für die Deutsche Wissenschaft, R&D expenditure by German industry is not expected to grow in real terms in the current year after several years of strong growth.

2 Structure of the Report

The three aims of this study are, as stated above: to gain understanding of the relationship and operation between direct measures that support R&D from public sources and private sector investment in R&D – specifically to focus upon the so-called leverage effect; to identify the conditions which affect the operation and impact of such direct measures and the associated leverage effects – the framework conditions; and to provide guidelines for future use in the development of policy for direct support measures and recommendations concerning the limitations provided by framework conditions.

The report initially presents a broad typology of direct measures which distinguishes those concerned with supply-side issues of finance or services to firms from those which condition the demand for business R&D. This is followed by an analysis of the scale and scope of the challenge through an examination of relevant statistics. The theoretical basis for policy intervention through direct measures is then discussed. The following section examines the evidence on international mobility of R&D investment and the factors which drive this. The scene-setting concludes by a discussion of the specific problems facing cohesion and accession countries and the implications of these for policy prescriptions.

Policy measures themselves are examined in two sections based upon the supply/demand distinction. On the supply side grants and loans are discussed, while demand side policy measures include procurement, the role of standards and regulations in creating lead markets and systemic policies, including clusters.

The next section addresses framework conditions that have a bearing on the level of business R&D spend and the effectiveness of direct measures. A short chapter considers issues of policy mix and delivery, followed by a summary of some lessons emerging from practice.

Finally conclusions are drawn on the policy options available.

3 The Analysis of Measures

3.1 Developing a Typology of Direct Measures

The range and number of policy instruments available is large. The Innovation Policy TrendChart lists 1,340 instruments in use in 28 countries. To identify the specific role of direct measures and the various policy instruments which fall under this heading requires a systematic exploration and classification of what is available. This section aims to develop a typology of such measures.

A useful framework is to classify the policy types by the deficiencies they seek to remedy[2]. These may be summarised as:

- **Resources:** Where there is insufficient resource, usually money, to undertake the work, without public funds. This is generally the case for academic research and is accepted to be so for certain areas of business R&D which are highly uncertain and/or where social returns justify an investment which does not meet private criteria.
- **Incentives:** Where the scientific structures or the market do not provide sufficient incentives for socially desirable behaviour, for example academic-industrial collaboration.
- **Capabilities:** Where organisations lack key capabilities needed for the innovation process, for example the ability to write business plans or raise venture capital.
- **Opportunities:** This refers to the generation of opportunities for innovation and provides one of the main justifications of public science.

Table 1 lists the main categories of measures available to policymakers, though it does not capture the variety which can be achieved through differences in application process and eligibility for participation, sectoral, technological or innovation phase specificity, financial conditions and intellectual property frameworks to name but a few characteristics.

It should also be recognised that support for innovation involves measures downstream from R&D, including for example assistance with market research for innovative goods and assistance in securing investment. The existence of such measures may nonetheless increase the propensity of firms to perform R&D. It is also true that the increasing pace of innovation means that these measures are frequently integrated into R&D measures, for example market research is done concurrently with R&D.

Also not clear from the Table is the interactive nature of such policies. To a large extent they are complementary, addressing different deficiencies in the innovation system, but they can also interact in negative ways, for example fiscal incentives may reduce the resource impact of grants. At a more basic level, the multiplicity of policy instruments can itself be a source of confusion and cost for firms and create incentives for "frequent users" of public schemes who have moved up the learning curve of application.

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[2] For an earlier classification of European policies by this framework see Metcalfe JS and Georghiou L, Equilibrium and Evolutionary Foundations of Technology Policy, June 1998, *STI Review* No.22, Special issue on "New Rationale and Approaches in Technology and Innovation Policy",

However, from the Table it may be seen that "Direct Measures" as defined in our terms of reference constitute the great majority of policy instruments available. Those addressed here are shaded in the Table.

Table 1 Policy Measures

Measure	Deficiency addressed	Comment on Application
Support for basic research	Opportunities Resources	Directed to universities and public laboratories
Support for public research directed to industry	Resources Incentives Capabilities Opportunities	Includes support for public sector scientific institutions with conditions attached to increase the benefit to industry eg prioritisation of areas of interest to industry, grants conditional upon collaboration with firms, arrangements for use of equipment belonging to either party, and incentives and awards for collaboration. Public laboratories carry out increasing proportions of contract research for industry, extending the range of industrial R&D and potentially bringing R&D to firms without the capability to do it themselves.
Support for training & mobility	Resources Capabilities	As well as the basic production of graduates this covers tailored courses or graduate schools for firms, training in entrepreneurship and innovation skills, promotion of secondments from science to industry and vice versa, and employment subsidies for recruitment of researchers by firms.
Grants for industrial R&D	Resources Incentives Opportunities	Gradual evolution away from support of near-to-market research, large firms and single company support in favour of support for SMEs and for collaborative, "pre-competitive" R&D. Conditional loans are a variation on grants. Principal value in providing finely tuned incentives, for instance encouraging firms to do higher risk R&D or to perform it in different ways eg collaboratively.
Fiscal support for R&D	Resources Incentives	Offer non-discriminatory finance for R&D either by volume or for incremental spend with no selection process.
Equity support for venture capital	Resources Incentives	Compensates for deficiencies in VC market. Particularly important in pre-seed and seed capital phases.
Co-location measures	Opportunities Incentives	Increase innovation through proximity of industry and science and critical mass effects. Include provision of facilities for company labs on campuses, and establishment of incubators, science parks and technology parks. Total amount of R&D taking place in such environments is relatively small but is important in terms of generating new firms that may subsequently grow large.
Information and brokerage support	Capabilities Opportunities	Include support for databases of contacts relevant to innovation, advisory services, provision of information on technological developments in other countries, technology transfer offices, organisation of brokerage events, funding for demonstrators and for use of patent databases. Almost exclusively directed towards SMEs.
Networking measures	Opportunities Capabilities	Include support for clubs which exchange information and for activities such as foresight programmes which aim to develop common visions around which future oriented R&D networks can be formed
Procurement	Incentives Opportunities	The situation when a public agency places an order to another organisation for a product or service that does not yet exist. This means that R&D and innovation need to take place before delivery. The procurer specifies the functions of a product or system but not the product as such. This measure is normally appropriate for large scale systems and hence large as well as

		small firms. Measures are also possible to stimulate innovative procurement between private organisations, as in a supply chain. Can attract new public resources into R&D and present firms with a guaranteed market, thus lowering the risks attached to their own R&D investments
Systemic policies	Incentives Opportunities	These policies, for example cluster policies, aim to stimulate interactions between strong concentrations of industries supporting each other. Enhancement of private investment in R&D through clusters comes through increased awareness and confidence among firms, lowering risks associated with innovation and providing linkage between global players and their actual or potential sub-contractors, including those further down the supply chain.

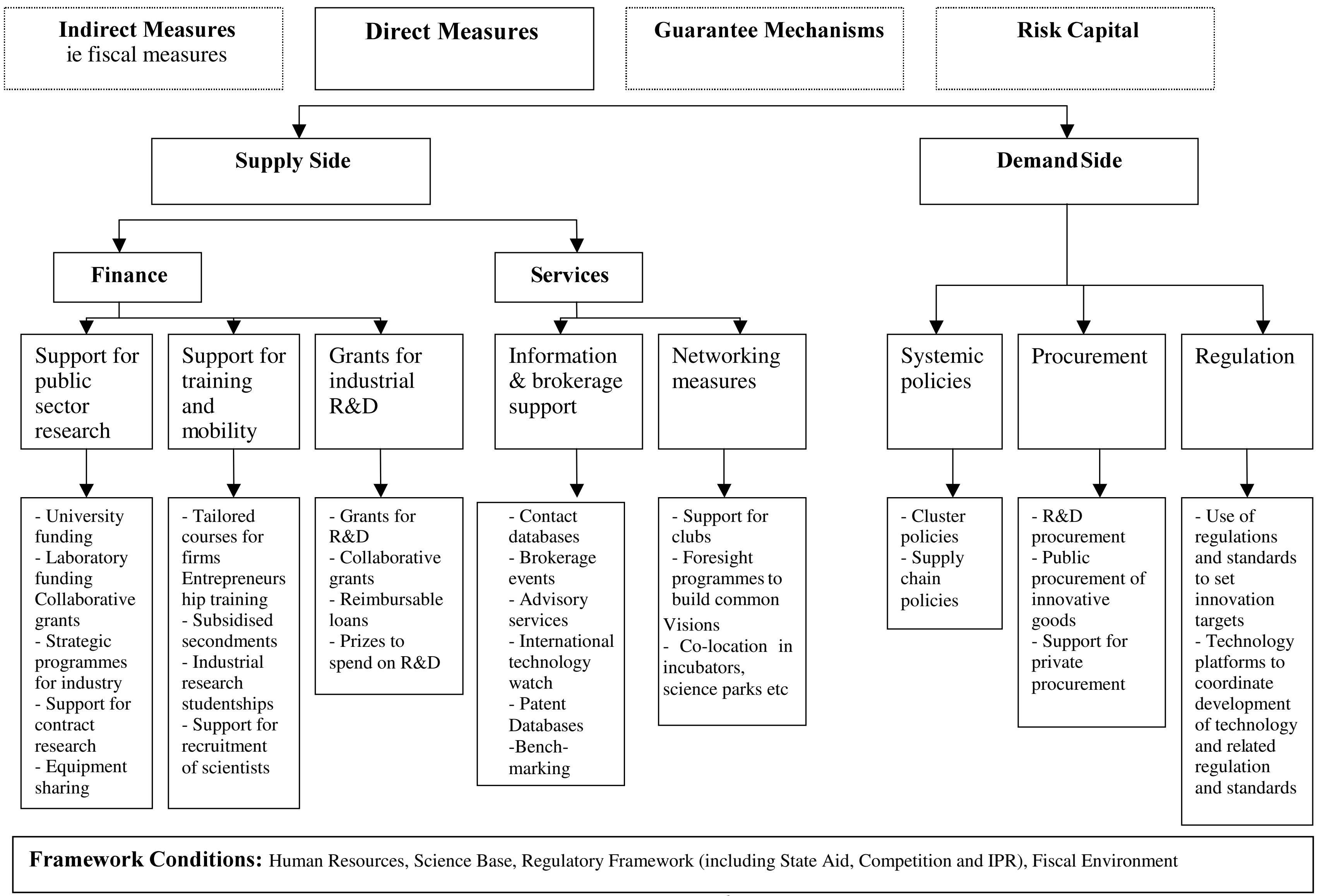
Having identified the main categories of Direct Measures, the next task is to consider how they may be classified. Figure 1 presents a general classification and indicates which specific types of measures fall under each branch. The main distinction made is between supply-side and demand-side policy measures. By supply-side we mean those policies which are intended to provide a transfer to firms from government or its agents of the resources and capabilities needed for innovation. These resources are often conditional upon specified behavioural changes and hence also act as incentives. In turn this category may be sub-divided into provision of finance and provision of services. Under finance we include funding schemes of all types, including support for basic and strategic research and subsidies given to firms for R&D. Support for training and mobility is included here to cover the sub-category of policy measures which directly subsidise the acquisition and retention of people or innovative skills. The supply of human resources is also, of course, a framework condition and is discussed in that context elsewhere in this report.

Provision of services to support R&D and innovation represents a growth area for policy measures and is focussed largely but not exclusively upon addressing the gaps in capabilities of SMEs. The two sub-categories separate the provision of information and expertise and support for networking as a means to build new combinations of technological competences. These measures cannot be separated entirely from finance as they may consist of grants towards the cost of sourcing such services from the private sector.

The second main category, demand-side measures, refers to those policies which ultimately seek to increase the demand for innovative goods and hence increase the incentive for firms to perform R&D. Policy measures under the sub-heading “regulation” refer to the development of regulations and standards which structure markets, and in particular how these may be used in harmony with R&D support to create a European home market that provides an incentive for firms to invest R&D resources to supply it. Technology platforms, in this typology, are used to describe the coordinated use of multiple policy measures (direct and otherwise) towards a goal. Linked to this is the second category, that of procurement. As well as the direct procurement of R&D by government to meet its own needs for knowledge, the category covers the procurement of innovative goods, services and systems by government as a means to expand market opportunities for firms willing to take the risk of producing them.

This connects to the third sub-category, called here “systemic policies”. Such policies aim to stimulate interactions between strong concentrations of industries supporting each other (clusters) and to exploit natural vertical linkages between firms, for example supply chains, as a means of providing incentives for innovation.

Figure 1 Direct Measures General Classification



4 Situation of European R&D Expenditure

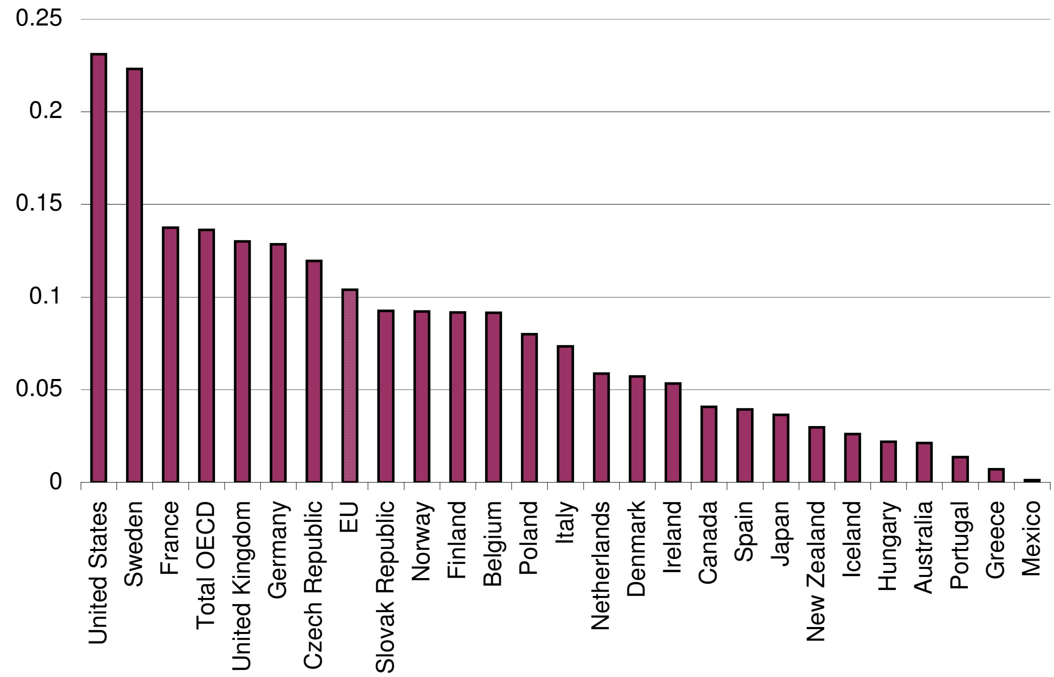
In this section we consider first the present status of government funding for Business R&D. This represents only one aspect of direct measures support. It excludes measures which are funded through support for research in public sector institutions and also the costs of providing services to assist innovative firms. Nonetheless it gives a measure of the extent of the most visible of direct measures, grant and loan schemes. The following sub-section reviews the rationale for intervention through direct measures and contrasts the arguments deriving from different economic perspectives. Also discussed is the issue of additionality of public intervention – assessing the difference made by public support.

Section 4.3 moves onto factors affecting the international mobility of business R&D and the motivations for locating facilities in a particular country or region, including the effectiveness of policy measures. The section concludes by considering the distributional aspects of the 3% target and in particular the issues confronting those countries with the largest gap, notably cohesion and accession countries.

4.1 Role of Government Funding of Business R&D

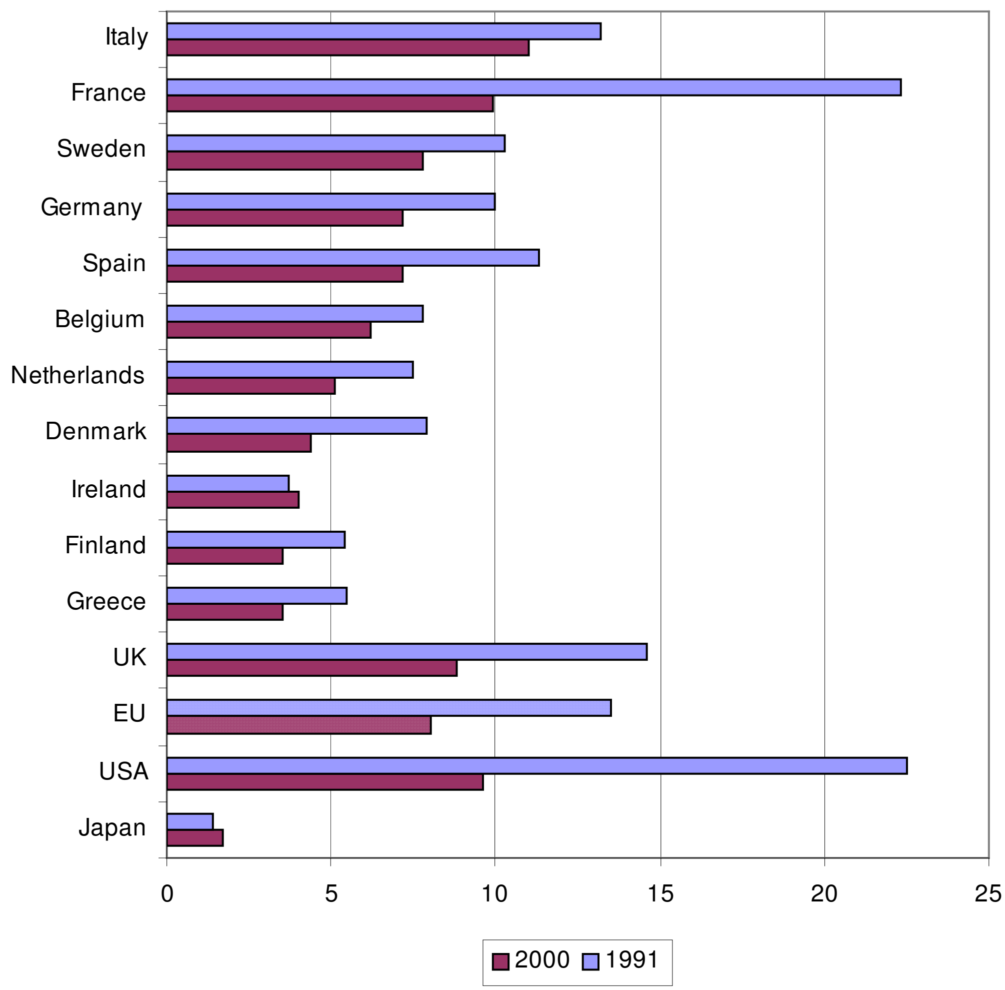
Given that many Direct Measures involve government expenditure, the first issue to examine is the potential role for government support for R&D in addressing the gap. Bearing in mind that the EU-US gap for R&D as a % of GDP stood at 0.8 percentage points in 2000, Figure 2 shows that it would take an order of magnitude increase in government spending on BERD to cover the gap. Given the expectation that two thirds of Europe's increase is expected to come from the private sector, it can be safely concluded that government finance for business R&D cannot cover the gap directly. Hence, the attention of this report is focussed upon potential leveraging effects, both of this direct spend and of other government measures in support of science, technology and innovation.

Figure 2 Share of Business R&D financed by Government as % of GDP, 1999



Note: 2000 data for Belgium, Canada, Czech Republic, Germany, Hungary, Poland, Slovak Republic, United States; 1997 for Ireland; 1999 for all others, including EU and OECD averages.
Source: OECD, STI Outlook 2002, based on data from OECD MSTI database, June 2002.

Figure 3 Percentage of BERD Financed by Government 1991-1999

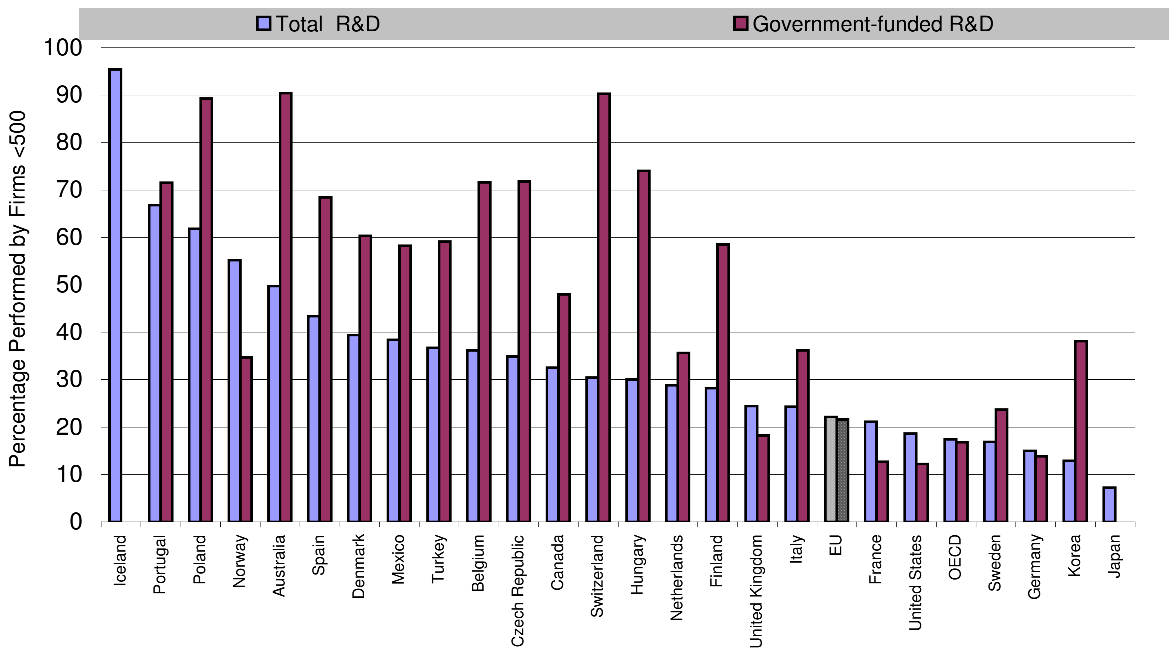


Note: 1999 data for Denmark, Greece, Ireland, Netherlands and Sweden
Source: OECD, Main Science and Technology Indicators, January 2003.

Figure 3 shows the change in the percentage of BERD financed by government between 1991 and 1999. Overall there has been a strong fall, five percentage points for the EU as a whole, with a particularly marked fall in France, from 22.3% to 10%. Two factors are at work here, the first being cutbacks in defence R&D and the second the growth of business-financed BERD. Within the EU, only Ireland has increased the percentage (along with Japan). These figures indicate a general trend of reducing public finance for industrial R&D.

The final graph in this section separates government funding for BERD by firm size. This indicates that most countries target SMEs as a priority for financial support for R&D indicated by the fact that the relative share of government financed BERD for SMEs is greater than the relative share of :SMEs in total BERD). In the EU the exceptions are the UK, France and Germany. In the first two cases the main explanation is the role of support for defence and aerospace R&D which is predominantly carried out by large firms.

Figure 4 Share of Total Business R&D and Share of Government Funded Business R&D Performed by Firms with Fewer than 500 Employees 1999



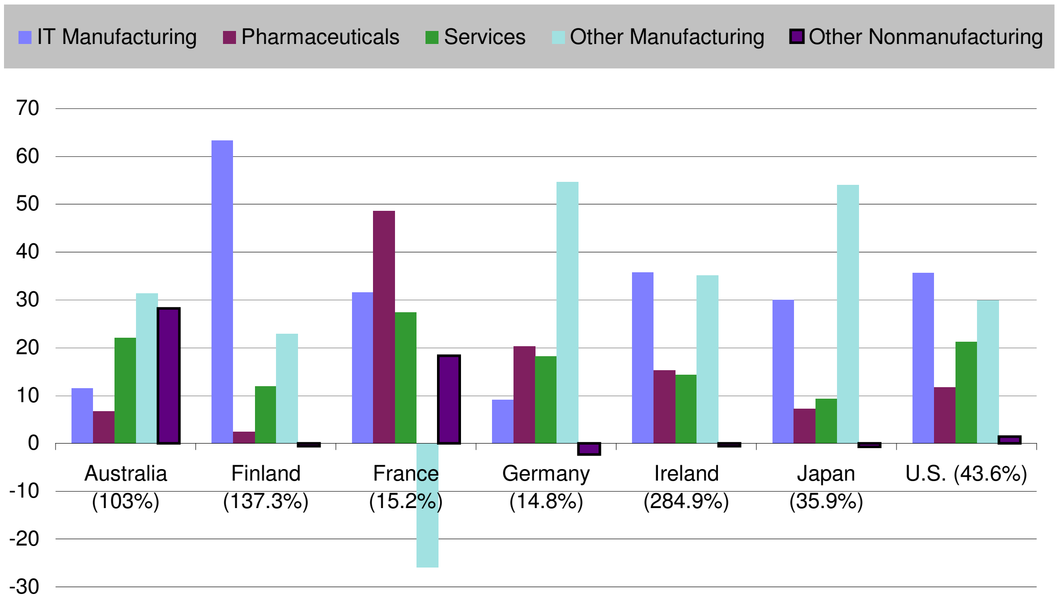
Source: OECD

4.1.1 Sectoral Patterns of Growth in R&D Spend and the Role of R&D in Services

As Figure 5 illustrates high-technology industries, such as ICT and pharmaceuticals, and the services sector account for a disproportionate share of business R&D. Some parts of the ICT sector are now under considerable economic stress, with companies such as Lucent, Northern Telecom and Ericsson for example announcing very substantial cuts in R&D spending. However, others such as Microsoft have continued to increase their R&D spend.

Figure 5 Distribution of the growth in business R&D by industry, 1990-1998

Percentage of total increase in BERD



Notes: Information technology manufacturing includes office, computing and accounting machines, communications equipment and electronic components. The decline in R&D in other manufacturing industries in France derives from steep reductions in defence expenditures (OST, 2000)
Source: OECD ANBERD Database, June 2002.

The situation of R&D in the service sector is of particular interest. Some part of the increase is accounted for by the trend towards outsourcing of R&D and hence the growth of the R&D services sector itself, discussed in Section 7.2 below. However, the role of R&D in the service sector more generally is a topic of significant importance. Beyond the specific cases of telecommunications and computer services, the traditional view of the service sector was that it did not engage in R&D[3]. Tether (2002) analysing the second European Community Innovation Survey (CIS-2) found that about half of the service firms that engaged in innovative activities undertook R&D, with roughly half of those doing so on a continuous basis. There is substantial variation between sectors but even the lowest, transport services, showed 30% of firms with R&D taking place at least occasionally.

The service sector is also important because of its link with manufacturing. There are close links between products and services, also growing over time. Every product provides a bundle of services for the user and most services require for their provision a bundle of products and capital equipment (buildings, instruments, tools etc.). The distinction between service and manufacturing industries is related to a traditional organization and conceptualisation of industrial activities that often becomes fuzzy, perhaps also increasingly so.

[3] See for example Pavitt's (1984) taxonomy of technological activities in which private services were classified as 'supplier-dominated' passive adopters of technologies developed elsewhere.

A technology-based service industry could be defined to mean an industry that principally provides services, the provision of which requires embodied and/or disembodied technology to a considerable extent. Technology is then taken to typically mean engineering and applied natural and science knowledge. The R&D to sales ratio, i.e. the R&D intensity, is then one indicator of the degree to which an industry is technology based.

Table 2 utilizes the denominators capital and technology intensity to provide an overview of service industries in general and technology-based ones in particular. Note that the (physical) capital base embodies technology in its "hard" form. However, capital intensity and technology intensity is not perfectly correlated since there are low-tech/high capital intensive services as well as high-tech/low capital intensive services (e.g. higher science and technology education and engineering consultancy). Moreover, the technology and capital intensity may change over time. Especially the “technification” of many services is noteworthy, that is they become increasingly technology-based. In this connection it should also be noted that telecom services increasingly penetrate other services, e.g. medical, education and entertainment services.

The proper recognition and conceptualisation of technology-based service industries is important in relation to the "3% R&D/GNP-goal", not the least since several of them have been deregulated with a consequent likely drop in R&D spending and decreased relevance of any policy measures traditionally applied to them. The increasingly blurred sectoral boundaries in the new type of ICT-intensive knowledge economy also call for new classifications of industries, for example classified according to dominant IPR type, such as copyright industries or database industries.

Table 2 Illustrative classification of service industries[1)]

Capital intensity[2)]	Technology intensity[2)]		
	High-tech services	Low-tech services or	"no-tech" services
High capital intensive services	Telecom services	Rescue services	Rental services
	Medical services (surgery etc.)	Entertainment	Hotels and accommodation services
	Surveillance and security services	Retailing/wholesale	Religious services
	Defense services	Gambling	
	Energy services	Disposal services (sewage, garabe etc.)	
	Transportation services		
		Water supply	
		Financial services etc.	
Low capital intensive services	Universities and higher educational services	Entertainment	Social services[3)]
			Insurance services
	Consultancy services (engineering, data, etc.)	Financial services	Restaurants
	Medical services etc.		Consultancy services (management, legal, advertising, accounting etc.)
		Police services	Travel agencies Cleaning, house keeping
			Gambling Prostitution[4)] etc.

Notes:
1) Some services are not in everyday language associated with 'industries' but nevertheless encompass production and transactions of some sort.
2) The principal classification variables used here are capital intensity and technology intensity referring to the relative degree of hardware and R&D employed, respectively. These variables are continuous but for illustrative purposes here divided simply into high and low. Obviously, this distinction can be disputed, but still be useful for illustration. In several border cases, the technology intensity is rather non-existing than low, that is the corresponding service industry is not technology-based, although possibly based on other professional competencies. Most service categories vary considerably along the variables and thus could be found at several places in the table, which is illustrated in some cases. A third important variable is information intensity, which could have been used as well (cf. the notion of 'information industries'). Technical information is then a special case. Additional variables for the classification service industries are private/public (the public sector contains a variety of services); legal/illegal; location bound/unbound etc.
3) Typically in the public sector.
4) This is included as an extreme case to illustrate the span of services, also in a legal dimension.

Source: Bohlin, E. and Granstrand O. (eds): "The race to European Eminence - Who are the coming tele-service multinationals". Elsevier Science – North Holland, 1994.

There is some evidence to suggest that R&D in the service sector may be under-reported as firms may believe that R&D needs to be a formal distinct activity (Howells et al, 2001). The argument is that a great deal of service sector innovative activity takes place in the context of work for a particular client. This work may entail customisation which is currently excluded from the Frascati Manual definition of R&D. Nonetheless, it may involve systematic generation of new knowledge. Larger firms, particularly those engaged in the development of complex product systems, are now seeking to codify such knowledge. There is also a tendency over time for passive users of technology to move towards an active engagement in its development (see for example the involvement of users in the EU's Telematics Application programmes).

In a discussion of direct measures, the main comment that could be made about R&D in the service sector is that it is largely not recognised or addressed by current policy measures. There is at least a risk that the total amount of R&D being performed in Europe is constrained by the definitions in the Frascati Manual. **The importance of the service sector and the growth of non-technological innovation (often in a complementary relation to technology) make a case for reconsideration of what we define as the creation of new knowledge by industry.** Even if this did not improve Europe's ranking with respect to the USA and Japan, **recognition of these activities as R&D would be a first step to understanding the conditions and policies which could stimulate its growth.**

4.2 Rationales for policy intervention and additionality of public support

While most of the evidence that we present in this report is clearly empirical, the theoretical foundations for technology policy intervention and in particular of direct measures cannot be ignored. The reason for this is simple – competing theories have guided policymakers to different conclusions and solutions as much as the evidence from policy outcomes has guided the theories – they are a part of the story[4].

Traditional rationales for subsidy of private R&D rely on the notion that the knowledge created has the properties of a public good, being non-rival in use and non-excludable. Hence, firms under invest in activities where the social return is at a desirable level but the private return is insufficient to motivate investment[5]. Other market failures, according to these arguments, arise from information asymmetries and uncertainty associated R&D investment and innovation more generally. To this basic framework has now been added a recognition that the failures may arise in the rigidities and mistakes of innovation agents (firms, public agencies etc) and in the system itself through a lack of linkages and fragmentation between innovation actors[6].

The market failure rationale has been criticised for assuming that optimality is achievable and for failing to provide practical guidance for policy design[7].

[4] A full discussion of the theoretical issues underpinning rationales is presented in Orsenigo, (2002)
[5] Nelson, 1959, Arrow, 1962
[6] Metcalfe, 1995, Edquist, 1997
[7] Metcalfe and Georghiou, 1998, Lipsey and Carlaw, 1998

The systems and agents failures approach justifies public support for private R&D on multiple grounds:

- Creation of technological opportunities through support for basic research;
- Support for competence creation and development;
- Stimulation of faster adoption of new opportunities to overcome lock-ins;
- Support for maintaining a variety of technological options to respond to unforeseen changes;
- At a macro level breaking sectoral lock-ins or switching from inefficient equilibria;
- Developing and reconfiguring the innovation system to fill gaps and eliminate redundant elements; and
- Facilitating coordination in areas such as standards setting.

Assessment of the impact of direct measures is normally set in the context of additionality. This concept encompasses the issues concerning the difference made by a policy – whether the subsidy caused additional funds to be spent and if so on what. Without additionality, the subsidy could be considered as being spent on activities the firms would have undertaken anyway (deadweight), with the money going either to profits or to an activity (possibly other R&D) not targeted for support. Further concerns are that the subsidy could increase the price of scarce R&D inputs and that the effect might be one of "displacement" of the activities of a competitor firm which lost market share to any eventual innovation resulting from the support. David et al, 2000 provide a comprehensive review of the literature on this issue and find the evidence inconclusive.

However, the input additionality question, of whether resources were incremental, is crucial only in the case where the policy principally exists to provide resources (as with fiscal incentives). We are also interested in output additionality – the additional private and social returns generated. Moreover, where direct measures are aiming to change the competences, capabilities, organisation and strategies of firms, a more useful concept is that of behavioural additionality[8], defined as the persistent changes arising from interaction with the policy measure. Under a behavioural additionality perspective, funding from a direct measure is seen as a means to an end beyond that of simply increasing the money spent on a given R&D project. The goal of the intervention normally is to guide the firm towards desirable behaviour, including joining new networks either with other firms or with the science base, overcoming technological "lock-ins" to enter a new technological area, changing management practice and so forth.

Notwithstanding the benefits of providing firms with finance to correct specific market failures, this report will argue that the principal rationale for the use of direct measures rests in the systems failure perspective and its micro-level manifestation of seeking behavioural additionality. Wherever possible resources, financial or otherwise, should be used to guide firms strategies towards behaviour which will strengthen their innovative capacities and hence their motives to perform R&D.

[8] Georghiou, 2002

4.3 Internationalisation and investment

4.3.1 Role of International R&D Investment

At first sight, the contribution towards the 3% goal is the higher:

- the more foreign companies locate research in Europe – that is the more they spend in existing research facilities (assuming that the net investment effect is positive – i.e. that possible crowding out effects are lower than the foreign R&D investment and the agglomeration effects ; and

- the more European companies spend their R&D money inside rather than outside Europe (re-location) (assuming that the loss of access to extra-European knowledge sources is over-compensated by the activities within Europe).

This section explores the factors affecting R&D location decisions and the role of public policy in respect of these but first the scale of technology-related direct foreign investments is assessed.

These investments have increased. Multi-national enterprises (MNEs), with different intensities and motivations, increasingly realise the potential benefit of the international exploitation and augmenting of their technological knowledge. There is an obvious tendency for multinational companies to acquire or build up research capacities in foreign knowledge markets, as indicated with R&D investment data (input) or patent statistics (output)[9]. A recent study on the strategic technological management of more than 200 top R&D-spending MNEs from Japan, the US and Europe indicates that this tendency may continue, although there seems to be a ceiling for the degree of international R&D investment[10].

Host country differences

Speculating about possible policy measures to increase R&D investment of non-European companies within Europe, one has to consider the current differences in the relative weight and intensity of foreign R&D within the different EU countries (Figure 6). Obviously, attracting more foreign R&D capacity would mean very different things to different countries within Europe.

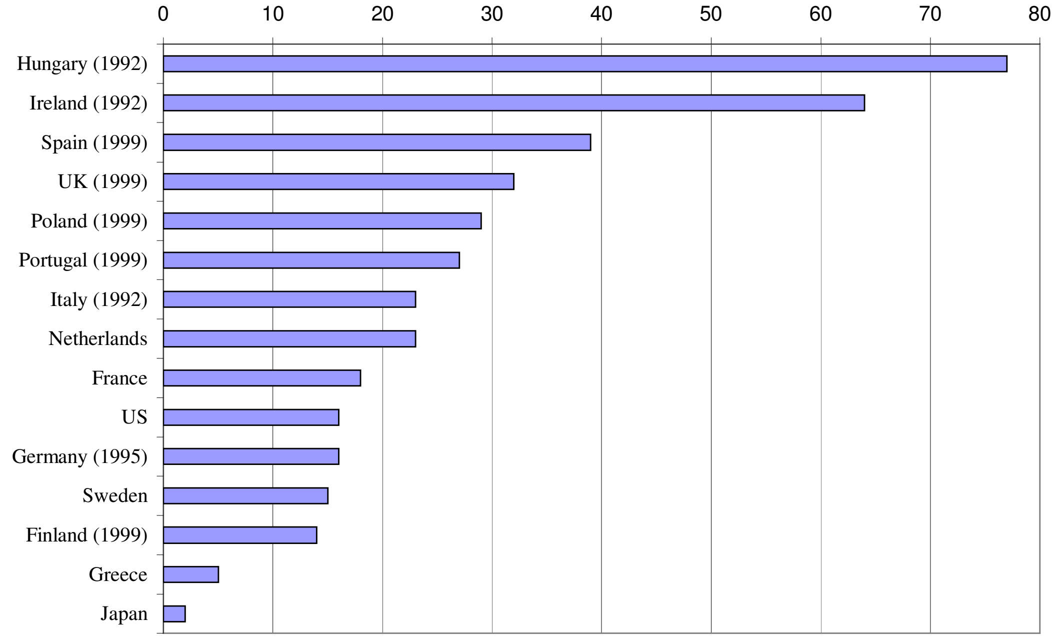
- The weight of foreign manufacturing R&D ranges from 5 % in Greece to more than 60 % in Ireland.

- R&D output data more or less confirms the variance between the countries, albeit with a slightly different pattern. France, Germany and Netherlands have a very similar level of foreign R&D output of about 20%, while in the UK, Italy and Sweden foreign companies play a much greater role.

[9] Reger 1997; OECD 1997a, 28; 1998b; 2001; Council on Competitiveness 1998; Kuemmerle 1999; Serapio/Dalton 1999. Patel/Pavitt 2000; Edler 2002

[10] Edler, Meyer-Krahmer and Reger, 2002

Figure 6 Share of foreign affiliates in manufacturing R&D expenditures 1998 (%)



Source: OECD 2001, figures rounded.

The degree to which companies of different nationalities have internationalised their activities varies considerably between countries and between the Triad Regions (Europe, North America and Japan). There are striking differences *between European countries*, with companies from large countries (with the exception of the UK) being less internationalised than companies from smaller countries (see Figure 6).

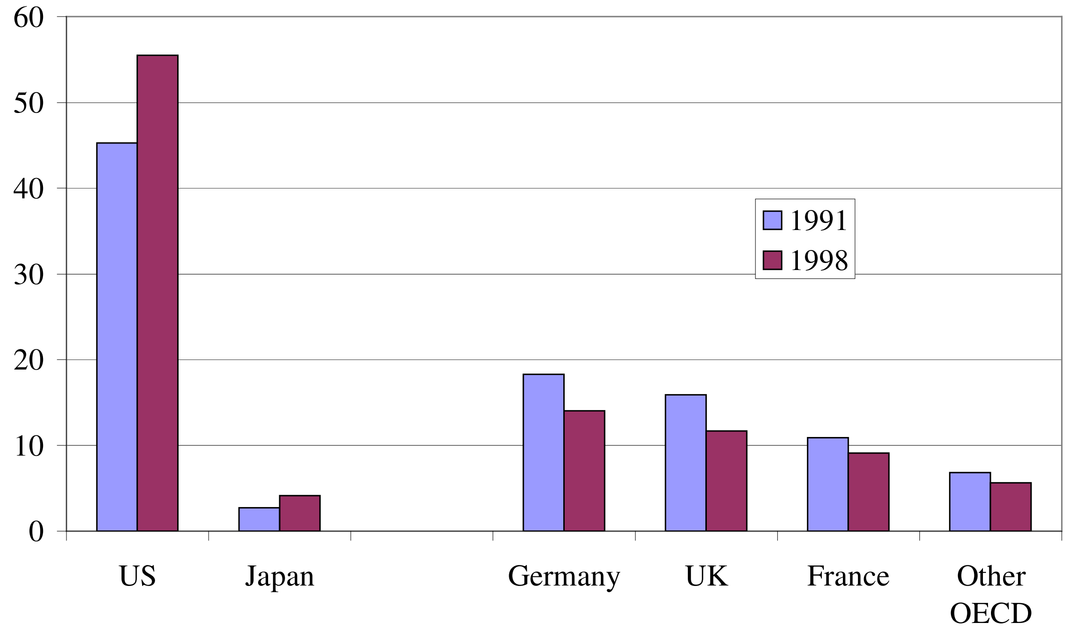
Across all sectors, the inclination to go abroad is higher for European companies than for non-European companies. In other words, for the technological strategies of European MNEs it is more attractive – or important – to go to the US than it is for the US companies to invest in Europe. For the 1990s, US Patent data and R&D expenditure data alike show a stronger internationalisation of European firms as compared to US and especially Japanese firms[11]. Furthermore, OECD data (compiled in Edler et. al. 2001) indicates that MNEs show very different R&D intensity within difference host countries. In 1994, for example, the R&D intensity of US firms in Germany was about 2 %, in France 1,3%, in the UK 1% in the Netherlands 0,3%.

4.3.2 The (decreasing) weight of European countries

In the course of the 1990s the *relative* attractiveness of Europe as a location of foreign companies has declined, even though for several European countries the share of foreign-controlled R&D has increased. Of all R&D expenditure *under foreign control* in the manufacturing industry *within the OECD countries*, the share that is spent in the United States has grown from 45,3% to 55.5%, the share of Japan has grown from 2.8% to 9.1%, while the share of Germany, France, the UK and the rest of the OECD countries has declined (OECD 2001;Figure 7).

[11] Pavitt/ Patel 2000

Figure 7 Share of R&D expenditure under foreign control in the manufacturing industry in selected OECD countries



Source: *OECD 2001.*

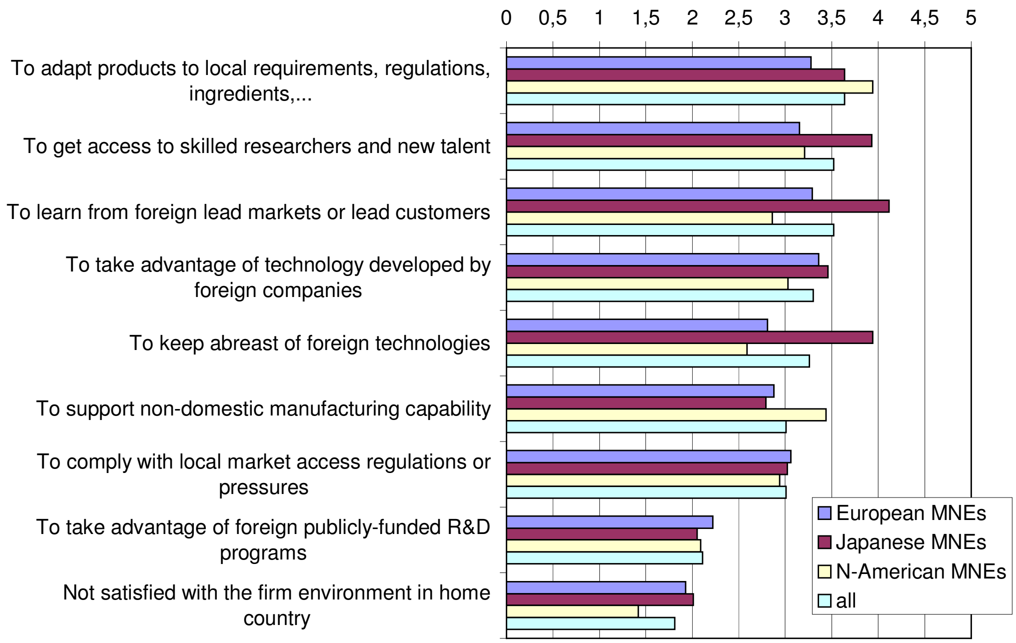
4.3.3 Location factors

The results of a survey of companies in Europe, North America and Japan (Figure 8) illustrate the range and the level of importance of motivations[12]. The three strongest motives for the *European* companies are to take advantage of technology developed by foreign companies, to learn from lead markets/ customers and to adapt products to local needs. For the *Japanese* companies learning and generating knowledge abroad is more important, they want to learn from lead markets/ customers, to keep abreast of foreign technology and to have access to foreign researchers and talent (confirming Granstrand 1999). *North American* companies are strongly motivated by adapting products to local requirements, supporting non-domestic manufacturing capability and to get access to skilled researchers.

What is most important for policy makers is the fact that for companies of all three regions, the factors that are related to policy action are least important, both as for supporting schemes in the host countries and framework conditions in the home country.

[12] Edler; Meyer-Krahmer and Reger 2002

Figure 8 Motivations for MNEs from the Triad regions to invest in R&D abroad



Source: Edler, Meyer-Krahmer and Reger 2002

Two major categories of motivations

The multitude of studies being done in the last five to ten years has shown that R&D is motivated by a very broad variety of reasons.[13] However, one overarching duality of motives is *knowledge exploiting* vs. *knowledge augmenting*.[14]

Knowledge exploitation (R&D abroad to meet the peculiarities of foreign markets)

Mode: Knowledge exploitation encompasses all motives that are related to R&D work being done in order to adjust the existing technologies, products, and processes to meet the needs of local demand, supply, regulation (standards etc). In this mode, the major knowledge is generated in the home country and in a second step exploited abroad by fine-tuning technological developments towards different needs and to support foreign markets.

Empirical evidence: For the most companies the bulk of activities is still the support of local production and marketing abroad[15]. For example, for German MNEs various studies[16] have shown that the technological areas developed abroad are very similar to those at home, indicating that the companies mainly adapt what they have developed at home. This also means that for the bulk of R&D investment in a given host country the characteristics of its internal market (size, advanced users, advanced suppliers, product or process regulations) are more important than the quality of the science and research system.

[13] See Criscuolo et. al. 2001 for a overview.

[14] See e.g. Dunning/ Narula 1995, Meyer-Krahmer et al., 1998; Edler/ Meyer-Krahmer/ Reger 2001; Meyer-Krahmer 1997; Niosi 1999; OECD 1999; Pearce 1999; Pearce/Singh 1992; Criscuolo et. al 2001; Gassmann, v. Zedtwitz 1996, 5; Zander 1999; Kuemmerle 1997; 1999; Kumar 2001; Schmaul 1995.

[15] Cantwell/ Janne (1999); Cantwell/ Kosmopoulou (2001); Patel/ Vega 1999; Patel/ Pavitt 2000; Serapio/ Dalton 1999

[16] Legler u.a. (2000), Beise/Belitz (1998), Belitz (2002), Edler 2002

Knowledge augmenting

Mode: Knowledge augmenting, on the other hand, means that that the international arena is used to generate new knowledge. Innovation is more and more knowledge and speed driven, MNEs are forced to be quick and excellent at the same time. Therefore, it is a genuine motive of MNEs to tap into existing forefront knowledge centres of excellent abroad and to take advantage of them. This might be done through simple monitoring activities, through integrating into existing scientific networks or through employing scientific talent. In this paradigm of international R&D, the search for excellent research centres around the globe and to build up and re-transfer knowledge is a major task for the “globally learning companies”[17].

Empirical evidence: A growing number of studies finds the knowledge augmenting mode becoming more and more important[18]. It has been shown that knowledge seeking and generating abroad correlates with

- the knowledge intensity of the technological area,[19]
- the intensity and scope of the corporate R&D,
- the perception of researchers and managers that the knowledge base of the host country is the more advanced.

Secondary location factors

Beyond the two major strands motivations a set of other location factors can be defined, the meaning of which as identified in surveys is in most cases lower than the meaning of the two sets of reasons just discussed.

- Vertical *co-operation* with local partners (suppliers, (lead) customers). The importance of vertical integration has grown, and so has the inclination of MNEs to locate parts of their R&D near their most important suppliers and/or customers (Just 1997).
- Efficiency *(research costs)*: in some areas of research, the actual costs of performing it play a major role. It has been shown that if the level of expertise needed is available for less cost, and if the infrastructure limits transaction costs, research also follows efficiency[20].
- *Follow the* competitor: In some cases, mainly in oligopolistic markets, a “follow the leader” effect has been observed even for R&D activities[21].

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[17] Meyer-Krahmer et al 1998
[18] Florida 1997; Koopmann/ Münnich; Boutellier et al. 1999; Cantwell 1995; Edler/ Meyer-Krahmer/ Reger 2001; Dunning/ Wymb 1999; Grandstrand 1999; Pearce/Singh 1997; Pearce 1999; Criscuolo et. al 2001, LeBas, Sierra 2001; Narula 2002
[19] A recent study on German MNEs abroad and foreign MNEs in Germany has shown a clear correlation between knowledge intensity of a technological field (average number of cited publications in a patent) and degree of international activity (Edler 2002).
[20] Gerybadze/ Meyer-Krahmer/ Schlenker 1997
[21] Kumar 2001; Pearce/ Singh 1997

- *General* political *and financial framework conditions*: in none of the recent studies the general political framework or a different financial framework (venture capital etc.) does play a significant role as a driving force for R&D investment.[22]

- *Public R&D policy*: All studies reviewed[23] find that public policy (R&D programmes, patent regime, some kind of indirect supporting schemes etc.) are *not* a major determining factor, they are by far less important than market size and requirements or the various forms of knowledge supply.

- *"Side effects"*: Finally, in interpreting data on R&D internationalisation it is important to note that the build up of foreign research capacity is very often the by-product of merger and acquisition activities that are not driven by R&D considerations[24]. As Archibugi (2000) has stressed and as has recently been shown for German MNEs abroad[25], the R&D intensity of foreign subsidiaries tends to be smaller than that of domestic companies. Therefore, it's true that external growth in R&D capacity by foreign firms through "side effects" increase the share of international R&D activities. However, in the medium and long run, such "side-effect" R&D capacities are very often reduced if not closed down. Moreover, there are instances where existing linkage to the local knowledge base dissolve after post acquisition re-organisations.[26]

From the perspective of direct measures, a point of interest is what measures affect the ability of firms to tap into the local innovation environment. Provision of organisational interfaces which make it easier for inward technology-based investors to form local linkages with the science base is a growing area of policy action. The Alba Centre in Scotland is one example:

Good Practice Example – Regional Technology Infrastructure to Support Inward Technological Investment
Activity: Alba Centre
Country: Scotland

The Alba Centre, an innovative collaboration between industry and academia, provides a business environment to support System Level integration. It offers access to a comprehensive range of business development facilities, covering fully-serviced accommodation, methods, tools, financial assistance and employee training support.

The Alba Centre grew out of an initiative by Scottish Enterprise, Scotland's leading economic development agency, to develop Scotland as a leading world location for System Level Integration technology. Working in partnership with four of Scotland's top Universities in this field (Edinburgh, Heriot-Watt, Strathclyde and Glasgow) and a range of private sector partners both inside and outside Scotland, the initiative consists of a single point of contact for a wide range of business needs, providing:

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[22] However, in most cases big MNEs are analysed, different cultures to provide venture capital may play a very different role with small and young companies.
[23] including especially Kumar 2001; Edler/ Meyer-Krahmer/ Reger 2002 and Döhrn/ Edler/ Rothgang 2002
[24] Gassmann/ von Zedtwitz 1999
[25] Döhrn/ Edler/ Rothgang
[26] It will be an important issue for future research on foreign R&D investment what kind of *negative* effects might occur for local or regional innovation systems in the long run.

- A Dedicated Centre of Excellence. The Scottish Embedded Software Centre (SESC) at the Alba Centre; an initiative designed to reinforce Scotland's collective capability in embedded software. The Centre acts as a hub for embedded software expertise, and is already proving to be a valuable resource for a growing number of Scottish companies.

  The nature of embedded systems means that they are not necessarily seen as business critical in themselves, and it can be difficult to justify the budget involved in exploring new platforms, or indeed, the potential risks, particularly in smaller enterprises where budgets and internal resources may be tight. Scottish Enterprise has developed the SESC in direct response to these issues with a view to driving Scotland's capability in the embedded software market forward. The Centre provides access to embedded software expertise, with links to local industry and academic institutions combined with the Centre's own technical and strategic resources to offer a comprehensive range of technical services and strategic counsel. The Centre provides support to Scottish industry at many different levels, on the one hand providing in-depth technical expertise and advice, or involvement may be as simple as directing enquiries to the appropriate industrial or academic sources. The Centre offers is direct access to ground breaking new technologies, in the form of both hardware platforms and software tools. This allows companies to access demonstrator projects, giving first hand experience of the advantages or disadvantages of a particular platform and its environment. For a company seeking the means to develop its business and move up the value chain, or to replace its existing system with a new platform, the Centre provides the opportunity to assess what new technologies are available and how best to deploy them.

- Institute for System Level Integration - ISLI - providing training, research and technology associated with SLI. The Institute is delivering the world's first MSc in System Level Integration concentrating on the understanding of the process of system-on-chip design, the use of intellectual property (IP) blocks and the architecture of modern electronic systems. It offers facilities for training, education and in-company corporate events and conferences.

- Intellectual Property expertise and trading via the Virtual Component Exchange. VCs are pre-designed blocks that can be 'plugged' into a complete system-on-chip design. This enables system companies to realise ever more complex electronic systems. and can speed the actual design phase. This new paradigm presents a new and challenging business transaction process for both providers and users of VCs.

  Sourcing suitable external 3rd party intellectual property and tackling the huge legal and business issues, has now become a priority. The Virtual Component Exchange concentrates on the business and legal issues involved with system-on-chip designs, with the ultimate goal being the creation of an efficient, international and open market-infrastructure.

4.3.4 Driving forces to stay

As already indicated above, European companies not only spend a much larger part of their R&D budget abroad than companies from Japan and the US, they also tend to invest in R&D abroad significantly more in the US than in other European countries. If one intended to make European companies refrain from going abroad, the same logic as for the attraction of foreign companies applies as illustrated above. However, there is a second dimension here, which is the reason for companies not to go abroad in the first place. If making European companies stay in Europe is a major goal, there are a couple of *additional* location factors to keep in mind for policy makers. However, one has to keep in mind that poor policy framework conditions at home are not a major force driving companies to locate R&D abroad.

For the sake of illustration, the major reasons for some big German MNEs to spend only very little R&D abroad are - in order of importance attached to them[27],[28]:

- synergy with other corporate functions at home,
- economies of scale[29],
- appropriate and well established technological co-operation with customers or public research[30],
- appropriate and well established supply of scientists[31],
- frictions and high transaction costs for re-integrating globally produced knowledge,
- familiarity with and influence on scientific, technological, corporate and policy context.

To make Europe an even more attractive R&D location for European firms, it would be of importance to highlight these specific advantages of staying in Europe and to offer to European firms all possibility to exploit their home match advantage.

However, there is ample evidence that poor home country conditions are of very minor importance for the majority of companies. In addition, from what we know about the motivations to go abroad, incentives to make companies come back might backfire. If companies are provided with incentives in order to make them stay in some area deemed important for the national innovation system, the long-term effect of not adjusting to the global scientific division of labour might be to lose touch with leading edge knowledge.

4.3.5 Policy requirements within the EU

The policy challenges arise from the location factors identified above. In a first step, the distinction between "market adaptation" and "knowledge creation" is maintained, while it is clear that the combination of measures to foster both modes at the same time are the most promising.

Policy challenges stemming from the market adaptation mode:
Companies can be driven into the investment in R&D if they sense a market to be a **lead market** requiring R&D presence next to production or sales. This can be caused simply by different local demand (taste, tradition etc.), by technologically advanced public or private demand, by advanced regulation or future oriented standards. If - in addition - a market has a

[27] Döhrn/ Elder/ Rothgang
[28] The motives are given in the order of importance attached to them by German firms that have been asked for reasons for not going abroad (Döhrn/ Rothgang/ Edler).
[29] See also Gassmann, von Zedtwitz 1996
[30] See also Narula 2000, Döhrn/ Edler/ Rothgang 2002
[31] See also also Narula 2000

certain critical size, the adaptation to those local conditions triggers R&D investment. **Therefore, European policy should identify and foster possible lead market areas, i.e. areas in which the end-user market is regarded as a trendsetter internationally. Especially in these markets standard-setting regulations will drive European and non-European companies into R&D activities**[32].

In this lead market oriented mode, direct policy measures seem to be of less effectiveness. **Nevertheless, policy must ensure that those foreign companies that are willing to exploit a lead market and learn within lead markets – thus creating value within a host country - have access to co-operation partners, especially to lead users. Here, public supporting schemes – including public procurement to trigger innovation - should not be discriminatory**.

Policy challenges in the knowledge creation mode:
The greatest challenge, obviously, is to make a country or region scientifically or technologically attractive. Attractive locations for MNEs investing in the generation of new forefront knowledge are characterised by an excellence science system (excellent human capital, especially talent) that is accessible to foreign companies. **European policy must foster the existence of and accessibility to scientific excellence and scientific-technological networks, including the eagerness of universities and institutes to co-operate with (foreign) MNEs, including long-distance co-operation**.

As the necessity to integrate knowledge from very diverse technological areas into the industrial R&D process increases and the absorption of knowledge from neighbouring fields becomes more important, locations that can offer accessibility to a wide scope of scientific and technological activities, or at least a focused and specialised competence which is well-networked with complementary technologies outside its geographical area, will become more attractive in the future.

Cost per researcher may figure in companies' considerations (a cost which may well be more affected by policies such as social insurance charges). However, a better way to think of such an investment decision is in terms of the productivity of researchers, encompassing both cost and quality.

In summary, our **main message on the attraction and retention of internationally mobile R&D investment into Europe is that subsidies (and for that matter fiscal incentives) are factors which mainly come into play at the margins.** Our evidence is that the **principal factors** affecting company decisions **are proximity to key markets and the availability of skilled researchers (along with the general knowledge infrastructure). Hence the most important policy measures are those which strengthen European markets by removing barriers, those which lead to greater numbers of highly skilled people and general investment in high quality science. In addition, the quality and scale of demand (through regulation and/or procurement) is important to create "lead markets" or advanced demand.**

[32] *Meyer-Krahmer; Reger 1997*

4.4 Distribution of Business R&D and the Link to Cohesion and Accession Country Issues

The problem of insufficient R&D intensity is by no means a generalised phenomenon. Large discrepancies exist within Europe, with business expenditure on R&D particularly lagging in cohesion regions and in accession countries. While we recognise that this is to a substantial degree explained by differences in the structure of the economies, we consider in this section the benefits and barriers involved in raising the R&D intensity of these two groups of regions and countries from the present levels.

4.4.1 Cohesion Countries

Greece, Spain and Portugal in their efforts to achieve the target of transition into a knowledge-based economy are presenting a positive course, with some of the highest growth rates in investment and performance levels in the knowledge-based economy being however at very low levels in 1999.

In terms of investment[33] in the knowledge-based economy, Greece and Portugal are grouped together with Ireland comprising a team of countries characterised by very high growth rates even above the Nordic countries. Greece and Portugal are still below average in terms of investment levels in 1999 but are catching up at a very rapid pace. Spain is put together with Italy in another group with lower investment growth rates and investment levels below EU average in 1999.

In terms of performance[34] in the knowledge-based economy the three cohesion countries (Greece, Spain and Portugal) are grouped together with Italy. This group was lagging behind the EU average in terms of performance level at the end of the nineties with a rate of growth around the EU average. The somewhat higher growth in Greece may be attributed to the strong efforts and investments made during the 1990s. However, Portugal's significant increase in investment has not yet been converted into clear effects.[35]

Despite the overall positive growth trends, Greece, Portugal and Spain are still at very low levels in the partial indicators as compared to the EU average:

[33] The indicator of investment in the knowledge-based economy is a composite indicator consisting of the following sub-indicators: a) total R&D expenditure per capita, b) number of researchers per capita, c) new S&T PhDs per capita, d) total education spending per capita, e) life-long learning, f) e-government, and g) gross fixed capital formation (excluding construction).

[34] The indicator of performance in the knowledge-based economy is a composite indicator consisting of the following sub-indicators: a) GDP per hours worked, b) European and US patents per capita, c) scientific publications per capita, d) e-commerce, and e) schooling success rate.

[35] European Commission, 2002a.

Table 3 Key Figures 2002 for the Cohesion Countries

Key Figures 2002 Indicators	Current Situation: EU – 15 average	Current Situation (latest available year: 1999 or 2000)			Average annual real growth: EU – 15 average		EU rank referring to average annual real growth (%), 1995 to latest available year		
		E	**EL**	**P**			**E**	**EL**	**P**
R&D Investment	Figure				Figure	Rank	Rank	Rank	Rank
R&D intensity (GERD as % of GDP)	1,93	-	-	-	0,32	11th	5th	1st	3rd
GBAORD as a % of GDP	0,73	≅	-	≅	0,81	10th	2nd	5th	3rd
Industry financed R&D as a % of industrial output	1,49	-	-	-	4,81	11th	6th	4th	3rd
Share of SMEs in publicly funded R&D	15,1	+	+	+	3,5	6th	10th	13th	2nd
Venture Capital investment in early stages (seed and start-up) per thousand GDP	0,45	-	-	-	48,2	10th	12th	11th	14th
Human Resources in S&T									
Number of researchers / 1000 labour force	5,4	≅	-	-	3,03	10th	4th	1st	5th
New S&T PhDs / 1000 population aged 25 - 34	0,56	-	-	-	1,54	11th	4th	3rd	1st
Science, Technology and Innovation									
Number of scientific publications per million population	818	-	-	-	4,07	10th	3rd	2nd	1st
Number of patents at the EPO per million population	139	-	-	-	10,81	11th	4th	3rd	6th
Number of patents at the USPTO per million population	74	-	-	-	9,78	12th	7th	2nd	1st
World market share of exports of high-tech products (including intra-EU trade)	34,05	-	-	-	- 0,79	7th	5th largest negative growth	2nd largest positive growth	4th largest negative growth
Competitiveness									
Labour productivity (GDP per hour worked)	32	≅	-	-	1,65	12th	15th	4th	5th
Share of value added of high-tech and medium high-tech industries as % of total output	7,77	-	-	-	1,86	7th	4th	10th	2nd
Employment in high-tech and medium high-tech industries as % of total employment	7,6	-	-	-	1,1	8th	3rd	13th	4th
Share of value added in knowledge-intensive services as % of total output	32,92	≅	≅	-	0,48	8th	12th	6th	4th
Employment in knowledge-intensive services as % of total employment	32,31	-	-	-	1,68	10th	6th	8th	5th

'-' means below 20% of EU mean

'≅' around EU average

'+' means above 20% of EU mean

(*) Publication period is 1996, 1997, 1998. Citation window is a four year fixed period: publication year plus three years, i.e. 1996-1999, 1997-2000, 1998-2001.

Nevertheless, all three countries present some of the highest growth rates in almost all benchmarking indicators. Greece appears among the three EU leaders concerning growth rates in R&D intensity, human resources in S&T and the science, technology and innovation indicators (with the second largest increase in world market share of exports of high-tech products). Spain is among the three EU leaders concerning growth rates in the government budget allocated to R&D, scientific publications and employment in high-tech and medium high-tech industries. Portugal presents some of the highest growths in R&D intensity, industry financed R&D (as % of industrial output), government budget allocated to R&D, share of SMEs in publicly funded R&D, new S&T PhDs, scientific publications, US patents and value added of high-tech and medium high-tech industries. Complementing the picture, the 2001 Innovation Scoreboard, based however on a slightly different set of indicators, placed Greece and Spain in the 'catching up' phase of development and Portugal in 'falling further behind'.

Innovation policy in general is increasingly recognised as essential for the economic development in all three cohesion countries. In Greece the new Operational Programme for Competitiveness and Development (2000-2006), continuing the success of the previous programme, addresses the weaknesses of the country from a networking approach more evident than in the past and makes essential efforts to establish a well-structured national innovation system. The previous Operational programmes in contrast (even named differently: Operational Programme for Science and Technology) were more used for strengthening and developing the research infrastructure and human resources of the country. The regional dimension is also supported since for the first time the regions of the country will earmark some regional funds for innovation supplementing the national funds distributed all over the country. A long-running good practice example is shown below, the PAVE programme, with one key lesson being the flexibility to update goals and objectives.

Good Practice Example Programme for the Development of Industrial Research – PAVE (Programme for the Development of Industrial Research and Technology – PAVET - renamed since 2000)

Activity: Support of Industrial Research and Technology **Country: Greece**

PAVE, which is a Greek government funded scheme for industrial research was launched in 1986 and has subsequently been regarded as sufficiently successful example of its type in the cohesion context of Greece to have been funded ever since. While its outcomes in terms of product development, which was an original and high priority goal, have not been regarded as a major success, and there have been problems securing the involvement of larger firms because of the small scale of finance offered, PAVE has achieved a significant increase in awareness of the importance of innovation and in the amount of research activity undertaken by firms in Greece.

Additionally, research collaboration among firms and between firms and university / research centres was considerably strengthened. PAVE has also led, directly, to an increase in the employment of research personnel in industry and in the training of human capital in R&D activities, and, indirectly, to far greater levels of participation in EU funded research (particularly under the FPs).

PAVE proved to have contributed to the development of some of the major elements of industrial research performance: innovation awareness, linking research with industry, employment of research personnel in industry. Under this sense, its role for Greece as well as the rest of the cohesion countries and the pre-accession countries facing weak industrial research performance is significant.

Thorough evaluations of PAVE completed in 1994 and in 1999 have contributed substantially to what is known about the way in which programme impacts have arisen and how these impacts have been affected by factors external to the programme and internal to it, particularly its operational rules, selection criteria and management systems.

PAVE's broad aims have been to improve the competitiveness of the Greek industry and thus enhance the economic performance of the country by developing a networking approach of the national RDTI system, linking research and industry, and widening the research community. Such a linking approach seeks to build bridges between different actors in the innovation process, building upon intermediary organisations enhancing research collaboration and organisations supporting SMEs to develop research ideas and execute research projects. The success of the programme has also stemmed from the way in which the programme is implemented. Although changes in programme specifications, such as financial and eligible costs' rules, have to be validated by a Presidential Decree, there is flexibility allowing the re-setting of goals, objectives, and sectors covered at regular intervals within the duration of the programme, and industry is involved in the programme design and at proposals evaluation stage. An emphasis upon documenting the technological, commercial and productive importance of the specific research to the company's development, the innovative character of projects and the social and environmental benefits anticipated, coupled with an obligation to submit a commercialisation plan for the research results within a specific time period after project completion also appear to affect the success of applications and in turn, the effectiveness of the programme.

Other factors, which ultimately affect the quality of programmes, are, an effective administering and management organisation with multi-disciplinary fields addressed, clear monitoring and evaluation criteria and requirements that work-programmes find the "middle way" and are neither too specific nor too imprecise. The selection criteria adopted which require co-financing of projects by industry, the involvement of 'users' in the projects and the ability of the programme applicants and their networks to exploit the research results are also considered to support programme effectiveness. Other characteristics of the process, which affect success, include an open-ended procedure for submission of proposals vs. specific deadlines according to programme aims, one or two stage project implementation: e.g. study and development phases or research and pilot phases according to programme objectives, and a thorough examination of the additionality of the programme itself, and its additionality and synergies in relation to other programmes.

Similarly, in Portugal the Regional Development Plan (2000-2006) adopts an integrated approach towards innovation and additionally the Integrated Innovation Support Programme was launched in 2001 to tackle the weaknesses noted in qualifications levels, basic education, and companies' innovation abilities.

In Spain, on the other hand, a single Ministry of Science and Technology has been established to facilitate the integration of the Fourth National Plan for Scientific Research, Technological Development and Innovation (SRTDI, 2000-2003) across the Ministries. The new SRTDI addresses most of the weaknesses of the Spanish national innovation system but technology transfer processes and supporting the creation of NTBFs have yet to be addressed adequately. [36]

A recent study carried out under the CONVERGE project (financed under the TSER programme) in 2001 examined the innovation performance in Spain and Portugal and

[36] European Commission, Innovation Scoreboard 2001.

indicated issues hindering the development of an innovation system in these countries: *Lack of a well - defined national innovation policy and of involvement of industry in priority setting / lack of coordination between institutions and ministries / bureaucracy of RTD administration / problems in addressing regional disparities / lack of communication / collaboration between research and industry*[37]. The CONVERGE project also addressed the issue of *imitating policies and measures adopted in more developed countries.* It was concluded that the creation of infrastructures and interface institutions followed patterns of imitations neglecting the local structural deficits with respect to bureaucracy, firms behaviours and actors' habits.

Notwithstanding the deficits of the national innovation systems in the cohesion countries that should be tackled, it can be concluded that *increase in business R&D in these countries additionally depends on the degree that the local business culture is adaptive to innovation, which in turn depends on the needs of the respective markets of their firms and of the competition they face.*

An increase in private R&D investments in these countries may still remain limited if technology transfer seems to be considered more effective and less costly than carrying out R&D and creating their own know-how. This, coupled with the fact, that research results from collaborative European projects seem to be exploited more by foreign, than local, industries, makes transferring of technology, know-how and innovation practices from abroad an essential complementary step to encouraging local industries to get involved in R&D. However, the importance of R&D in creating absorptive capacity should again be stressed.

4.4.2 Accession Countries

The RTDI system and performance of ten Central and Eastern European Countries (CEECs included in the pre-accession countries) was analysed in a study carried out for the European Commission in 1998.[38] This analysis referring to the mid '90s revealed several crucial issues that had to be tackled for the development of RTD and innovation activities many of which were repeated in individual country studies that were conducted the later years.[39] Issues of general concern included:

- Inherited scientific capacity which is focused in fields not well connected to emerging industry and hampered in many cases by the quality of infrastructure and research equipment.

- Insufficient applied research and innovation capacity to engage with surviving basic research.

- Economies where emerging SMEs are often unable to afford to perform R&D or else do not recognise the contribution it could make. Obstacles derive from the difficult economic environment in which many new firms operate at low levels of profitability, and with cash flow, credit and liquidity problems.

- Institutional restructuring is still needed, as well as adaptation of 'thinking' and policy-making towards a coherent market- oriented RTDI system with clear roles and linkages.

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[37] Emilio Munoz, et. al. 2000; Emilio Munoz, 2001.
[38] Coopers and Lybrant, 1998.
[39] De Jager D., et.al., 2002; Hernesniemi, H., 2000; Romanienen, J., 2001.

Stimulating industrial demand for R&D and supporting industry to undertake in-house R&D are priorities for all CEECS. Some positive steps have been taken. A range of financial instruments for in-house RTD and innovation is provided in Czech Republic, Hungary and Slovakia while new industrial policies were initiated in Poland, Romania and Slovenia. In addition technology transfer activities are supported in many countries through new established organisations (technology development agencies, innovation agencies, innovation funds, S&T parks, incubators, industrial liaison offices).

The major importance of SMEs development and innovation is also recognised for the economic growth in all CEECs. The SME sector is growing dynamically in most candidate countries, but the low level of innovation causes concerns. New policies strongly oriented towards innovation in industry with particular emphasis on SMEs exist in Hungary, Slovenia and Romania while Poland developed guidelines on innovation policy aiming to intensify technology transfer towards SMEs and to promote a positive view on innovation among them. A number of organisations, associations and bridging institutions were also established in Hungary, Czech Republic, Slovenia and Poland to support innovation in SMEs (innovation parks, networks of enterprises, associations of innovative enterprises, relay centres, technology centres, enterprise development centres).[40]

However, supportive government policies are not enough to stimulate industrial demand and performance of RTD or encourage SMEs to undertake RTD and innovation activities. One of the major obstacles in achieving this target, given the difficult economic environment in most of the CEECs, comes from the circumstances under which many new firms operate with low profitability, little retained earnings, cash flow, credit and liquidity problems. A full range of innovation support services is still needed. Government action is required to support SMEs in tackling these problems, to facilitate their development and risk-taking activities as well as to create a favourable environment for the creation of new SMEs, preferably in the new technology areas.

More incentive support for research activities in the private sector needs to be put in place along with a stronger focus of innovation policies on the needs of the demand side. The passive development strategies of firms should also be addressed by involving them in setting research priorities and designing supportive programmes design and the fostering of an innovation culture and service development for SMEs should be supported through the provision of added value advisory services and awareness raising activities. The upgrading of the management skills towards the requirements of the market-oriented economy through seminars and training schemes is equally essential.

At the same time linkages between the research actors and industry have to be established or strengthened, universities and research institutes need to get more involved in the innovation sphere through networking / clustering, and the establishment of innovative university spin-offs should be supported along with organisations for the patenting and licensing of research results.

40 The highest, among all CEECs, business expenditures in RTD were noted for some of these countries (Czech Republic, Slovakia, Poland and Slovenia) in the mid 1990s (Annex 2) while in 1999 Czech Republic, Poland and Slovenia presented BERD close or above the BERD of the cohesion countries (see Annex 3).

4.4.3 Conclusions on Cohesion and Accession Issues

Both the cohesion (despite their long membership in the EU) and the accession countries still face the **need to formulate clear national innovation policies and ensure support for more effective efforts at national and regional level to support the development of innovation in local industries and SMEs**. In both cases, though to different extents, there is lack of a well - defined national innovation system and of involvement of industry in priority setting, lack of coordination between institutions and ministries, bureaucracy of RTD administration, and problems in addressing regional disparities.

Additionally, the following have also been noted as essential in both cases:

- **the promotion of an innovation culture and a strategic, long-term and 'international' thinking among SMEs,**
- **the acquisition of skills in research and innovation management, exploitation of research results, technology and know-how transfer,**
- **the promotion of networking and improving collaboration and communication among SMEs and between industry, research performers, intermediary organisations and financing organisations,**
- **involvement of users in networks,**
- **and the adoption of evaluation, assessment and foresight approaches (strategic intelligence in policy-making) as crucial to optimise the use of limited available resources (human, monetary and infrastructural).**

Notwithstanding the deficits of the national innovation systems in the cohesion countries, increase in business R&D in these countries additionally depends on the degree that the local business culture is adaptive to innovation, which in turn depends on the needs of the respective markets of their firms and of the competition they face. **Direct R&D-supporting measures to encourage them to be involved in R&D and innovation, collaborate with research organisations, and the like, or indirect measures such as tax incentives, may still have limited results in terms of increasing the private investments in R&D unless complemented by actions to make firms aware of the opportunities and threats, but also the necessity, of innovation and going 'international' and of complementary measures to encourage their entrance to new, more innovation-demanding markets.**

While the cohesion countries face the risk of not increasing private investments in R&D due to short-termist business cultures and considering of their markets and environments as non innovation demanding, some of the accession countries face the risk of adapting 'ready made solutions' that have shown good performance in totally different cultural and innovation environments, without taking the time to analyse the success and failure factors of these solutions and adapt them to their local specificities mainly because of the major importance they place in the quick accession in the EU for the improvement of their economic situation.

The long and valuable experiences from the EU Member States are unquestionably a major knowledge and expertise source for the accession countries. However, it may be the case that 'failure stories' from imitating policies and measures adopted in more developed countries (coming for example from the cohesion countries) may prove more valuable and easy to avoid than 'success stories' to try to imitate.

Examining more thoroughly these factors and designing new or more effective measures to tackle the problems they cause in less-successful cases (like the cohesion countries) may prove more valuable for the accession countries than the 'success stories' they may find 'quicker' to imitate but 'harder' to exploit. Where success stories are used, the underlying cultural and historical factors should be made explicit if useful policy transfer is to take place.

In conclusion, while there is a correlation between direct R&D support measures and private investment in R&D (as shown from the relevant indicators till now), increasing private investments in R&D depends on far more, and different, factors and areas than those related to direct R&D support measures. **Increase of private investment in R&D seems to be a result of innovation demanding markets addressed by effective national innovation policies, resources and structures (including both direct and indirect R&D support measures), which are supported by healthy economic environments and by effective and accordingly coordinated industrial, education and training policies and measures for international cooperation in R&D and innovation.**

The target of 3% GERD/GDP (and the origination of 2/3 of it from industry) seems to be a target 'too distant' to comprehend and to design appropriate measures for achieving it. **The setting up of more specific 'intermediary' targets seems more feasible covering all the different nature of actions and factors influencing private investment in R&D, some of them, as indicated above, falling outside the innovation process but maybe being the ones still hindering innovation performance in the 'less-innovative' countries.**

5 Supply-side Policy Measures

5.1 Grants

At first sight, a grant to a firm to perform R&D is an uncomplicated direct measure more or less equivalent to a fiscal incentive but distinguished from that by a selection mechanism which applies criteria to applicants and imposes conditions through a contract with those chosen to receive funding. However, the combination of the selection process and the contractual obligations creates an instrument which has a variety of forms and which can be fine-tuned to meet a wide range of objectives. Grants in support of R&D may vary in terms of target group, eligibility, means of disbursement, exactly what activities they cover and to what proportion, specificity by region, technology or sector and most importantly, in terms of the behavioural conditions which they impose upon recipients. Among the latter, the obligation to collaborate is among the most frequent and important.

The ability to focus funding to create finely tuned incentives, as implied in the above taxonomy represents the principal strength of grants as a policy measure. Figure 9 illustrates the variety of dimensions which can be used to carry out the tuning. A few remarks can be made about each cluster shown in the figure:

5.1.1 Assumptions, Principles and Properties

Issues here include the basic rationale and objectives of the scheme. Good practice indicates that these should be clarified as a part of the programme formulation process and there is an increasing tendency towards verifiable objectives. Examples of this move towards formalisation include the UK Department of Trade and Industry's ROAME (Rationale, Objectives, Appraisal, Monitoring and Evaluation) system whereby a new programme has to have a statement incorporating the above before it can be approved, and the European Commission's efforts to clarify the concept of European Added Value.

5.1.2 Actors and Targets

These encompass some key variables that define programmes. One distinction is the type of actor targeted. From a business perspective the trend has been strongly towards emphasising support for SMEs in more general technology development programmes, though many measures also continue to be open to large firms and in a few sectors such as aerospace, transport and energy remain dominated by them. A trend (see the section on clusters) has been to exploit and develop linkages between firms, sometimes along the supply chain. Many other types of actors can be involved at project level including the science base and users of technology. This variety of actors may also be reflected in collaboration between sponsoring ministries or agencies – an increasing trend as countries attempt to increase the flexibility of their innovation support systems.

However, when resources for a single project come from more than one source potential problems include:

- **Different** timescales and procedures for getting decisions (possibly for different partners); and

- **Applications** containing proportions of resources between different types of partners that are different from the proportions available from the dedicated sponsors of different types of partner (eg different industry-science mixes).

Policy sponsorship and management control may be separated by the interpolation of an agency to manage or even devise programmes.

In terms of geographical scope, some programmes incorporate regional development objectives and in doing so confine or emphasise support to disadvantaged regions or else may be sponsored at regional level and simply support firms based there. Geographical scope also extends beyond national boundaries with specific incentives to work collaboratively outside the country, through EU, EUREKA or bilateral initiatives.

Programmes may be sectoral, defined by a market or by a technological discipline. There is some perception that following such definitions is likely to lead to incremental innovation. Some Foresight programmes have been seeking to define programmes in the context of socio-economic problem solving – for example the German *Futur* initiative has developed four "Lead" or "Guiding" Visions through a participative process which are now being incorporated into Ministry programmes.

However, the ability to target grant programmes on technologies also represents a strength as it provides an instrument to overcome "technological lock-ins" (see Section 4.2), whereby firms are unable to perceive that it is in their interests to widen or change their knowledge base because all of their internal and external contacts are structured by their existing knowledge base. Participation in programmes in areas such as nanotechnology, while small in themselves, may introduce the firm to a new knowledge trajectory.

5.1.3 Modalities

These are concerned with delivery of the direct measure. A key issue is the basis for allocation of resources. These may be disbursed on the basis of first-come, first served until the budget is exhausted within a particular time-frame, they may be allocated competitively through calls (with a further variety in the selection criteria and process) or they may be negotiated in a combination of these two. Different administrations vary in the amount of effort they put into assessing the viability of business plans following on from R&D, or the viability of the proposed recipient of funds. Contractual issues are significant, with a variety of arrangements for ownership and use of intellectual property, timescales, reporting obligations etc.

The dimensions shown in the typology interact as programmes are implemented. Broader issues such as the decision-making behaviour of firms and the influence of framework conditions come into play at this point. It can be argued that for large firms, the project described in the contract defining a grant often forms a part of a larger programme of activity that begins before the grant, continues after it, and involves parallel and related activities. In these circumstances, the policymaker is investing in the programme rather than the project. This is not necessarily a problem, since the scale of activity necessary for successful innovation may well be beyond the scope of most public programmes to support alone even if this were thought desirable. However, it does mean that an excessive focus on "deliverables" and "evidence of exploitation" of the grant may be missing the point. The true deliverables and exploitation come from the larger activity. The policymaker needs to understand the strategy of the firm and to assess the contribution of public support to that strategy. As argued above, the effect of that support, if successful, may allow the work to proceed faster, it may introduce additional options, including more advanced technology, or it may link the work into newer or wider networks.

Weaknesses of granting schemes attach mainly to the selection process. Apart from the costs this imposes, critics cite the more general problem of civil servants "picking winners", that is to say choosing projects when they are not qualified by experience to make commercial decisions in the field of operation of the company. The principal rejoinder to this argument is that firms generally meet at least half of the cost of the research project and usually all of the costs of commercialisation and hence their applications for funding are already set in the context of strategic industrial decisions. A further potential weakness of a grants scheme is its capture by lobby groups or by regular users who exploit a developed capacity to succeed in the application procedures.

Some evaluations of grant schemes have indicated that the "labelling" of a selected project with the approval of the scheme itself has a value to the firm. The value may be a "halo effect" in that the firm is able to attract additional private capital, either because its financial base is strengthened by the grant or else because the technical selection process is sufficiently rigorous that investors regard success as an indicator of reduced technological risk.

5.1.4 Grants in the Counter-Cycle or "warehousing" researchers in a recession

An important aspect of grant funding is its role during difficult periods of the economic cycle. There is a strong asymmetry in the supply of researchers whereby they take many years to train in specific functions but may lose their jobs rather quickly as a result of enforced cutbacks in industrial R&D. After a certain interval re-entry to the profession may not be feasible because of the fast pace of research. In these circumstances, grants may have the effect of "warehousing" researchers and allow a rapid take-up of technological opportunities when the economic cycle is on an upswing. Increasing the affordability and hence the scale of research during these periods also contributes to recovery directly through development of more competitive products and processes.

At a national level, the best documented example of successful counter-cyclical investment in R&D is that of Finland which, during its deepest recession in the early 1990s, took the decision to raise public funding for R&D by around 25%. An evaluation of that funding concluded that the decision had produced a positive impact on private R&D investment[41];

However, careful judgements need to be made to ensure that such funding is targeted at post-recession growth and not in maintaining applied research on mature or failing product lines. In such circumstances it is better to allow the springs of creative destruction to operate and instead to ensure that the redundant research labour force is supported in efforts to spin out or start new firms.

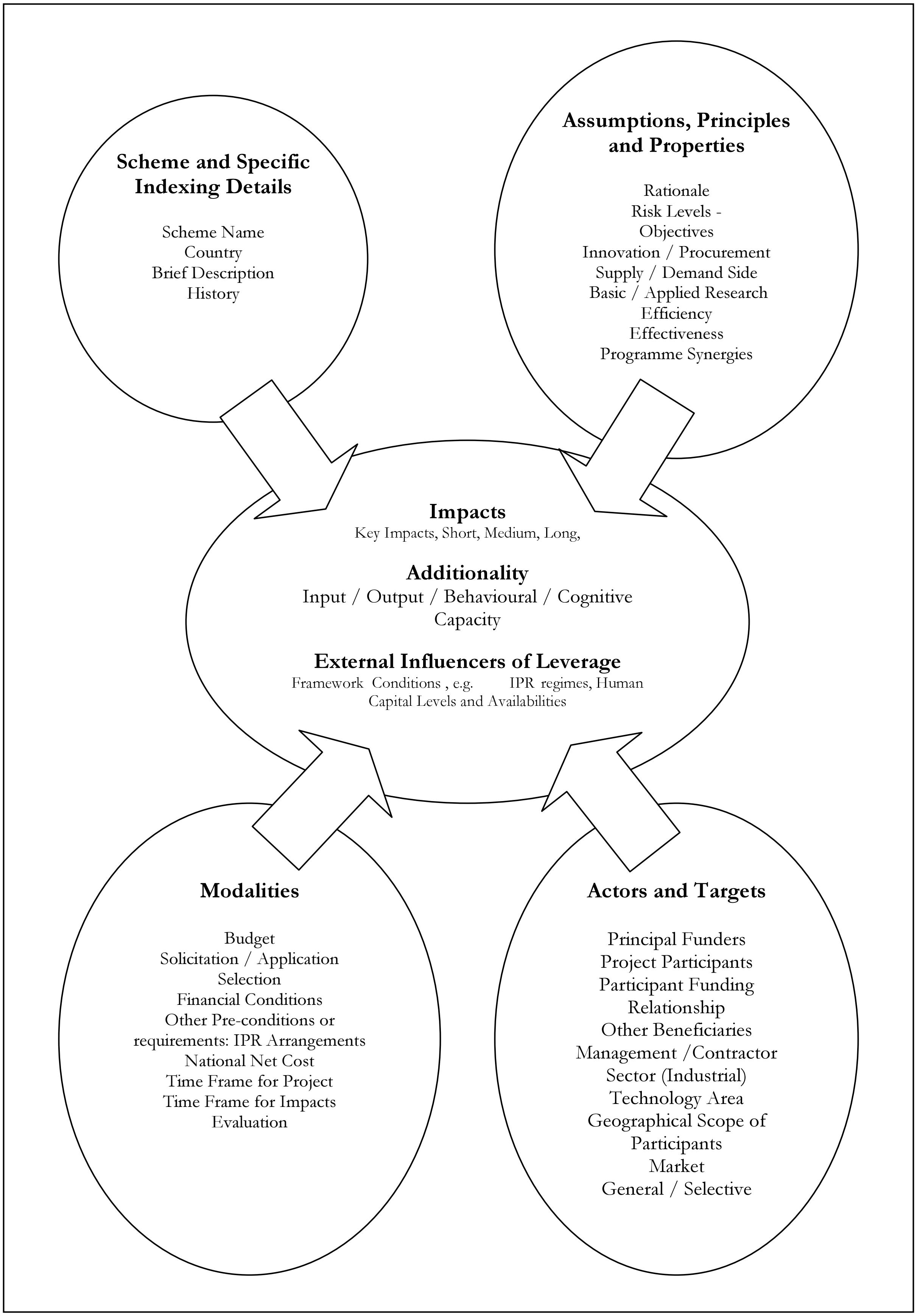
[41] Prihti et al, 2000

5.1.5 Conclusions on Grants

While finance is the motor for grant-based policy measures**, good practice policies appear to be founded in the behavioural additionality rationale and in particular towards using grants to provide incentives for developing new networks and collaborative linkages. Effects of this type are more likely to persist beyond the immediate funding period. This includes setting measures in the context of a broader strategy such as the development of a cluster. These approaches create cumulative technological assets which in the longer run enable firms to increase their returns on R&D and in turn their investment in it.**

The value of grant schemes can be diminished when there are too many of them, each trying to focus on a narrow objective and possibly at a sub-critical level. This can be confusing to firms seeking support and favours "regular users" who have developed skills in navigating the funding infrastructure. On the other hand there is also a risk in creating large and inflexible instruments which do not adapt to individual circumstances or to changing technological priorities over time. The right mix would appear to be a small portfolio of flexible measures with adaptive rules. There is also a need for policy coordination to ensure that addressing one deficit in the system does not create a bottleneck elsewhere.

Figure 9 Typology of Measures by Property and Characteristics



5.2 Conditional Reimbursable Loans

Loan guarantees are the remit of another working party. However, we have been asked to consider conditional reimbursable loans. These are effectively grants which are repayable if the supported innovation is successful. Clearly these are only feasible in nearer market situations where there is a clear link between the support and eventual returns. We have identified arguments for and against this approach.

A first point is that the instrument is inappropriate for the support of large firms which have sufficient access to capital to meet their R&D financing needs. For all firms there is a problem in that accounting policies imply that the loans are (partly) recorded as liabilities, being reservations or provisions to cover the risk of having to pay back the loan. Having to make such reservations/provisions limits the incentive effect. The third objection is that reimbursement can provide a disincentive to succeed, or at least to declare success.

On the positive side loans are well placed at the market-side of R&D (prototyping) because the risk-profile is clear and there is the opportunity to use intellectual assets as collateral. At least for the funding agency the incentive to promote commercialisation is greater as reimbursement is a clear performance measure. There may be a tendency to avoid higher-risk, higher-return activities as a result.

Good Practice Example: ANVAR innovation refundable grants programme
A scheme which has emerged as a success following a recent evaluation is the French innovation agency's (ANVAR's) Innovation Refundable Grants Programme. In the past seven years this has mobilised more than 1 billion Euros in soft loans and contributed towards the realisation of around 7000 innovation projects in around 5600 companies. A positive evaluation[42] found that a majority of companies were increasing their turnover as a result of the supported projects and that three quarters of the projects demonstrated additionality of public funding. The net impact of support was greater for young companies for which the innovation project is crucial and less for mature companies which had alternative sources of finance for R&D from cash-flow or private sources. However, mature companies reimburse more frequently.

In summary, while firms unsurprisingly prefer grants, there appears to be a niche for conditional reimbursable loans when applied to smaller firms operating nearer the market.

42 De Laat B., Warta K. and Williams K, Rammer A and Arnold E (1999) Evaluation de la procédure d'aide au projet d'innovation de l'ANVAR, Rapport Final, Technopolis France"

6 Demand-side Policy Measures

6.1 Procurement

Public procurement of goods and services was historically seen as a major instrument of innovation policy[43] but has not been emphasised in recent years. In this section we distinguish between three types of procurement:

- "Regular" procurement where ready-made products are bought "off-the-shelf" and where no R&D or innovation is involved. This is not discussed further in this report;
- Public Technology Procurement is defined as the situation when a government agency places an order to another organisation for a product (or service) that does not yet exist[44]. This means that R&D and innovation have to take place before delivery. The procurer specifies the functions of a product or system but not the product as such. It is a demand side direct measure. The public agency finances part of the R&D and decreases the uncertainty for the supplier thus encouraging his or her own spending; and
- Procurement of R&D directly by government in support of its own needs which normally involve support for policy and regulation, or more generally public goods. In this section we do not include more general support for science and technology.

Also discussed is the specific involvement of SMEs in procurement contracts and policies for private procurement.

6.1.1 Public Technology Procurement

The potential of this policy instrument is very large. EU figures indicate that €720 billion or 11% of the EU's GDP is spent annually on public procurement. While the great majority of this is currently for "off-the-shelf" products, many areas offer scope for a greater emphasis on innovative products. A change of emphasis of this type could attract significant new resources for innovation and hence for R&D.

Successful Use of PTP in Telecommunications
Nordic countries historically made successful use of PTP, for example in the development of the first digital switching technology, the AXE system, procured by the then public telephone monopoly and supplied by Ericsson. It is argued that this created a strong comparative advantage for Ericsson lasting decades (Fridlund, 2000).

When the NMT 450 mobile telephony standard had been developed by the Nordic PTTs, the Swedish PTT used this standard as the functional specification when placing four orders for mobile systems (which did not exist at that time). One of these orders led to the development of the first digital switch for mobile telecoms, developed by Ericsson and based on the AXE. Ericsson was reluctant at the time to start this adaptation of the AXE and had to be provoked to do so by the PTT (Lindmark 2002, Edquist 2003). PTP played a similar role for the Finnish mobile telecommunications equipment producing industry (Palmberg, 2000).

[43] Rothwell and Zegveld, 1981
[44] Edquist et al

It is important also to recognise some of the reasons why procurement policy has been criticised in the past. There are several examples where it was used to prop up ailing "national champions" at the expense of competition. Furthermore, the risk of a single customer having too much power created in some circumstances technologies that were over-specialised to the needs of one consumer and which were not internationally competitive –f or example the UK's System X Digital Telephone Exchange created for the then State telecoms monopoly. Good practice lies in maintaining multiple sources of supply including new entrant firms and in understanding the potential problems as part of the procurement management process. European cooperation offers a way around the national champions model.

Smart Procurement – UK Ministry of Defence

The UK Ministry of Defence spends around €14 billion on procuring and supporting military equipment. A Strategic Defence Review highlighted a need for radical changes in defence procurement to avoid long and costly delays in major programmes. Among the weaknesses identified were transfer of commercial and technical risk to contractors unable to absorb it, insufficient pricing pressure on inflation and the delays involved in decision-making on collaborative projects. A particular weakness was a failure to strike the right balance between cost, time, and performance in the very early stages of a project. Insufficient investment in risk reduction at this stage proved very costly later on. Other contributing factors were a tendency to use the same approach to procurement for widely differing projects, failure to give project managers sufficient delegated authority, and failure to provide properly targeted incentives to both contractors and staff.

To address these problems a revolutionary approach has been introduced known as the Smart Procurement Initiative (SPI). This aims to deliver projects on time and to cost through organisational, staff-training and procedural changes in acquisition. Among the changes were adopting separate procurement approaches for major and minor projects and for commodity and other low risk items. A through life approach has been adopted covering both acquisition and in-service support. Of particular relevance is a move away in some cases from competitive tendering towards formal partnering arrangements with industry which provide firms with significant incentives to perform and share benefits. When new projects are conceived, industry's input will be used to help establish what is technically feasible and at what cost. Industry will be represented on Integrated Project Teams overseeing the whole life of a project, except during tendering procedures.

PTP is dependent upon close relations between buyer and seller to allow mutual learning. Because of the risks of anticompetitive behaviour such collaboration is no longer allowed by EU regulations on procurement except in defence material and a few other exceptions. We believe that a new trade-off should be struck between maximisation of competition and promotion of innovation. The case of the UK's Smart Procurement Initiative in defence (see box) shows an example where the sponsors have stepped back from a fully competitive market model, with the realisation that the public interest is not served by an excessive transfer of risk to the contracting firm when the firm is not in a position to bear that risk. This type of partnership model could be broadly extended but requires maintenance of a high level of expertise in government, or at least at its disposal in a way that is clearly independent of its industrial partners. We are concerned that there has been a loss of expertise in purchasing in government. This will need to be rebuilt, implying increased public as well as private R&D to allow the type of intelligent and flexible specification to which we refer.

Specific measures which could be taken to promote PTP include:

- **Requiring governments to produce a regular plan and statement on the degree of innovation and technology development involved in their procurement practices;**
- **A recognition that public services should also be risk takers and hence an understanding that there is a trade-off involved which will involve some failures in procurement decisions en route to greater public service productivity;**
- **Investigation of the possibility of declaring a target for the R&D/innovation component in public procurement to be reported on in the plan mentioned above;**
- **Investigation of changes in competition regulations to allow negotiation and collaboration between procurers and potential suppliers.**

Mention also needs to be made of policies for public procurement of R&D to support Government in its many functions (legislation, regulation etc.). Under the right conditions these contracts can be leveraged to increase the level of R&D expenditure, for example by encouraging research contractors to develop spin-off innovations based upon the research findings. One area close to science where innovative procurement has been common practice is in the area of large-scale scientific instruments and facilities. In these cases leading edge developments have often arisen from customised items for scientists which are then developed to form commercial products. One of the best-known examples in that of Nuclear Magnetic Resonance Imaging which has become a key item in clinical diagnosis. Space technology is another example where the technological level of firms has been raised. These cases provide an additional justification for investment in science.

6.1.2 Defence R&D

Defence is an area of very substantial equipment procurement and in some countries of continuing large scale government spending on industrial R&D, despite the cutbacks since the end of the Cold war. Attempts over recent years to develop dual use technologies which allow the results of R&D to proceed from defence into civil research and vice versa have focused upon reducing the R&D burden and the overall process of R&D, rather than increasing the share of R&D within the defence sector per se. The high costs of defence R&D and the enormous relative expenditure of the USA are putting pressure upon European governments and defence contractors. One way forward is through achievement of economies of scale through international collaboration and industrial restructuring. Defence Ministers in six European countries have launched an initiative to promote these outcomes through the Letter of Intent/Framework Agreement process. In particular harmonised requirements and cooperative solutions are being sought, with efforts being made to address barriers such as security concerns and intellectual property rights.[45]

The Organisation for Joint Armament Co-operation (OCCAR) is an international European Agency, involving France, Italy, Germany and the UK, for purchase of defence equipment and has a mission to become the best international procurement agency in the world through principles such as renunciation of *juste retour* and harmonisation of requirements.

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[45] James A, 2002

More recently the Convention for the Future of Europe has been considering the establishment of a European Armaments and Strategic Research Agency. This would engage in harmonised procurement by Member States underpinned by support for research into defence technology including military space systems.[46] Irrespective of the defence case which is beyond our scope, an initiative of this kind could begin to fill the niche occupied by DARPA in the US innovation system (see box).

Defense Advanced Research Projects Agency

A specific case in defence procurement is the direct funding of R&D for military needs. Probably the best known agency in this respect is the US Defense Advanced Research Projects Agency (DARPA). With a FY2003 budget of $2.7 billion, this agency has pursued a mission of ensuring a US leading position in technology for military capabilities since 1958. A small, flexible and non-bureaucratic central office develops topics for funding and selects projects from contractors drawn from industry and often universities. Typical projects are in the range of $10-40 million though many are smaller. DARPA played a key role in the emergence of areas as microelectronics, computing and network communications, but describes the current situation as one where the DoD is able to somewhat influence the directions of a much-larger-than-DoD market. The orientation of DARPA is unusual in that it is able to support a technology area from academic research through to commercial success without gaps, so long as there is a clear defence objective[47]. The idea of extending the scope of DARPA beyond defence has occasionally emerged and resulted in its name being temporarily changed to its original formulation (ARPA) from 1993 to 1996. DARPA claims a number of historical successes arising from its work, including "between a third and a half of all the major innovations in computer science and technology"[48]. These innovations include timesharing, computer networks, landmark programming languages such as Lisp, operating systems like Multics (which led to Unix), virtual memory, computer security systems, parallel computer systems, distributed computer systems, computers that understand human speech, vision systems, and artificial intelligence. DARPA is currently facing some budgetary setbacks in the USA but US industry will benefit from greatly increased spending on national (homeland) security.

What conclusions can be drawn from considering defence and dual-use R&D? **First, it should be recognised that part of the gap with the USA results from the high level of defence expenditure in that country**, and with programmes such as DARPA plus a huge market for innovative goods, a major stimulus is available for company-funded as well as contracted R&D. **Restructuring and common procurement in Europe are clearly beneficial approaches but unless there is a major shift in policy there is no possibility of reaching the US scale of activity**. **If Europe is to have an equivalent procurement-led technology base it will need to extend to the civil sector. Lessons in procurement practice can be drawn from defence, including the benefits of flexibility, partnership with industry and the payback on R&D illustrated by the DARPA case.** To reproduce these conditions in civilian circumstances is a major task, involving changes in regulations, attitudes and in the level of expertise needed in government departments. There is also potential for action on the margins of defence technology, in the domains of dual use technology and in security and counter-terrorism measures.

[46] Research Europe 23 January 2003
[47] Etzkowitz et al, 2001
[48] *What Will Be*, by Michael Dertouzos, Harper Collins, 1997

6.1.3 Procurement and SMEs

Given the low R&D intensity of European SMEs relative to their US counterparts, the use of procurement to increase their R&D spend is an important issue. The *Comité Richelieu* representing high tech SMEs in France has identified access to public procurement as a key area for action. It makes a series of recommendations to increase the participation of SMEs in Public Technology Procurement:

- To **allocate** a share of technological public procurement and R&D funding to SMEs via
  - Establishing a list of involved public organisations
  - Producing an Annual Report on the actual participation of SMEs in procurement
  - Targeting an annual increase of the contract value of at least 10%
  - Producing an Annual Report on the state of SMEs

- **Requiring** a sub-contracting plan for public procurement greater than €1 million listing targets and promoting transparency, and publishing the selection criteria

- **Establishing** performance bonds for public procurement to support direct contracts to SMEs

- **Setting** up a national and/or European equivalent of the American Small Business Research Initiative (SBIR) – see box below)

- **Improving** SME involvement in large national and European cooperative programmes

- **Reconsidering** the definition of an SME, to allow for the fact that critical size varies according to sector and activity.

Good Practice: Example Small Business Innovation Research Programme (SBIR)
Activity: Procurement for Small Business
Country: US

The US has operated its Small Business Innovation Research Programme (SBIR) since the 1982 when it was created by the Small Business Innovation Development Act. The programme is regarded as the most important small business innovation programme in the US. The programme operates by way of placing a legal requirement on all federal agencies with extramural research budget expenditure of more than $100 million to spend a small percentage (currently 2.5% since 1977) of their procurement within SMEs (defined as businesses with fewer than 500 employees). The programme operated initially on a small scale within the National Science Foundation (NSF) eventually expanding to include many federal agencies. The agencies from which SBIR grants are available include many handling defence matters such as the Department of Defence, the Defence Advanced Research Projects Agency (DARPA), and the Army, Navy and Air Force, but also include major agencies in the areas of health, genomics, energy, and environmental sciences. More than €1.1 billion is awarded annually through the programme by the ten currently participating agencies. In the period 1983 to 1999, $9.9 billion was awarded to around 55,000 projects.

The SBIR uses a competitive three-phase award system in which suitably qualified SMEs propose innovative ideas that meet the specific research and research and development needs of the many and varied agencies of the Federal Government. Phase I is a feasibility study to evaluate the scientific and technical merit of an idea. Awards are for periods of up to six months in amounts up to $100,000. Phase II is to expand on the results of and further pursue the development of Phase I. Awards are for periods of up to two years in amounts up to $750,000 (originally $ 500,000). Phase III is for the commercialisation of the results of Phase II and requires the use of private sector or non-SBIR Federal funding. Only if a government agency is the potential customer for the Phase III results can government funding finance Phase III.

The success of the scheme results from a variety of factors, including a rigorous, staged and iterative selection process that ensures good quality applications and identifies projects with a high probability of success, the programme's reputational aspects, which are significant, and a efficient evaluation system Tech-Net, which allows programme managers to monitor the progress of individual and groups of projects and the balance between the three different programme aims of commercialisation, innovation and contribution to the participating agencies' missions. In the past, there has been concern that the programme is not sufficiently open and that a small number of firms and a small geographical area benefits unduly from the programme. However, there is now substantial evidence that the programme grants are being made to a significant number of new firms each year. The range of identifiable benefits is wide, with noted high social rates of return, the development of innovations, and there is evidence that scientists are choosing to commercialise their research more readily.

To the Comité's list we would add the development and propagation of European and Global standards to provide a stable innovation environment for SMEs which may be excluded from the early stages of standards creation. Some of the recommendations go beyond the scope of this report but the general conclusion, that specific measures are needed to engage SMEs in technological public procurement, is important and requires further investigation.

6.1.4 Stimulation of Private Procurement

Technology procurement policies do not have to be confined to operation solely through public procurement, as has been the case traditionally. Innovation research in general has, at least since the 1960s, again and again pointed at the importance of close buyer-seller interactions and R&D marketing interaction for economically successful innovation and diffusion processes. Also complementarity rather than one-sided choice between technology-push and demand-pull orientations has been emphasized.

There is a role for public policies in promoting such interactions in general, especially so in light of the changing conditions surrounding traditional public technology procurement with less room for public bodies to continually link up with existing, large, domestic suppliers.

A new and fairly untried type of technology procurement policy is that aiming at promoting private procurement as well as a complement to traditional public procurement. The purpose of such policies is to promote the initiation and sustainability of technically and commercially suitable buyer-seller interactions in general, thereby complement the functioning of market mechanisms. To some extent this is uncharted policy terrain and several options are feasible for economic experiments.

Straightforward policy measures in this direction are those that promote the build-up of competences and communication networks among buyers and sellers, through education, conferences, prize contests, grants, associations, campaigns at universities, media support etc. Regarding these policy measures, the use of information technology is potentially an instrument to strengthen their efficiency and thus provides a case for public (government) technology support in general. In addition various information technologies hold prospects to radically improve buyer-seller interactions and marketing in general on a broad scale, but with possible diffusion barriers. One candidate for such support is the use of intranets between prospective buyers/users and sellers/producers in various broad areas like health, energy, information services and building construction. (Incidentally the build-up of a European, national (regional) intra-net for public & private procurement could be a suitable case for public technology procurement in itself). Industrial sectors, which are fragmented on both the buyer and seller side, with low "natural" interaction in purchasing but after all with profitable technological opportunities (as in some consumer industries or in medical technology for that matter), could be an example of sectors expected to benefit from such policies.

Credit guarantees for innovative procurement contracts between firms are also a possible way to encourage greater technological risk-taking. Support for smart procurement principles could also apply here, as could promotion of buyer consortia to create larger markets and hence greater incentives for innovation.

All such measures are likely to be enhanced if promoted within the context of a cluster, the next topic for discussion.

6.2 Systemic policies including clusters

6.2.1 A changing innovation environment

Networking has become a key aspect of company strategy. More and more key innovations and related global businesses are developed and dominated not by single companies but by market oriented, value-chain based networks. Trends towards more integrated systems and towards developing and exporting concepts instead of individual products and /or services are leading in the same direction, that is innovations are becoming more and more systemic in nature. Customers and consumers are looking for packaged solutions instead of single technological gadgets or one-time services. These packaged solutions (or systemic innovations as they might be called) are developed and produced by networks.

Some sectors of national economies are still controlled at least to some extent by the public sector. The role of the public sector differs very much from country to country and from sector to sector. The public sector can be a customer, producer, service provider, facilitator, regulator, etc. What makes the public sector role sometimes a bit problematic is the fact that it can be in several roles at the same time. This is more or less common e.g. in environmental or health care related cases.

Most of these government-controlled sectors are politically important, which can bring additional unpredictability regarding long-term market development. This usually means that companies are less willing to invest in long-term innovative activities. This can, however, be compensated by incentives for innovation to both government controlled and private actors or by reducing government control.

As a conclusion companies and networks need to pay increasing attention to political and social aspects parallel to economic and technological aspects in their innovative activities.

6.2.2 Systemic approaches in innovation policy

The changes in firms' innovation environment and the underlying drivers have forced governments to re-evaluate their role in innovation. Currently the role of government is seen mainly as a facilitator, that is a provider of framework conditions conducive to innovation.

The new role of governments has made it necessary to find new approaches for innovation policy that can deal with a wide set of framework conditions and complex interactions between different types of actors. The answer has been sought in systemic approaches, which started to be adopted in the early 1990s.

The main idea behind the **innovation systems approach** is to see the firm's innovation environment as a system of actors, interactions and framework conditions. The original starting point was to analyse national innovation systems, but in recent years regional innovation systems have also been studied.

As already noted in Section 4.2 on policy rationales, the innovation systems approach brings into innovation policy the notion that instead of solving single identified market failures, the focus is more in the overall performance of the whole system. Policies based on the innovation systems approach focus on identifying systemic failures, i.e. weaknesses in the innovation system which can and usually do result in poor performance in innovation. Most European countries currently base their innovation policy on the systemic approach. Several larger regions have also adopted the systemic approach encouraged by European Commission activities.

The current understanding of innovation processes appreciates the complex nature of interactions and the role of networks. On the one hand, this means that each company is facing slightly different challenges and therefore has specific needs related to its innovative activities. On the other hand, policies should emphasise networks and facilitate processes instead of single companies. The inevitable result is that innovation policy consists of a mix of instruments, some more general and some more tailored for specific targeted purposes. One of the key challenges in innovation policy is to continuously identify the right balance between various types of instruments.

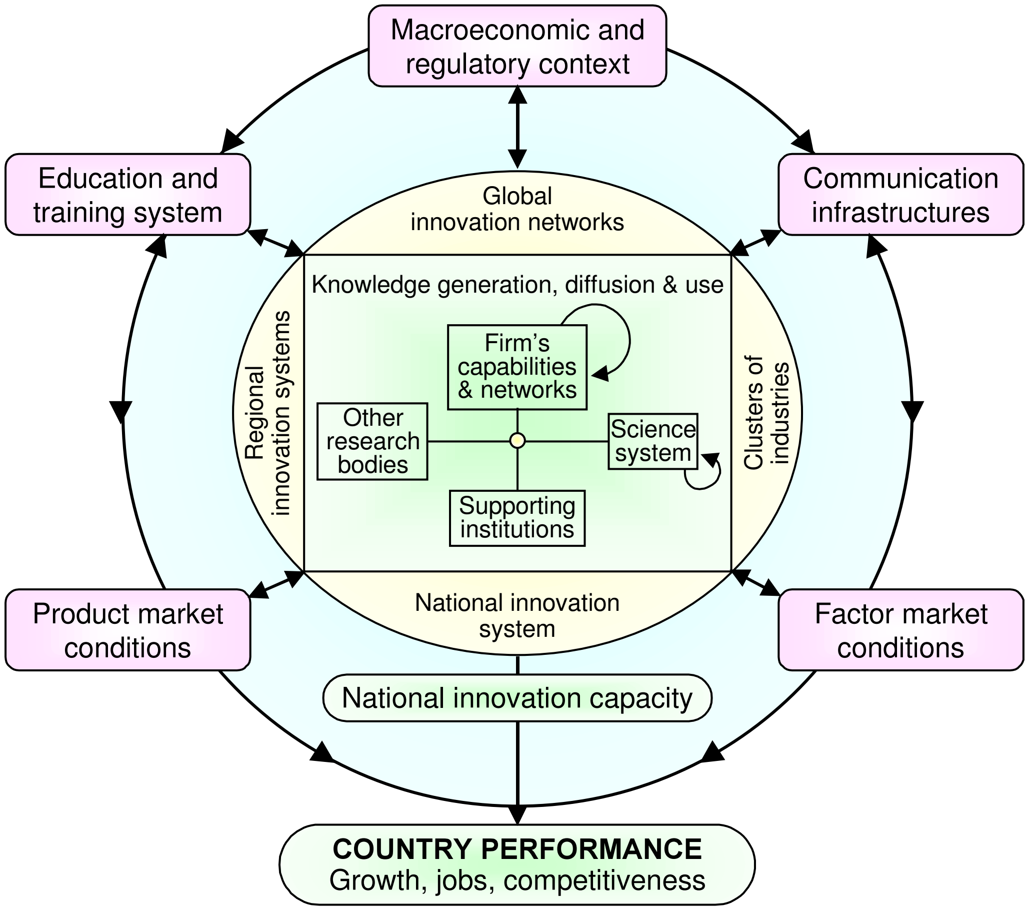

Figure 10 Actors and linkages in the innovation system (Technology, productivity and job creation, OECD, 1998)

6.2.3 Cluster Policies

The other systemic approach also introduced in the beginning of 1990s is the concept of **clusters**. The difference between innovation systems and clusters is mainly in the focus of the analysis. Whereas the innovation systems approach focuses on the system's ability to facilitate and produce innovations, the cluster approach focuses on the system's ability to be competitive in global markets. The idea behind clusters is that competitiveness cannot be explained simply by looking at individual branches of industries, but rather requires looking at concentrations of industries supporting each other, i.e. clusters. A cluster was originally identified through analysis of market interactions between industries, whereby clusters are defined as complementing industries along value-chains. Cluster analysis offers a systemic approach to complex economic interactions and helps realise the inter-linkages between industries and how various framework conditions affect these important inter-linkages. Thus, clusters provide a deeper insight into how economic structures are developing as complex systems and what factors affect this development in specific cultural and historical contexts.

Clusters represent an approach to policymaking, not a single policy instrument. Like the innovation systems approach, clusters are used to design policy mixes. Both of these systemic approaches can thus be used for integrating different policies horizontally. The most obvious integration is between industrial, economic and innovation policies. This is also the most common approach used in many countries, for example the Netherlands and Denmark.

However, the combination of these systemic approaches can also be used to combine other policies with innovation, industry and economic policy. For example, the inter-ministerial cluster based programmes in Finland represent an attempt to link environmental and social policies to innovation, industrial and economic policies through the cluster approach.

Good Practice Example
Activity: Inter-Ministerial Cluster programmes
Country: Finland

The knowledge based cluster programmes, whose creation dates from the decision by the Government of Finland in 1996-1997 to increase public spending on public R&D, have sought to develop and strengthen capabilities in particular subject, thematic and knowledge areas (knowledge clusters), rather than on innovation activities which are tied to particular geographical locations. Developing clusters in knowledge areas mobilises actors and networks by reference to the research focus of their activities rather than to the location in which these activities are carried out. Knowledge cluster programmes are a way of "playing to the strengths" of an economy by focusing on the areas of an economy in which there is potential for innovation and growth and connecting types of actors which are known to be of pivotal importance for innovation.

Cluster programmes are aimed at a wide range of actors, including research providers, government, industrial companies of all sizes including SMEs, venture capital organisations and consultants. The Finnish knowledge cluster programmes are operated by different ministries of the government, with separate rules, application procedures, selection, and monitoring and evaluation, although an international expert group was convened by the Ministry of Trade and Industry to carry out an evaluation of the economic and social effects of the programme. The size of the cluster programmes has been large with around €100 million of government money allocated in total to the scheme with an annual budget of around €33 million. Other sources of funding include private and industry co-funding, and from the National Technology Agency of Finland, Academy of Finland, and the EU.

Cluster programmes have achieved significantly in the process of integrating innovation actors in particular research areas, but some difficulties have been experienced in integrating firms and funders. Other issues of major interest for policy makers concern the attempt to develop appropriate funding instruments when many kinds of actor may be participating, and the question of whether clusters should and indeed could be restricted to operation within national boundaries.

The original cluster concept was introduced to explain the competitiveness of nations, but much like the innovation systems approach it has since been used in the context of regions and other geographical areas. The cluster approach has also been applied in analysing non-market interactions resulting in, for example, knowledge clusters.

Good Practice Example – Cluster Policy - Regional

Activity: "BioRegio" Contest
Country: Germany, Federal Ministry for Research and Education

Conscious in the mid 1990s that the country's biotechnology sector lacked the dynamism which would allow it to compete internationally in this important area of the new knowledge economy, the German Government launched a programme named "Bio-Regio", an initiative that would allow regions to build up their cluster infrastructures in biotechnology. The programme was competitive and, in addition to support for clusters, direct project financing would be subsequently available to those who were successful in winning infrastructure funds. The main aims of the programme were threefold: to improve knowledge and technology transfer within the regions, from scientific institutions into (new) enterprises and finally the market; to support start ups in the biotechnology sector; and to improve the competitiveness of the region.

Of the two lines of funding available, the first provided a total of DM 50 Mio (EURO 25,56 Mio) allocation for successful regions to set up an appropriate supporting infrastructure and finance model projects. The rules underpinning the use of this fund broke with the traditional government approach of supporting regions which lagged behind by supporting those which already had extensive capabilities. Secondly, privileged access from regions which were successful in winning money from the first fund was allowed to the Federal direct support programme for the biotech technology of DM 1.5 billion (EUO 0,77 billion), a far more important funding source in real terms than the infrastructure funding for the regional clusters.

18 regions eventually applied for funding of which 3 were finally chosen (Rhineland, Rhine-Neckar, Munich), although the government had expected more, around 30 in fact, to bid. Success in the competition depended upon the condition of existing infrastructure and its ability to contribute throughout all stages of the innovation process, including the development of academic knowledge, availability of testing facilities and IP legal and consultancy services.

The success of the programme is attested by increases both in employment and in the number of firms operating in the biotechnology area. Preliminary data for early 2000 suggests that more than 500 companies and 3500 new jobs have been created in total within the regions, while in the whole of Germany, the number of dedicated life sciences companies has risen from 75 in 1995 to 222 in 1998.

The main conclusions of the review which took place into the scheme in 2000 were that the support of the stronger areas was a highly effective method of realizing endogenous potential. Furthermore, even those regions which did not benefit directly from the scheme appear to have benefited indirectly through learning and imitation. It is also notable that Government financial support also appears to be more effective under certain conditions: when monies are disbursed through a one-stop location which carries out central co-ordination and funding of service institutions; where there is focus on real co-operation (not just in the documents), combined with a strong marketing aspects; where large companies are integrated into the process of developing start-ups; where research institutions are more open to co-operation; and where there is mobility of human capital between research/education and industry.

6.2.4 Adopting the cluster approach in practice

The cluster approach has been adopted in various forms in national and regional policies. At the macro level, the idea is to identify mega-clusters of supporting industries explaining national competitiveness. The policy context is typically industrial policy. At the meso level the analysis is based on industrial branches and sectors and their inter-linkages along the value chain. The aim is to explain competitiveness of specific industries. The policy context is either national or regional industry and/or innovation policy. At the micro level the idea is to identify firm level networks and explain their competitiveness. The policy has typically a strong emphasis on SMEs and is usually linked to industrial, regional and/or innovation policy.

Building networks and clusters involves costs not justifiable for any single actor, although all actors will eventually benefit from the network once it is established. This offers a clear rationale for public sector action which, once the network is established, is no longer there. Public intervention should thus change over time as the network or cluster develops and matures.

The more challenging part of the identification of clusters and networks is recognising missing or weak linkages and actors. What makes this even more challenging in practice is the potential influence of the strong lobbying power of existing industries. Especially clusters and networks in smaller geographical contexts typically have some linkages outside their region. This can also lead into lock-in problems in cases where the policy has too strong a regional emphasis.

At the macro and meso levels the identification of missing and weak linkages can be attached to a common foresight activity or some other future or strategy oriented process. This might help to avoid some of the potential lock-in problems. One of the tools that can be used at all levels is SWOT analysis of the key actors, i.e. firms, groups of companies or industries. At the firm level one can also use technology audits to identify technological needs of individual firms. This helps firms recognise potential complementary competencies offered by other firms and organisations and thus form a basis for further networking activities.

The government role in cluster policy can be summarised as being to:

- **Establish** a stable and **predictable** economic and political **environment**.
- Create **favourable framework conditions** for the smooth and dynamic functioning of markets (infrastructure, competition policy and regulatory reform, provision of strategic information).
- Create a context that encourages innovation and upgrading by setting a challenging economic **vision** for the nation or region (technology foresight studies, strategic cluster studies).
- Raise **awareness** of the benefits of knowledge exchange and networking.
- Facilitate the informal and formal **exchange of knowledge** (platforms, workshops, other forms of interaction)

- Provide support and appropriate **incentive schemes for collaboration** (competitive programmes and projects). Ensure that (public) institutions (especially schools, universities, research institutes) cultivate industry ties.

- Act as a **facilitator** and **moderator of networking** and knowledge exchange and initiate network brokers and intermediaries to bring actors together.

- Act as a demanding and **launching customer** when addressing needs.

The cluster approach has been adopted in various forms and at various levels in different countries during the 1990s. An OECD report analysed the motivation behind the approaches adopted by selected countries and arrived at the following four categories: national advantage, inter-firm networking, regional development and industry-research clustering.

Table 4 Policy models and their main instruments and public roles

(*Public policies to facilitate clusters: background, rationale and policy practices in international perspective* by Patries Boekholt and Ben Thuriaux in Boosting Innovation: The Cluster Approach, OECD, 1999)

	Mega level	Meso level	Micro level
1. National advantage	• Mapping • Competitive markets • Regulations and standardisation	• Foresights • Specialised RTD facilities	• Collaborative RTD programmes
2. Inter-firm (SME) networking		• Supply chain development	• Brokerage • Networking programmes • Awareness raising
3. Regional development	• Regional Competence Centre development	• Focused Inward investment • Supply-chain associations • Specialised technology transfer • Marketing clusters	• Brokerage • Networking programmes • Awareness raising
4. Industry-RTD clustering	• Incentives RTD-industry collaboration (IPR, financial, etc.)	• Collaborative RTD centres programmes in specific areas • Prioritisation of R&D expertise	• Technology circles • NTBF support • Procurement policy

The national advantage category is closest to the original Porterian approach and is mainly linked to industrial policy. Inter-firm networking might be regarded as a SME focused micro level variation of the basic approach. Regional development, adopted in many European countries, emphasises the regional dimension and often links the cluster approach to the regional innovation system and knowledge concentrations. Industry-research clustering is basically about networking around specific knowledge bases or technologies and as such closer to horizontal networking than vertical networking. The way some countries have adopted these approaches can be seen in Table 2. In addition to the countries mentioned in Table 2, the cluster approach has also been applied in other countries including Japan, Belgium/Flanders, Portugal, Spain and Switzerland. The main focus of cluster policies in most of these countries has been on regional development at micro or meso level.

According to the same report, the most common features of the cluster policy as adopted in various countries include:

- Competition and **regulatory reform** policy (almost all countries).

- Providing **strategic information** through technology foresight studies (e.g. the Netherlands, Sweden,), cluster studies (e.g. Austria, Denmark, Finland, Italy, the Netherlands, Sweden, the United Kingdom, the United States), special research groups (e.g. the Austrian TIP research programme, Denmark, the German Delphi report), or special Web sites (e.g. STRATEGIS in Canada).

- **Broker and network agencies** and schemes (e.g. the Danish network programme and the Dutch Innovation Centres).

- **Cluster development programmes** (e.g. cluster programmes in Finland and the Netherlands, regional development agencies in Germany, the United Kingdom and the United States, and Flemish R&D support to clusters).

- Initiating **joint industry-research centres** of excellence (e.g. Belgium, Denmark, Finland, Germany, the Netherlands, Spain, Sweden, Switzerland).

- **Public procurement** policy (e.g. Austria, Denmark, the Netherlands).

- **Institutional renewal** in industrial policy making (e.g. Canada, Finland).

- Providing **platforms** for constructive dialogue (e.g. the Danish reference groups, Dutch broker policy, the Finnish National Industrial Strategy, the German Council for Research, Technology and Innovation, the Swedish industrial system approach, the UK regional development agencies, and the US focus groups).

6.2.5 The cluster approach in enhancing private investments in R&D

Innovation follows a complex inter-connected process where several actors and ideas interact and finally filter out a commercially successful product, process or service. The need to innovate continuously has brought the previously separate innovation and business processes closer together. The same is also implied through lean production, just-in-time supply chains, better quality control over the whole manufacturing process and supply chain and stronger customer focus. This means that companies have tighter linkages to specific value chains and more and more innovations are endogenous to value chains. Therefore, clustering and networking specifically along value chains is important both in terms of economic growth and innovation.

The cluster approach is not an instrument, it is a systemic approach to policy. Same applies to networking, which is a means towards the real goal, enhanced innovation performance. Measures to enhance creation and development of innovative networks and clusters should therefore be in the core of modern innovation policy.

What networking and clustering emphasise is the need to have a deeper understanding of the structures, framework conditions and processes related to innovation. Better understanding forms a basis for the design of more targeted and therefore more efficient and effective policy measures. Cluster approach also emphasises the need to find a balanced policy mix combining direct and indirect measures, general and more targeted measures, innovation and non-innovation policies and integrating regional, national and international level policies and measures. Therefore, clusters and networks is a useful approach to foster horizontal policy co-ordination, design policy mixes combining both direct and indirect measures and encourage companies to invest in R&D.

Some of the main benefits of the applying the cluster approach in policy in general and especially with the aim of enhancing private investments in R&D include:

- Cluster analyses help **identify** networks and **linkages among industries**. Better understanding of various types of networks helps, for example, in the design of measures aimed at enhancing technology transfer and diffusion.
- Networks are efficient in **transferring and diffusing knowledge**, skills and technologies. This is especially important in clusters built around global technology leaders.
- The cluster approach is useful for identifying technologies and problems common to several industries, which helps create platforms to enhance cross-disciplinary and **cross-industry interaction**.
- Clusters can also be used to link traditional programmatic approach of building critical mass of knowledge and specific technologies in innovation policy to more commercially oriented approach of building value-chain based networks. In this way clusters can complement the more scientific disciplinary based approach with a more **innovation oriented multidisciplinary approach**.
- Applying the cluster approach to **integrate** social and environmental policies to economic, industrial and innovation **policies** helps realise the different roles of various public and private sector actors, thus creating a platform for building public-private partnerships[49].
- Clusters also offer a natural **platform** for **combining foresight and strategy** elements **to direct measures** supporting R&D. All actors are linked to a single value-chain and their future success is dependent on the success of the whole cluster. Therefore, it makes sense to work on cluster strategies and foresight. Common understanding of future challenges can form a strong basis and interest for joint R&D and innovative activities.
- Cluster analyses can also provide the possibility to **identify emerging growth** areas and the role that various organisations can play in enhancing performance. Better understanding of new growth mechanisms can be used to design more effective policies.
- Since clusters represent a mainly value-chain based market oriented approach, it is **easier to attract companies**, especially smaller to participate in networking activities. Clusters help companies identify their role and position in value-chains and, thus, see what their value added is to the whole cluster or a network. It also helps companies to identify complementary resources available in other companies and research organisations. The awareness of being part of a bigger and more powerful market actor can increase the willingness to take risks.

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[49] Public-private-partnerships (PPP) are traditionally used either as a way of channelling money to R&D which has specific political or social importance or as a way of reducing costs by improving the public sector bargaining power. The need for social or non-technological innovations adds another dimension to PPP, which is co-development of the economy and society. PPP are increasingly used as a way to develop public services linking technological and non-technological innovations.

- The **raised awareness** among cluster actors of the availability of additional resources, inter-dependencies with other actors[50] and realisation of the larger context can **increase** the **willingness to take risks**.

- The **access to** a larger **knowledge** and skills base lowers the risks and **increases the potential to innovate**. Networks are also an efficient way to increase flexibility, which is necessary especially in fast changing markets.

There are also some potential challenges or pitfalls in using the cluster approach in innovation policy. These include:

- Cluster initiatives should be very sensitive to public sector market intervention. If not carefully planned and monitored, clusters can be a step back to the old industrial policy of **"picking winners"**. In general, while clusters offer a possibility for a more targeted and thus more efficient policy, there is a constant danger of going too far.

- Another danger linked to the cluster approach is the role of **horizontal actors**, e.g. knowledge intensive business services (KIBS). KIBS are typically actors creating linkages between clusters instead of being linked to single clusters. They are thus very important actors transferring knowledge and technologies across clusters. Policies should identify the important role these kinds of horizontal actors, who do not necessarily form a cluster themselves. Having only cluster specific policies might result in quite unexpected opportunistic behaviour of horizontal actors, if selected clusters offer a more conducive framework conditions or direct support than others.

- There are also sectors or branches of industry or the economy which belong to several clusters. How to deal with these **overlapping areas** is yet another challenge in using the cluster approach in policy. Again, cluster specific policies might lead to unexpected behaviour of these actors if one cluster appears more conducive than others.

- There are sectors which can not, on a national level or regional level, be defined as full-fledged clusters, although they might be economically very important. In fact, this is the case in many emerging high-tech growth sectors. In these cases, the analysis should be extended beyond regional or national borders and these sectors should be identified as part of **international clusters**. Otherwise cluster policies might lock-in to more traditional clusters which are more typically regionally or nationally centralised. However, there are equal dangers in shifting the focus too far towards emerging clusters forgetting the more traditional sectors. The probability of high-tech myopia is increased by focusing solely on high-tech and ignoring non-technological aspects of innovation.

- Cluster should always be identified through a **systematic and transparent analysis**. Otherwise there is a danger of lobbying and other political reasons resulting in clusters which have no real potential. It is also important to find the right policy mix combining direct and indirect measures as well as top-down and bottom-up measures.

- Cluster policies should be **balanced** between creating and sustaining clusters, between existing and emerging clusters, between cluster specific and general measures, between innovation oriented and non-innovation oriented measures,

[50] The realisation that "I am not alone in this" favours interaction. It can also reduce the perceived risk, as others share the risk.

between technological and non-technological innovation, etc. If the cluster approach is widely used in policies, there should also be a balance between macro, meso and micro level policies and measures.

- Cluster policy should include a **sufficient mix of instruments** enhancing the development of general and cluster specific framework conditions as well as selected clusters. Focusing on a too-limited set of instruments might lead into non-sustainable impacts. For example focusing cluster policies on facilitating and supporting the build up and launch of networks without any support to actual co-operative activities might lead into networks which will dissolve immediately after the support for networking is withdrawn.

All networks require some form of **leadership**. Identifying or helping build up the appropriate forms of leadership is one of the key challenges in networking. This is especially important in smaller and emerging clusters and networks. Lack of appropriate forms of leadership will eventually lead to failure.

6.3 Regulation, standards and support for technology platforms and public-private partnerships

There are several definitions in circulation of the concept of a technology platform. Within a large firm it can refer to an area of maintained competence in R&D which is used to support a range of product and process developments. However, in the public domain the definition extends to cover the situation where multiple actors are engaged in building up the area of competence and where government is engaged not only as a sponsor of R&D but also in its capacity as regulator and standard setter. The ability to predict or influence regulations and standards is an important success factor in innovation. Involvement of government in the platform reduces the risk of miscalculation and hence increases the incentive to perform R&D. At a European level, the establishment of technology platforms was a central recommendation of the Strategic Review of EUREKA in 1999[51]. However, in many ways the Commission is better placed to pursue this type of policy given its central role in many areas of regulation.

The role of regulation in stimulating innovation has been explored in a recent study for the Commission[52]. This proposes a “Third generation innovation policy” which emphasises the benefits of coordinating actions across a variety of policy areas in support of innovation. Regulatory and institutional reform are seen to involve:

- Content of regulations (for example of market liberalisation);
- Reducing the regulatory burden;
- Building more flexible regulatory approaches; and
- Innovation in regulatory policy itself.

Within the domain of innovation policy regulatory reform is seen to affect innovation indirectly through affecting the funds available for investment and market size and structure,

[51] Georghiou et al, 1999
[52] Louis Lengrand et al, 2003

and directly through its impact upon the perceived profitability of particular lines of development. Regulation can be used to set targets for innovation (so-called performance based regulation). For example an environmental emissions target beyond current capability may anticipate and aim to stimulate innovation.

Governments have begun in recent years to experiment with the concept of public-private partnerships to defray costs of creating and maintaining infrastructures. In a narrow sense this refers to the use of private capital in the provision of public service investment. However, in the domain of research and innovation policy the concept is used more broadly to refer to any type of scheme which is co-financed and involves sharing risks and rewards. This also extends to public technology procurement. Any scheme which goes beyond simple financing of firms to create mutual obligations could be seen to involve elements of such a partnership

Probably the most significant conclusion from this section for the purposes of this study is that **innovation policy is a cross-governmental function and that the stimulation of innovation (and hence of R&D spending) also involves ministries other than the traditional science, industry or education portfolios. The need for coordination is as great here as in procurement.**

7 Framework Conditions

7.1 Strong and collaborative science base

As indicated above an important element in firms' R&D investment decision is a strong and collaborative science base. The literature on this topic indicates that good science is not only important in terms of the opportunities for innovation it creates through production of new knowledge. It is also a vital source of highly trained people who act as vectors of technology transfer. Contact with academic research also offers firms a window on the world to monitor new developments, and a source of knowledge which can be tapped in response to problems as they emerge.

It might also be noted that sufficient basic science is needed for adapting new knowledge created elsewhere, i.e. basic research is vital for creating and sustaining the adaptive capability of an innovation environment. This might even be more important (in view of economic growth) than the role of creating new knowledge, at least for some regional and/or smaller universities and/or research institutes.

There is ample evidence of the existence of "islands of excellence" in European science. A four country benchmarking study indicated that four European institutions led the world in terms of citations per article published in the field of biological sciences (Table 5). However, it can also be noted that the number of papers produced at this very high quality level is much lower than that for the American institutions which occupy the next eight positions.

Table 5 Average impact of the top institutions in Biological sciences

World average citations per journal paper = 5.46

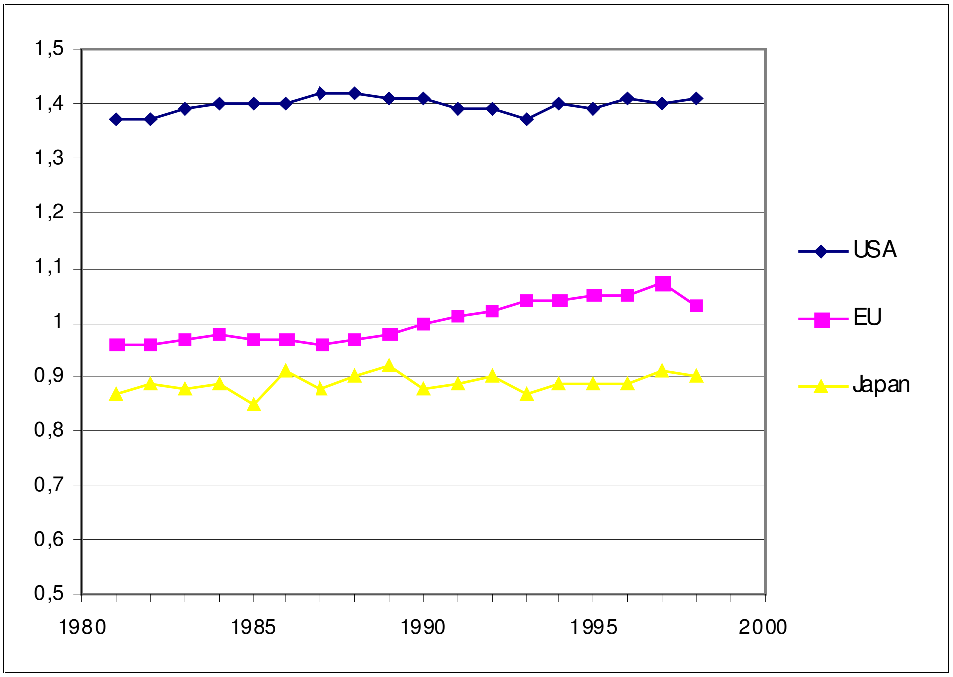
Institution	Country	Impact	Journal articles	Citations of articles	Impact cf. World
MRC LAB MOLEC BIOL	UK	34.80	401	13954	6.37
MPI FRIEDRICH MIESCHER	Germany	30.23	35	1058	5.54
MPI MAX DELBRUCK LAB	Germany	27.13	55	1492	4.97
MPI PHYSIOL & CLIN RES	Germany	26.15	102	2667	4.79
ROCKEFELLER UNIV	USA	25.29	1440	36417	4.63
MIT	USA	23.08	2179	50296	4.23
UNIV MASS WORCESTER	USA	22.43	826	18527	4.11
UNIV TEXAS DALLAS	USA	21.36	1778	37985	3.91
UNIV TEXAS ARLINGTON	USA	20.53	1837	37721	3.76
HARVARD UNIV	USA	20.53	8355	171536	3.76
SCRIPPS RES INST	USA	20.22	1899	38404	3.70
COLUMBIA UNIV	USA	18.42	2300	42356	3.37

Data from PREST/Evidence study[53] covering 1994/98 publications for four countries (Canada, Germany, UK and USA)

This conclusion is confirmed by Figure 11 which demonstrates the clear lead of the USA when unadjusted averages are used.

[53] Georghiou et al 2003

Figure 11 Relative citation rates of the EU, the US, and Japan related to world average



Source: Olle Persson, Umea University, Note: without normalisation by field (one is world average) published in Krull et al 2002

The need for excellence as a driver for competitiveness is clear. From the above exhibits it may be concluded that despite its many strengths, the science base in Europe lacks the strong concentrations of excellence which can be found in the USA. Loss of economies of scale in equipment and of the critical mass needed for interdisciplinarity are accompanied by a fragmented interface with industry at a time when major firms are seeking to consolidate and focus their academic links into a smaller number of deeper and long-term relationships. **The implication is that radical restructuring is needed in some fields towards policies based upon concentration of resources and creation of well-networked "centres of excellence".**

Excellence is insufficient if the scientists and institutions concerned are not engaged with relevant industrial communities. The collaborative element of the science base operates through many mechanisms, explicit and implicit. The supply and mobility of trained people are critical and are covered extensively in the section on human resources below. At the other end of the scale there is the flow of knowledge in the public domain, principally through scientific publication. However, in addition to these mechanisms there are several other potential points of contact and in these spheres public policy plays an important role. Recent exercises on benchmarking industry-science relations carried out by the European Commission[54] and the OECD[55] have emphasised both the importance of framework conditions and the specificity of national institutional arrangements. Within these constraints it is the case that the great majority of new initiatives in the sphere of direct measures seek to promote better linkage between the science base and industry through collaboration or commercialisation. Recent trends indicate efforts to cut the level of transaction costs involved. These include large firms focussing upon key collaborating institutions at a higher level of resource and sometimes in a "broadband" relationship encompassing business and technological training as well as research cooperation.

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[54] Polt et al

[55] OECD (2002)

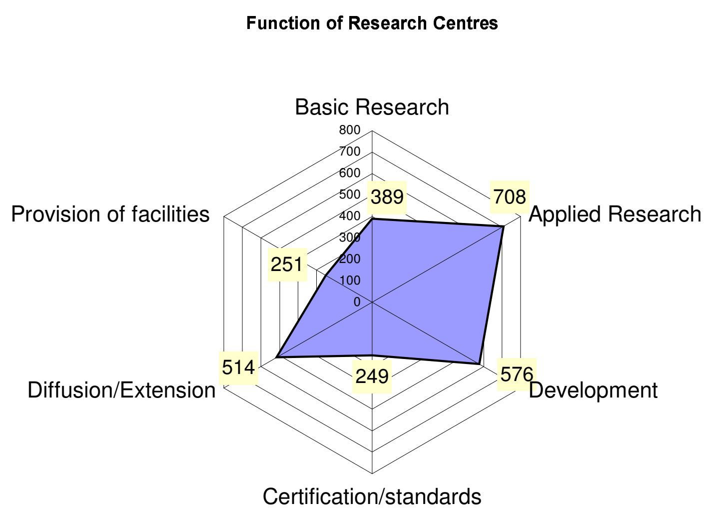
In summary, the relationship between an excellent science base and industrial innovation is far from automatic. Continuing emphasis upon the whole range of direct measures that exist to promote industry-science relations is needed, along with complementary measures to train students in entrepreneurial skills and to induce a similarly entrepreneurial culture among researchers in academic and other public laboratories. Training in the management and the exploitation of technology are further priorities for direct measures.

A related sector is that of charitable investment in R&D. This has several facets. In the USA, wealth generated by industry has been used to create endowments which underpin the research finances of leading universities. In many ways this then subsidises future research cooperation by providing the academic partner with a high quality infrastructure. Firms may also benefit from charitable funding of R&D, particularly in the medical sector where endowments and collections from the public play an increasingly important role in research finance.

7.2 Role of contract research/ technology suppliers

Many firms do not have the capability to perform R&D, or at least to cover the full range of R&D relevant to their business. Nonetheless, such firms can contribute substantially to the growth of R&D in Europe by increasing the amount of R&D they contract to external organisations. Outsourcing of R&D has trebled in recent years (Howells, 1997) and a large contract research sector exists in both the public and private sectors.

Figure 12 Function of Research Centres

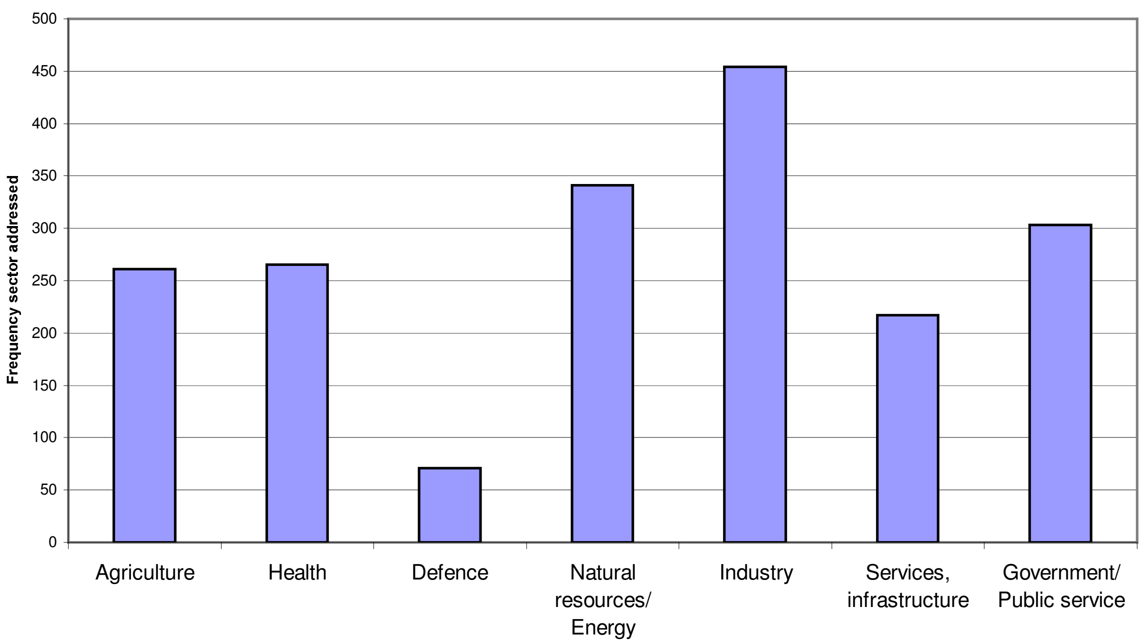


Source: Eurolabs database

A recent study of 769 public, semi-public and recently privatised research centres in the EU[56] found the sector heavily oriented towards the performance of applied research and development (see Figure 12). Over half of the research sectors (450) addressed industry as a main client (Figure 13) and 84% of them had linkages with industry, which were rated as major linkages by 54%. Financial and political pressures have motivated many former state organisations to seek an increasing proportion of their income from commercial sources. In some case the main mission has changed from a national objective, such as development of nuclear power, to an explicit mission to support industry through research and technology transfer. In other cases the *raison d'être* of the organisation is the performance of research and development on behalf of small firms in a sector. The "research association model" is far from new but in some countries has grown in strength as it is perceived as a means for companies without their own technology base to access the benefits of R&D.

A further role for research centres is in the provision of facilities which are too large or expensive for individual firms to operate for themselves. Such facilities may result from the needs of big science or be relevant for both academia and industry (for example sources of ionising radiation). A facility may also act as a pole around which a cluster of related technology-based industrial activity can develop. Facilities of an engineering nature, for example pilot plant, can be a key link in the development of a cluster (see Section 6.2.3).

Figure 13 Sectors Addressed by Research Centres



Source: Eurolabs database

Policy measures to strengthen this market provide the best opportunity to widen the range of firms investing in R&D. However, attention also has to be paid to the absorptive capacity of recipient firms, to ensure that they can use the technology being developed.

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[56] Georghiou et al, 2002

A second EU-funded project, RISE explored Research and Technology Organisations which it defined as *organisations with significant core government funding (25% or greater) which supply services to firms individually or collectively in support of scientific and technological innovation and which devote much of their capability (50% or more of their labour) to remaining integrated with the science base*[57]. The project emphasised the service delivery aspect of such organisations, seeing them as customised versions of generic government service products and government funding programmes for innovation as specialist financial products at the core, with tangible or intangible scientific and technological deliverables added in to complete the service package. RTOs are being shifted away from core institutional funding and towards various forms of contractual/results-oriented funding, based on the delivery of specific services. This includes public programme funding or service contracts for government departments on one hand, and service contracts for firms on the other.

Good Practice Example: Involvement of Intermediary and Contract Research Organisations - Faraday Partnerships, UK

The Faraday Partnerships initiative is named after Michael Faraday, the 19th Century physicist and chemist known for his experimental work in electricity, who maintained strong links with industry while pursuing fundamental research. The Faraday Partnership initiative is aimed at promoting improved interactions between the UK science, engineering and technology base and industry through the involvement of intermediate organisations. Intermediate organisations have strong connections with both industry (particularly SMEs) and with academia. Examples include Research and Technology Organisations (RTOs) or their analogues, universities, government agencies or private sector laboratories, but are not restricted to these organisations.

Faraday Partnerships are business friendly, knowledge base/industry partnerships that are recognised nationally and regionally as centres of expertise and collaboration in their sector or technology. Since 1997, twenty-four Faraday Partnerships have been established with support from two ministries and two research councils.

The establishment of Faraday Partnerships is intended to strengthen the way technology is developed and exploited within the UK by stimulating better coherence between researchers and new product developers. By bringing active players together around a common sector or technology theme, with common targets and agreed methods of working, the necessary elements for coherence will be put in place. Central to this is a style of management that seeks to work for the benefit of the Partnership as a whole rather than a sectional and self-interested group or organisation. The aim is for a long-term strategy which produces a cultural change among all parties and leads to a private sector self-sustaining business model for value-added knowledge trading (AIRTO, 2001).

The role of the intermediary is seen as important in providing leadership and management and allowing: multidisciplinarity and multiple partners without any one group's interest being allowed to dominate, neutral help to resolve problems and ownership of the exploitation process through the "development gap". The Association of Independent Research and Technology Organisations sees the scheme as addressing "purchasing demand" for knowledge transfer services.

[57] *Hales, 2001*

Faraday Partnerships work in subjects identified from Foresight priorities and the technology needs of a knowledge driven economy. They are in topics of key importance to the industrial well being of the UK and are intended to be of interest to a wide spectrum of firms, research organisations and funding providers.

The message from both of these projects is that a large intermediary sector acts in multiple roles:

- as a conduit for government funding for R&D in firms without the capability to do it themselves;
- as a means of leveraging R&D expenditure by supporting strategic research which develops and maintains the development of capabilities in these organisations to perform contract R&D for industry;
- as a means of implementing programmes which develop intersectoral linkages; and
- as a repository of technological and managerial innovation skills and capabilities which may be disseminated to firms, in particular to SMEs.

However, to encourage strategic alliances between industry and public research institutes and universities, there is a need to develop clearer explanations on the restrictions on State aid in public-private R&D cooperation.

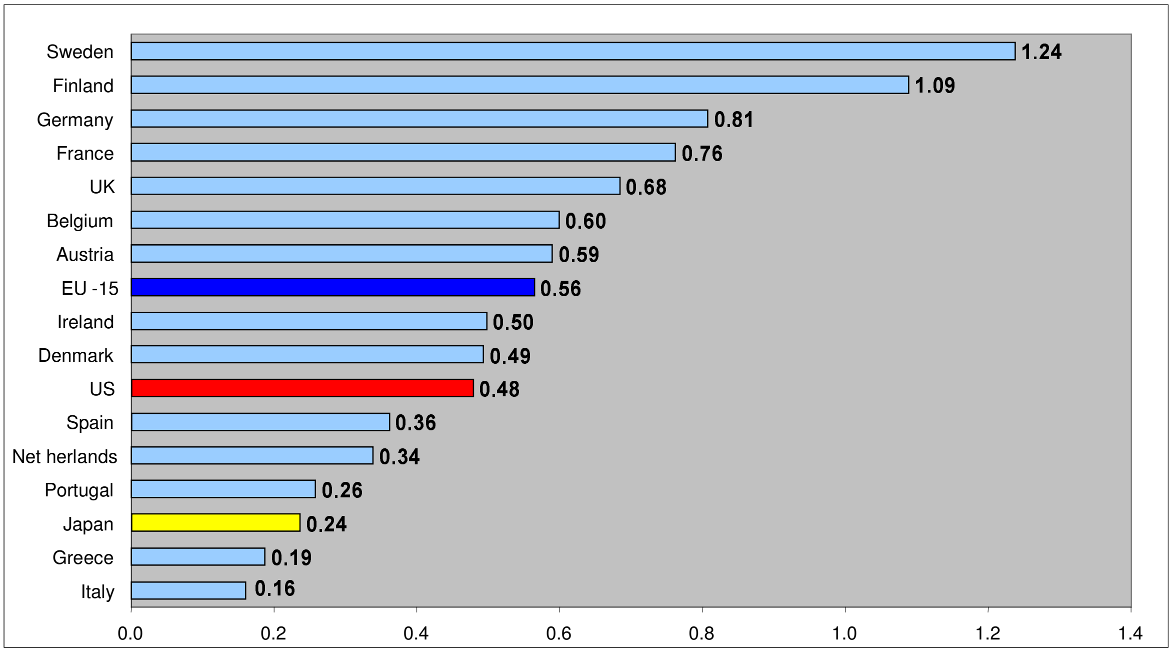
7.3 Human Resources

There are significant national disparities in Europe in the intensity and distribution of human resources for R&D and in the proportion of those working in the business sector. Issues of importance affecting the supply of researchers include pay of researchers (and other career incentives) and the ability to train them. This supply issue is of paramount importance. Failure to address it would make achievement of the growth targets for R&D impossible.

7.3.1 Supply of Human Resources to Meet the 3% Target

The human resource issue may be considered both as a framework condition and as an area of activity for Direct Measures. In the first context the principal challenge is to deliver the very substantial increase in the number of industrial researchers that would be needed to meet the 3% target. A rough calculation indicates that there were 460,000 business enterprise researchers in the EU in 1999. Assuming that capital intensity is constant, the *minimum* increase implied by the 3% target is 300,000. In addition a large increase in the number of technicians and other support staff would be needed. Since these researchers would almost certainly need to be trained in the public science and engineering system, general policies for human resources are of critical importance.

Figure 14 New S&T PhDs per thousand population aged 25 to 34, latest available year (1)

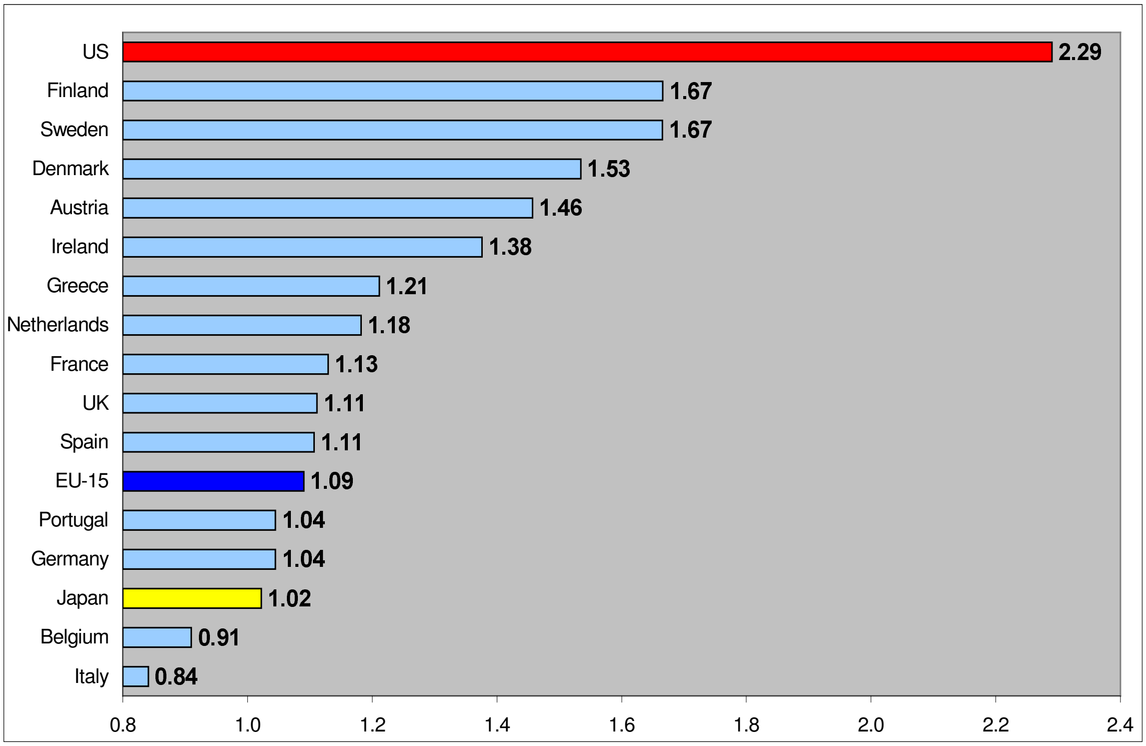


Source: *DG Research. Key Figures 2002*
Data: *Eurostat, Member States, OECD*
Notes: *(1) 2000; I, EL: 1999. E is provisional. EU-15 without L*

From this supply side perspective, the larger the number of new science and technology graduates and PhDs in relation to the population in the corresponding age group, the greater the effectiveness of direct measures to support private investment especially in countries, regions and sectors where there exist S&T skills and manpower shortages. Educational policies affect the various decision steps involved in the researchers' careers. According to the recent Human Resources in RTD Report, the single most defining choice in developing Human Resources for S&T is a decision to enter postgraduate training (Strata Etan, 2002). The prevailing picture is of slow increase in numbers and proportions through the 1990's in most European countries. However, the proportions of PhDs in S&T are higher than the US or Japan (Figure 14).

S&E is relatively strong in Ireland, France and the UK. There appears to be a correlation between PhD production, investment in PhD programmes and PhDs in the workforce, with Finland and Sweden as prime examples. Figure 15 shows national differences on the expenditure on tertiary education, and it is worth noting the difference between the EU average and US figure. Expenditure on tertiary education is that which finances the production of S&T graduates (Figure 14). Therefore, much can be done from the point of view of educational expenditure.

Figure 15 Private and public expenditure on tertiary education: percentage of GDP 1998

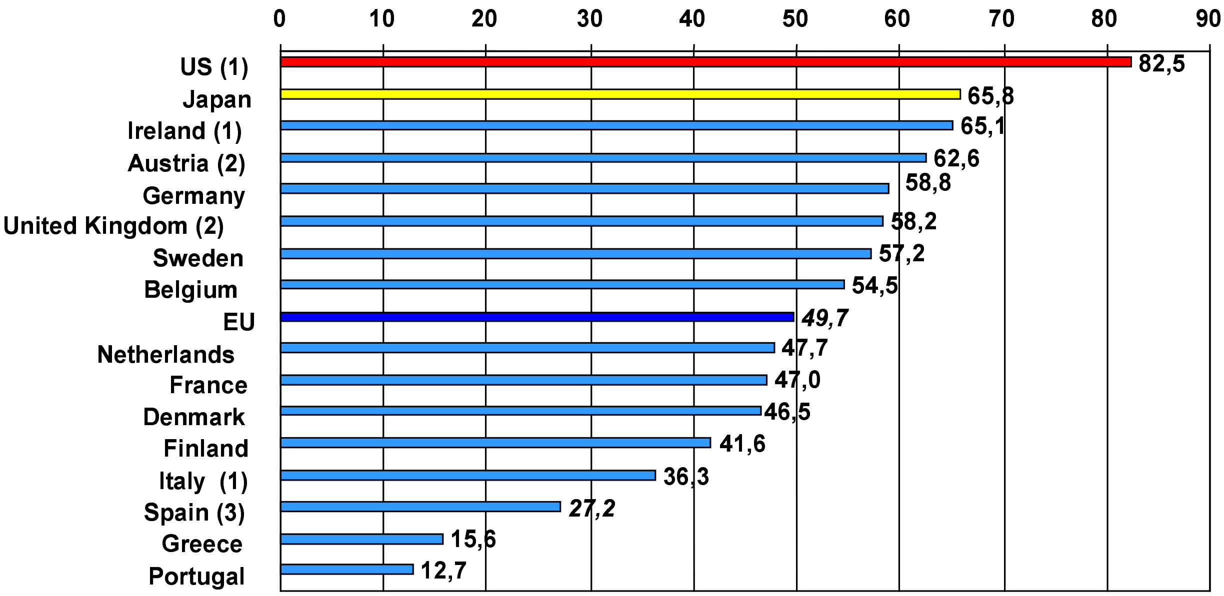


Source: *DG Research. Key Figures 2002*
Data: *OECD*
Notes: *Data for L are not available; so it is not included in the EU average.*

If we consider the gender bias of the distribution of graduates by discipline, taking the EU average, women are underrepresented in mathematics & computing and engineering, and over-represented in educational sciences, arts & humanities. A more even distribution is found in the natural and the social sciences. The differences of men and women employed as researchers are also high, ranging from 19% women in Austria to 43% in Greece, while the UK and France each register 26%. Improving the attractiveness for women of careers in S&T may contribute to the growth targets faster.

On a different matter, special attention should be given to the first destination phase of recruiting young PhDs to research careers. The strengthening of the links between university and industry in doctorate programmes, or even in the last year of the university period, might one of the possible ways in which direct measures can contribute to improving trends. Since one of the disincentives associated with the decision of not entering a research career are related to perceived lack of employment and economic returns, early contact with industry prospects might influence positively that decision.

Figure 16 Business Enterprise researchers as a percentage of national total

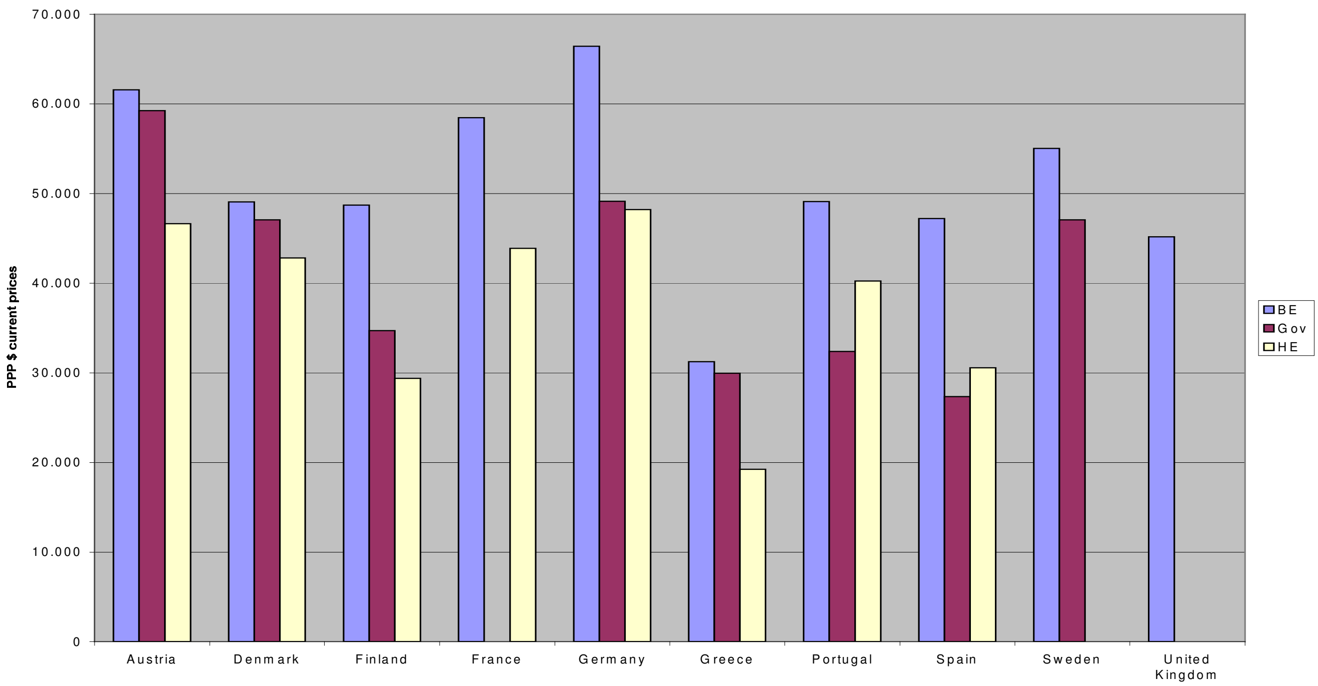


Source: OECD, Main Science and Technology Indicators, November 2001
Notes: Full Time Equivalent; Data 1999; (1) 1997; (2) 1998; (3) 2000 (estimated)

Possibly the single most important indicator of human resources as regards private investment in R&D is the proportion of researchers working in the business sector in the EU. Significant differences can be seen regarding the sectors both within Europe and in comparison with the US. Figure 16 shows how, on average, in the EU, the private sector employs only one half of the researchers, while the proportion is 82,5% in the US. However, Ireland (with the highest figure 65,1%), Austria, Germany, the UK, and Sweden are above the average. The proportions are extremely low in Portugal and Greece.

Two main economic barriers that may prevent a young person from entering a career in science and technology have been identified (Strata Etan, 2002) -the difficulty of financing high level education, including, and probably most importantly doctoral studies, and inadequate economic reward from pursuing a research career after qualification. Salaries in research professions are a major competitive factor in the European Research Area and countries that fail to reward researchers adequately are likely to lose scientific human capital. Limited data on 10-year salary trend tend to show that from a common post PhD starting point, the salary escalator for the research scientist has a much shallower incline than that for the equivalent individual leaving science for other professions (Strata Etan, 2002).

Figure 17 Labour cost of GERD per capita R&D personnel, 1999 or last year available



Source: OECD, R&D database (DSTI/EAS Division), September 2002. Own calculations.

Although comparative data on S&T occupations salaries are not available, some information can be obtained from analysing data on labour costs associated with R&D personnel and researchers. Figure 17 shows comparative labour costs (from gross expenditure in R&D) per capita R&D personnel in the business enterprise, the government and the university sectors for some countries where data is available. Without exception, R&D personnel labour costs are higher in the business enterprise sector, but there are significant disparities among countries: Germany, Austria, France and Sweden are above the average, while Portugal, Denmark, Finland, Spain and the UK are around the average, and Greece is notably below. Differences between the business enterprise and the other two sectors are significant in Finland, France, and Spain. Whether or not we can conclude from these indicators that the private sector has the potential for being more attractive in terms of retribution, depends or other factors such as the relative employment opportunities in the different sectors by country, and also relative employment stability. The asymmetric distribution of human resources we have seen in many EU countries is reflecting in some cases the fact that the public sector has been traditionally the main employer of researchers in those countries, and that tenure prospects have had an important impact on the first destination choices of PhDs.

Internationally comparable data on earnings by educational level and field of study –which would tell us which science and technology graduates are experiencing an increase in earnings growth relative to other graduates over a given period- are unavailable. Data on earnings by level of educational attainment provide a broad indication of the premium for university research qualifications[58] relative to workers with only secondary education. In

[58] We have used ISCED 5A and 6 categories. ISCED 6 is PhD or equivalent. ISCED 5A include university degrees of 3 to 5 years of cumulative FTE duration since start of tertiary.

Portugal, Ireland, Finland and the UK, the premium is significant, while in Denmark, the Netherlands and Sweden is relatively low. Most studies that deal with the labour market performance of S&T graduates concentrate on first destinations and unemployment trends, usually with little information on salaries[59]. Some recent survey research on the earnings of German Engineers and scientists (Pfeiffer, 1999) shows that working in the research and development sectors of industry is financially attractive up to the age of 45 and that earnings in a research and development division are higher than in other divisions (excluding management). In the future, collecting earnings data from graduates' surveys, could provide insight on the earnings profiles of science and technology graduates in the public and private sectors within individual countries[60].

7.3.2 Policy Instruments to Address Mobility in the Workforce

A number of policy measures exist to promote the development of firm's internal human resources capabilities. Some of these provide industrial input to doctoral training (through addressing an industrial problem, registering a researcher working in industry or providing business and management and transferable skills training for scientists and engineers), while others subsidise the recruitment of researchers by firms (especially SMEs). A third category promotes inward mobility of researchers, including expatriates.

Encouraging links between industry and academia is widely supported as an effective mechanism for addressing some of the current pressures experienced in both sectors, and mobility of researchers between the sectors is perceived as an effective mechanism for encouraging these links. As observed in Figure 17, in many EU countries, there is a clear asymmetric distribution of human resources among sectors, which are concentrated in the public sectors to a large extent. Measures to target this unbalance should pay attention not only to fostering business first destinations of new PhDs and S&T graduates, but also to the removal of existing obstacles to the mobility from the public to the private sector. The relatively low proportion of researchers employed in the business sector in EU countries relative to the USA or Japan demands more efficient links.

The barriers reported by the Member States (EU Commission, 2001) are not only related to administrative and legal issues, but also extending to the lack of understanding of the nature of the other sector. For instance, conflicts such as publication versus confidentiality, or best science versus product development have been reported as obstacles whether real or perceived. Most countries endorse simultaneous employment in both sectors but some apply time or salary restrictions. The extent to which academics must declare their commercial relations with the private sector to their academic establishments also varies from one Member State to another. Transfer of pensions and social security rights is problematic in some countries. Entitlements built up over several years in the public sector can be lost or not readily re-established after an extended period in industry. The civil service status of researchers in some countries has been reported as a disincentive for public to private sector mobility.

[59] See for example: Martinelly, D. 1999. *Labour market performance of French PhDs: a statistical survey*; and ESRC. 1998. *Survey of postgraduates funded by the Research Councils*, Economic and Social Research Council, London.
[60] Data for the US reported by Cervantes (1999) show that median salaries are higher for S&E graduates than for non-S&E graduates, and this holds true both in the business and government sectors.

In all Member States there are schemes to promote intersectoral mobility and training in industry; however, a few good practice examples as regards public to private sector mobility can be identify. In Italy, for instance, academic researchers can be seconded to industry at low costs to the industry and with financial support from the ministry to replace such researchers. The French law on innovation and research of 1999 provides some measures to facilitate mobility from academia to industry, including the possibility to create or to be associated with the creation of a spin-off company exploiting the research, without losing the status of civil servant for up to six years and taxation relief for companies employing young PhDs. Austria is moving towards a system where researchers in the public sector are no longer civil servants and therefore not part of the specific civil service pension system. Some countries have developed significant opportunities for start-ups and spin-offs. For example, in the Netherlands, a large programme has been created in the area of life sciences. In any case, efforts to increase networking between industry and academic institutions should continue.

International mobility of the highly skilled is a hotly debated topic in European Labour and education policy. The issue of expatriates is of great relevance because it is at the centre of the "brain drain" problem. This issue has been more extensively addressed in relation to academia both for graduates and PhDs, but a lot of research and data is needed to understand the dynamics taking place in broader S&T labour markets. Although some EU countries have set up initiatives to attract scientific talent back from abroad, however, these measures tend to emphasise the public sector as the return destination of applicants[61]. In order to increase the effectiveness of S&T direct measures in relation to private sector investment, these return mobility schemes could include, where appropriate, the business sector as a possible return destination. In this sense, two cases of direct measures best practice may be mentioned. The development of Germany biotechnology industry, supported in part by the government's *Bio-regio* initiative to leverage public research funding with private investment, has been credited with attracting the return of German Researchers and Scientists from the US; and the French foreign ministry sponsors meetings between French post-doctorates working in US research institutions and French companies[62].

Nonetheless, with respect to non-national S&T human resources, immigration legislation remains the first and most important legislation area where human mobility is concerned. Countries that have special legislation to allow highly skilled immigrants to take jobs in their local job markets have better chances to tackle some R&D human resources shortages in the short-term.

[61] For a short review of return programmes in various EU countries, see the JRC/IPTS-ESTO Report, *"The mobility of academic researchers. Academic Careers and recruitment in ICT and Biotechnology"*, 2001; see also OECD 2002.
[62] OCDE. 2002. *The international mobility of the highly skilled*, Policy Brief, July.

Good Practice Example: KIM Subsidieregeling Kennisdragers in het MKB - Knowledge Carriers in SMEs (Netherlands)

The goal of this initiative is enlarging the innovative capacity of SMEs. Companies can be subsidised for hiring a recently graduated "knowledge carrier". The graduate implements a previously drafted innovation plan, directed at organisational-, market-, product- and/or process innovation. Knowledge carriers are graduates at Master level. By employing knowledge carriers, innovations should take place for which otherwise funding or time would not be available. Companies with a maximum of 100 employees can apply. They must hire the knowledge carrier for at least 32 hours on a weekly basis for a period of at least one year.

The programme is a separate EZ scheme, administered by Syntens. For the overall project coordination the project bureau KIM was instituted in 1998. Applications must be sent to this bureau. The bureau provides secretarial and administrative services, including maintaining monitoring data concerning the progress of the projects.

The conditions of the programme establish that applicant should formulate an innovation plan (in co-operation with Syntens in the region of the applicant), including: a) a description of the development trajectory, b) the goal of the innovation project; c) a definition of the contribution of the knowledge bearer. At the time of submitting the proposal no agreement should yet exist between employer and knowledge bearer regarding carrying out activities (with the exception of apprenticeships or final projects). The knowledge bearer should be a recent graduate (graduation within 5 years from submitting the proposal); - applicant should not have received a subsidy based on this scheme previously; - applicant should not have already submitted a proposal for the innovation plan based on the R&D scheme, unless this proposal has been withdrawn or rejected; - the labour contract should be for at least a year and with 32 hours; - the company should have at most 100 employees; - per company at most one HEI graduate is allowed be employed previously (maximum of 2 in case of a limited, including the director).

Support is giving as a one-off wage-cost subsidy of € 9,000 maximum. The amount can be reduced if the wage-contract is terminated prematurely (within the first year). The total amount of subsidies received in the preceding three years, for which no approval has been asked from the European Commission, should not exceed € 98,000.

Budgets in previous years have been:
1997 - € 1 million
1998 - € 6 million
1999 - € 5 million
2000 - € 4 million
Co-funding from company is expected

The instrument was last evaluated in 2000. The evaluation has assessed the impact of the subsidy in terms of :

- the importance of the subsidy: for approx. 75% of the firms the non granting of the subsidy would have had an impact on the implementation/size/start/duration of the project. In 23% of the cases the projects would have proceeded anyway.
- first order effects (impact on R&D input): for 50% of the old participants and 53% of the new participants KIM has had a positive effect on the R&D intensity - an average

increase of 0,9 fte in personnel for R&D in case of old participants and 0,5 fte in the case of new participants. On the other hand, there are also companies where there has been no demonstrable or even a negative impact.

– second order effects (impact on R&D output/innovativeness): 91% of the old participants and 84% of the new participants have realised innovations; the majority of product innovations has been successfully commercialised; 57% of the companies have improved their efficiency due to process innovation.
– third order effects (impact on company performance): in 52% of old participants and 80% of 'new participants' KIM has had a positive impact on turn-over. In 45% of old participants and 68% of new participants KIM has had a positive impact on employment - an average increase of 3,6 fte in old participant, and 3,3 fte in new participants; in 20% of old participants and 23% of new participants KIM has contributed to retention of jobs - on average 2,0 fte in new participants. In 30% of 'old participants' and 42% of new participants KIM has contributed to an increase in the number of high-skilled personnel in the company - on average an increase of 1,4 fte in old participants and 1,8 fte in new participants.

On the whole, KIM appears to be an effective instrument. However, the costs of administering the measure are relatively high. In order to check or even reduce costs, cutbacks on project support by Syntens are recommended by the external evaluators. As regards the mechanisms that seem to function well in the measure, selective acquisition should be mentioned: Syntens does not try to 'sell' KIM to as many companies as possible. The organisations look for value-added (fine-tuning). Also, a close monitoring through regular contact with company and the knowledge carrier exists. However, due to its character, the implementation costs are relatively high.

Policy design factors which could improve the situation include:

- Rewarding recruitment of new personnel in grant and indirect tax schemes (Although such schemes for ***new*** hires could face the same problems of identifying what is really new as experienced in incremental schemes for R&D tax credits).

- Linkage of R&D training of industry personnel with the acquisition of formal qualifications to provide a signalling effect in the labour market, improve the ownership of individuals of their own skills, and provide a clear indicator of the return of the R&D training investment. The involvement of academic institutions in these qualifications in turn facilitates the building of long-term networks.

- Setting up S&T return mobility schemes that include the business sector as one of the possible destinations could increase the effectiveness of other measures.

7.4 Intellectual property conditions

Intellectual property conditions have increasingly been perceived as a central issue in the innovation process with the extent of IPR protection having a powerful influence upon the rate of innovative activity and the direction in which technological change occurs. A recent report by the European Commission[63] confirms the growing importance of IPR policy in shaping participation in collaborative research, a form of research of vital importance both scientifically and strategically for the European Union.

The expert group confirms the importance of a Community Patent and the need to increase the awareness and expertise amongst SMEs and research organisations of the importance of IPR strategy, including protection, collaborative research and sharing arrangements. This parallels the ECOFIN report (2002).

From the perspective of direct measures, the importance of IPR in the "pro-patent" era that has emerged since the 1980s in turn stresses the significance of policy measures which seek to enhance the capabilities of firms and scientific institutions in IP management. Figure 18 illustrates the role of patent strategies in technology strategy. To support these firms need capability in technology intelligence through analysis of patent information, and an understanding of how to manage licensing and other forms of technology transfer in the market. This is in addition to the basic skills involved in securing and defending IP. Policy measures of relevance include:

- Training in IP management;
- Provision or brokerage of awareness and advisory services on IP; and
- Ensuring that public technology programmes have clear and fair intellectual property conditions which support subsequent exploitation of their results.

An area of controversy concerns the ownership of IP by universities and other public scientific institutions (or by their staff). Again the most important aspect are competence (to ensure that IP is properly secured) and clarity (to avoid prolonged disputes or costly negotiations with industrial partners).

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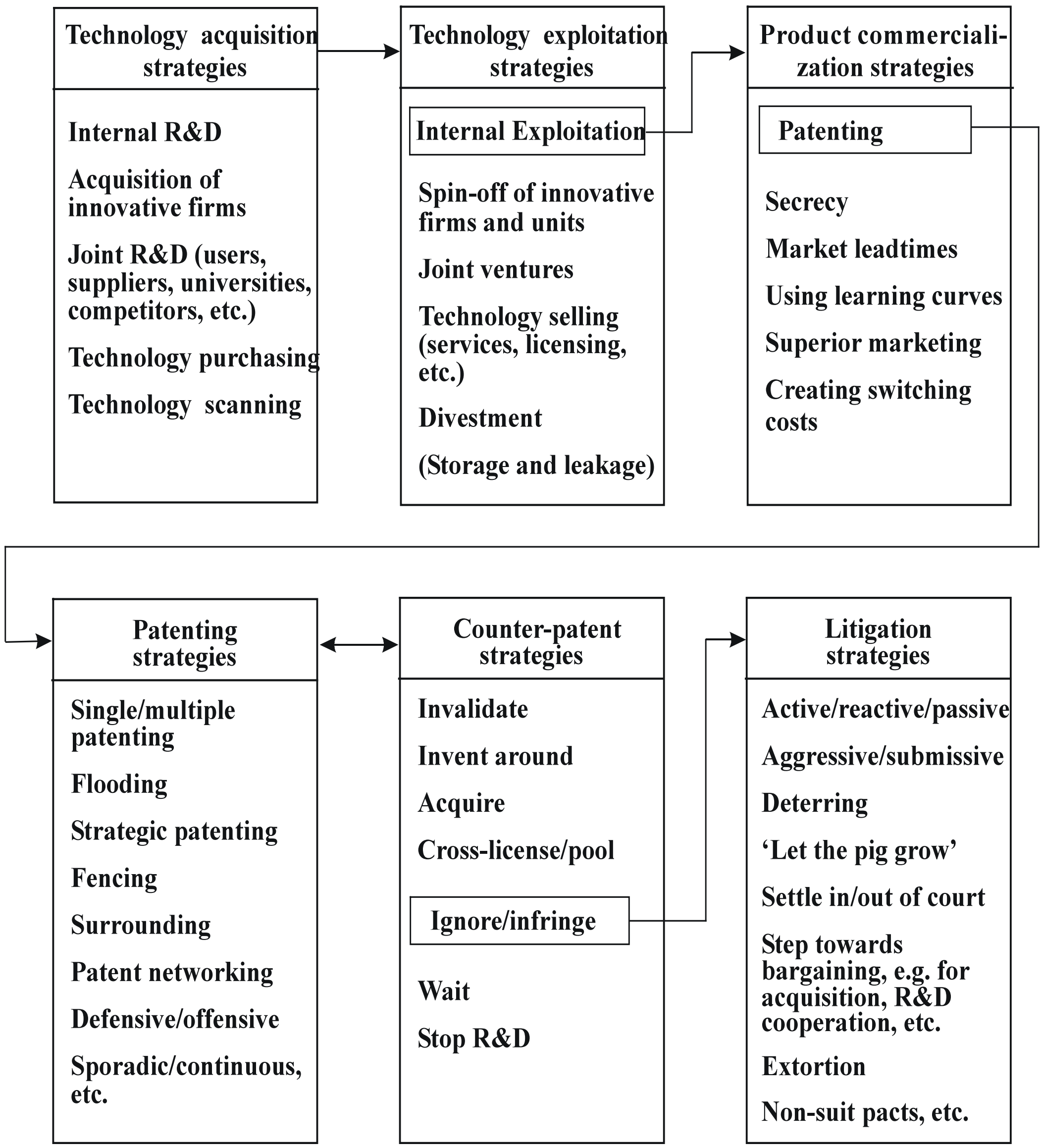
Figure 18 Summary of Technology and Patent Strategies



Source: Granstrand (1999)

7.5 State Aid and competition regulations

We recognise the importance of EU rules for State Aid for R&D to prevent distortions of competition in the internal market. However, we concur with evidence from industry that the present formulation may not be operating in the overall European interest. In particular:

- WTO rules were less onerous than those of the EU and in any event have expired. The USA does not have internal rules to control support of private R&D. Near market R&D is supported there, particularly at State Level. There are issues of a level playing field.
- The present rules are based upon the outdated linear model of innovation which presumes that innovation proceeds in a sequence from basic research through precompetitive and applied R&D to precompetitive development and prototyping, to product development and manufacturing. It is now widely recognised that innovation is an interactive process with boundaries between the stages blurred in concept and in time. **There is a strong case for accepting that the currently separate stages "industrial research" and "precompetitive development" should be replaced by a single category " industrial R&D" covering all innovation activities other than product and service development and subsequent manufacturing or service implementation**. Our understanding is that this viewpoint is becoming widely held.
- The key issue then is the level of public support which the new category should attract. In our view **"industrial R&D" should be recognised as carrying the same level of risk as the current "industrial research" and "precompetitive development " categories and hence be eligible for support up to 50% of costs depending upon circumstances.** The main argument against this would be on competition grounds, with those advocating a lower ceiling maintaining that excessive subsidy could distort competition. The rejoinder to this is that **competition in Europe is at present hampered by an insufficient rate of innovation – this underpins the whole debate on the 3% target. Rather than seeing the problem as a straightforward trade-off between research policy and competition policy, it should be recognised that the impetus of increased R&D investment stimulated through State Aids is itself an instrument of dynamic competition policy.**

The concept of (input) additionality is also a source of difficulty. We do not take issue with the expectation that State Aid should not be allowed if it has little or no effect on the firms R&D activities. However, we do not believe that an external judgement of whether the supported R&D pertains to a *core activity* of the firm is an appropriate way to enforce this criterion, for three reasons:

- The uncertainty of the current environment for innovation means that the "core" is a rapidly shifting concept and not amenable to external judgement;
- Evaluations have indicated that it is increasingly difficult to distinguish research done under the terms of a grant from research funded by other means (public or private). This "project fallacy" (see Georghiou and Roessner, 2000) does not mean that the grant has no effect, but rather that innovation involves the assembly of a complex set of elements from R&D, other knowledge sources and other competences. Quantifying the effect of a grant for work at some distance from the market is rarely possible; and

- Radical (and therefore risky) innovation can take place equally within the firm's core competences as outside them. The criterion for aid should be risk or the desire to achieve social benefit, not a counterfactual judgement about firm behaviour.

Recognising that the additionality test is one fundamental to competition policy across all areas and therefore that it is difficult to isolate R&D policy, **we recommend that the way forward is for the additionality test to be made explicit at programme level in such a way as to provide clear guidance for those selecting projects.** Thus if a work programme and rationale make it clear that the content concerns risky and potentially breakthrough technologies, then it becomes a simple matter to judge that the support is justified irrespective of the (inappropriate) model of the firms strategy being applied.

We also note the recent under use of the derogation foreseen in Article 87 of the Treaty whereby "important projects of common European interest" are to a large extent exempted from the restrictions of EU State Aids rules.

We welcome the improved situation for SMEs but call attention to the specific needs for support held by young companies.

The general point here is that creation of dynamic competition may require a departure from some regulations aimed at static efficiency.

8 Policy mix, governance and delivery

Our principal interest in the "policy mix" within our remit is to stress the interactions which take place between direct measures. Support for R&D programmes is strongly amplified if it is coordinated with actions on framework conditions, including human resources, intellectual property, regulations etc. Support is also more effective if it can be continued and adapted to different parts of the innovation process, to avoid the creation of bottlenecks at the pre-prototype stage.

We have also been asked to comment on the applicability of direct measures in comparison with fiscal incentives. If innovation policy can be seen to act on the resources, incentives, capabilities and opportunities available to firms, fiscal measures are restricted only to provision of resources. Grants and loans can also be used simply to provide resources but in the present era this motivation is generally confined to schemes for SMEs only. Direct measures of various types can be targeted at encouraging firms to alter their risk profiles, enter new technological areas, acquire new capabilities or form new networks nationally or internationally. These networks also encompass public-private partnerships addressing public or semi-public goods and technological systems in which government plays a part as user or regulator.

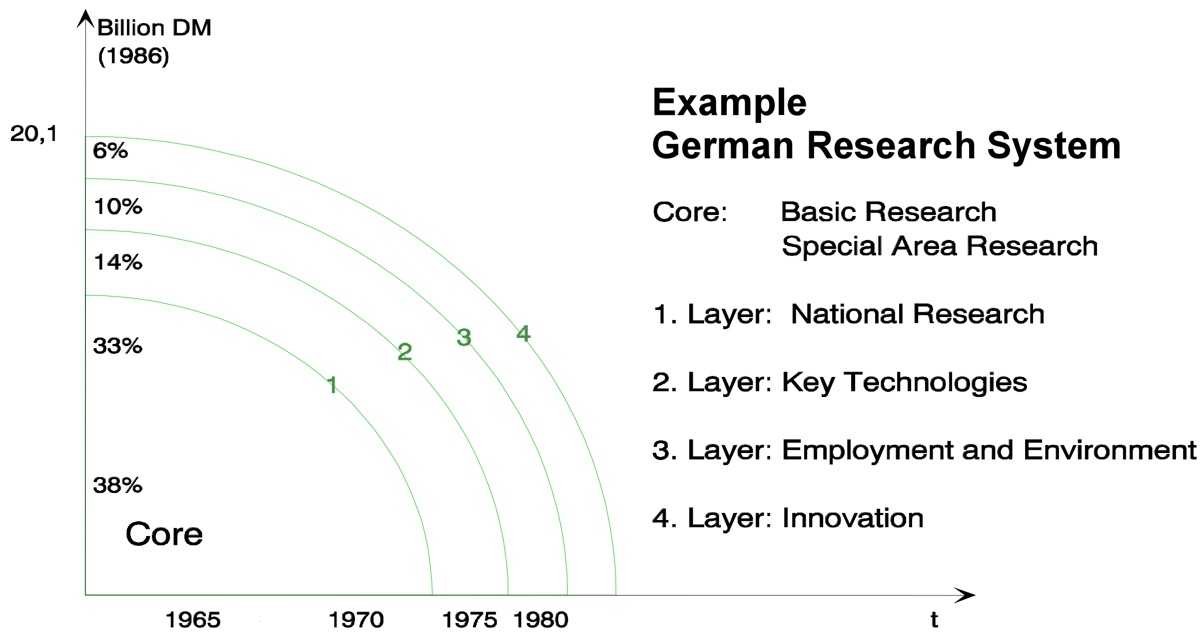
8.1 Government roles and links to agents

Addressing the role of government more generally we note that governments have multiple roles as legislators, rule-setters, facilitators, financiers, matchmakers, single-issue agents and policy entrepreneurs. The lines are increasingly blurred between public and private actors. There is no Olympian position for government as an all-seeing coordinator. The policies which we are concerned with emerge from multiple levels and agencies within government and are formulated in the context of multiple levels of governance ranging from broad legal and cultural frameworks, through specific policies and legislation, but then are implemented through relationships with operating agents and the relations of those agents with their customers.

Increasingly, multi-level governance also reflects the layers if government, with measures originating from local, regional, national and supranational levels and interacting with one another intentionally or otherwise.

8.2 Historical Accumulation of Commitments

Figure 19 Shell Model to Show Cumulative Policies and Institutions



The actual mix of policies and agents is often the product of a historical legacy (sometimes called the "shell model[64]") in which new instruments and paradigms coexist with their predecessors from earlier decades. The importance of finding a balanced policy mix needs to be emphasised in relation to e.g. building competencies (lifting low capability actors to higher capability levels vs. building global level excellence), facilitating change (competition vs. innovation), overall policy orientation (innovations as a source of economic growth vs. innovations as a means to solve social and/or environmental problems; the role of technological vs. non-technological innovations) or geographical context (international vs. national vs. regional vs. local). All of these co-exist. The issue is to identify a balanced mix of policies and instruments for a particular context.

Awareness of innovation and its benefits remain a challenge, especially in cohesion and accession, as well as in more developed countries. In particular SMEs in traditional industries and services suffer from lack of awareness. A mix of direct measures (incentives + framework conditions + networking + other) are the most efficient way to tackle the awareness problem.

The challenges raised by this complex policy setting require that governments and the European Commission achieve a high degree of internal and external coordination in the formulation and implementation of innovation policy. As noted in the discussion on technology platforms, such coordination should extend horizontally across government, well beyond the departments traditionally responsible for science and technology, and probably should have its locus at the centre of government.

[64] The concept was originally named by Gerhard Braunling.

9 Learning from Experience

9.1 Status of evaluation of direct measures

Direct measures, and in particular grant funding schemes, have probably been subjected to more evaluations than any other type of policy instrument in this sphere. However, many such evaluations have been limited in scope and methodology, placing excessive emphasis on the satisfaction of participants in programmes. This indicator, and the more limited range of independent case study based investigations have generally shown positive returns for programmes as a whole but with a skewed pattern typical of R&D (typically around 10% of projects account for 80% of direct commercial benefits while 50% show little or no return on this indicator, even though they produce broader knowledge benefits).

There is a need to increase policy makers' capabilities to analyse the innovation system and identify its failures, set up horizontally and vertically integrated/co-coordinated policies (in a consultation with a wide range of stakeholders) and set up effective and efficient implementation measures. All this must be achieved in an environment that is continuously changing, thus making it virtually impossible to evaluate the impact of any single policy or policy instrument. This means that policy makers should continuously have at their disposal a strong up-to-date knowledge of the innovation environment and its changes.

The role of cultural and historical context specific factors should always be acknowledged when attempting to either transfer good practice or attempting to benchmark innovation environments.

9.2 Lessons from Practice

On the basis of a series of case studies we have abstracted the following lists of elements of good and bad practice. It must be stressed that the design of measures is highly sensitive to the context in which they are to be applied and hence that different combinations of these elements are appropriate in different circumstances. Positive and negative features may also be linked – for example a highly targeted programme offering help and advice to companies may as a result incur higher administrative costs.

Elements of good practice

- Larger programmes offer the opportunity to be more comprehensive in their coverage and have greater visibility to industry.
- Cooperative R&D, both between firms and between firms and scientific bodies creates a critical mass of effort.
- Programmes which widen the research community by attracting traditional firms and lengthen their R&D horizons usually involve advisory and support services as well as finance.

- Widening the set of stakeholders, for example by involving sectoral ministries, increases the scope for application of R&D to solve social problems. Regulatory measures emanating from these ministries may be used to stimulate uptake.

- Ideally policies or programmes should modify behaviour permanently for the actors concerned such that there is no need for continuing support after initial incentives to change.

- Programmes which include personnel mobility between academia and industry strengthen the likelihood of knowledge transfer.

- Existence of a strategic mid term plan as a structural framework for direct measures and their co-ordination.

- A leverage or multiplier effect of direct measures – especially as regards cluster policies - can be obtained through well tailored and demanding contests (between regions, networks etc.), that lead to positive structural adaptations and even cognitive changes far beyond those clusters that are finally supported.

- A clear rationale is necessary to ensure that the programme is addressing a priority need. Foresight may help to clarify such needs.

Elements of bad practice

- Excessive administrative overheads for applicants and participants resulting from low success ratios in obtaining funding, complex application procedures and delays resulting from over-zealous application of financial viability criteria to SMEs. The latter could be mitigated by recognising that accountability has its limits and hence by adopting a risk portfolio approach similar to that of a venture capitalist. This would recognise that a certain proportion of financial failures is acceptable and costs less than the net effect of checking in detail all applicants.

- A large number of small grants or low funding levels per project increase the relative overhead costs of participation and reduce the attractiveness of a programme to firms.

- A programme with too widely defined scientific/technological areas may help to address all areas of interest (at national and beyond levels) but it also hinders the development of strengths and a critical mass of human resources and qualifications at sectoral level; 'ability to do everything' hinders specialisation and excellence in specific areas and limits research and innovation efforts only at the 'surface' especially if the funding approach is to fund as many projects as possible (with consequently smaller grants).

- Procurement of R&D tends to focus almost exclusively on large firms if there is no quota set for SME involvement (either directly or through sub-contracting).

10 Conclusions

Direct measures encompass the great majority of the instruments used in science, technology and innovation policy. As an overall message it is important to stress that their cumulative effect is already one which raises the quantity and quality of R&D in Europe and has the potential to do more towards bringing Europe to a position of at least shared world leadership in business R&D. Public support for private R&D provides firms with incentives, capabilities and technological opportunities as well as resources and offers the opportunity keep the innovation system more adaptable and connected than it would be without intervention. The 3% R&D target has symbolic value in mobilising change. However, implementation requires a recognition that R&D is an input not an output and that at the level of the firm it is the output indicators of success in innovation and increased share of existing and new markets which must be pursued. The real challenge is to create the conditions where firms recognise that R&D investment in Europe will provide them with high returns and sustained profitability.

To achieve these conditions, we argue that demand-side policies are needed to foster the lead markets for innovation that could drive the step-change needed. Supply-side policies can act as a positive supporting force while favourable framework conditions and policy coordination are critical conditions. Specific recommendations are to be found throughout the report but we summarise the most important here. Taking each area in turn:

Supply-side

- Among more traditional direct measures such as grants and reimbursable loans we note a strong trend towards good practice policies founded in the behavioural additionality rationale and in particular towards using grants to provide incentives for developing new networks and collaborative linkages. This includes setting measures in the context of a broader strategy such as the development of a cluster. These approaches create cumulative technological assets which in the longer run enable firms to increase their returns on R&D and in turn their investment in it.
- Grants are often valuable measures in themselves but we have heard concerns about the confusing array of measures available in many national situations. On the other hand there is also a risk in creating large and inflexible instruments which do not adapt to individual circumstances or to changing technological priorities over time. The right mix would appear to be a small portfolio of flexible measures with adaptive rules. There is also a need for policy coordination to ensure that addressing one deficit in the system does not create a bottleneck elsewhere.
- One aspect of flexibility is currently constrained by the present structuring of State Aids around the outdated linear model of innovation. We support a change in the rules to make awards up to the current maximum level of support available for any part of the R&D process where there is a clear rationale for support from public funds. The present interpretation of the additionality criterion is also based upon an incorrect model of strategic decision-making in the firm and a narrow concept of "input additionality". In particular regulators should not attempt to distinguish between "core" and "peripheral" R&D in a company. This fails to recognise the real nature of risk and uncertainty in R&D.
- In terms of their contribution to the 3% target, grants and other subsidies are clearly constrained in their potential to grow. During the recent growth in industrial R&D

they failed to keep pace and now as business slows its growth, fiscal difficulties for many governments are impacting upon the funding available for R&D. The core message to policymakers on this point is that grants are at their most valuable during a recession. They enable firms to rebuild their technology bases when their own revenues are stretched and they also maintain research capacity which could be easily destroyed but far less easily recreated.

- The strengths and limitations of R&D support policies should be clearly recognised in certain circumstances, including encouragement of inward investment and achieving industrial development in cohesion and accession countries. The evidence is that they are a marginal factor in the relocation of international R&D investment while in less developed regions at least equal priority should be given to the transfer of existing technologies. For cohesion and accession countries measures to promote an innovative culture are a priority. However, R&D provides a key to the absorption of technologies and must also be supported.
- SMEs often do not have the capability to perform R&D directly, or at least alone. The contract research sector has a vital role in providing such capabilities. For government policy in this area the main challenges are to ensure that contract research organisations maintain their scientific and technological capabilities through strategic research programmes and that they act as a focus for networking between companies and universities.
- The total amount of R&D being performed in Europe is constrained by the definitions in the Frascati Manual. The importance of the service sector and the growth of non-technological innovation (often in a complementary relation to technology) make a case for reconsideration of what we define as the creation of new knowledge by industry. Even if this did not improve Europe's ranking with respect to the USA and Japan, recognition of these activities as R&D would be a first step to understanding the conditions and policies which could stimulate its growth.

Demand-side

- In pursuit of these higher returns we believe that the main area of neglect in recent years has been in demand-side policies. These have different forms including strategic use of public procurement, changing the conditions for private procurement of R&D, and the development of technology platforms (sometimes called public-private partnerships) in which direct measures such as grant support are combined with measures such as the use of supply chains and clustering, the development of standards and regulations and customer involvement in order to accelerate the emergence of new markets for technology-intensive goods and their take-up. Loss of actual and potential R&D investment from Europe has been as much driven by the attractiveness of markets elsewhere as by any factors intrinsic to the performance of research.
- Public technology procurement is probably the policy instrument with the largest potential to contribute to the 3% target. With a spend of at least €720 billion per year, only a small increase in the proportion devoted to R&D would provide the mutual benefit of more innovative public goods and increased incentives for firms to be funded for and invest their own resources in R&D. The boost to innovation derived from defence spending in the USA could be matched by innovation-oriented procurement in sectors such as health and public security.

- Specific measures which could be taken to promote PTP include:
    - Requiring governments to produce a regular plan and statement on the degree of innovation and technology development involved in their procurement practices;
    - A recognition that public services are also risk takers and hence an understanding that there is a trade-off involved which will involve some failures in procurement decisions en route to greater public service productivity;
    - Investigation of the possibility of declaring a target for the R&D/innovation component in public procurement;
    - Investigation of possible changes in competition regulations.
- The experience of the defence sector shows both the advantages and the risks involved in use of PTP in innovation policy. The large boost to the innovative capability of US industry from defence procurement is clear. While there are gains to be had from better coordination of defence procurement in Europe in terms of larger lead markets, efficiency gains for government could conceivably reduce industrial R&D. The defence experience clearly demonstrates the need for “smart procurement” practices involving close coordination between purchaser and innovative supplier.
- The exclusion of SMEs from a large proportion of procurement is one reason for their low R&D intensity on Europe. Within the report we recommend a series of actions to remedy this, including the establishment of a analogues to the US SBIR either at national or at European level.
- Measures to increase the innovative content of private procurement by improving purchasing information and reducing risk also offer important opportunities towards creation of lead markets.
- Technology platforms create gearing effects by combining financial support with regulatory and other policies. They can also create the scale of activity needed to address critical problem areas.
- Promotion of clusters offers a further means to maximise the effectiveness of policy combinations. Guided by foresight and other strategic approaches they can frame the formation of integrated policies.

Framework conditions

- Framework conditions determine the attractiveness of R&D investment in Europe and can only be temporarily offset by financial measures alone. It is necessary to recognise that some framework conditions result from broader economic and social policies (for example labour, personal taxation and social insurance laws). However, some fall clearly within the ambit of science and innovation policy. Of these the most important is the availability of highly skilled researchers.
- Specific good practice schemes have shown that as well as emphasising the critical role of support for basic science and engineering in universities to produce the additional qualified people who would need to be employed if the target is to be met, there is a role for direct measures in rewarding the recruitment of new personnel and in promoting training of industrial personnel against a background of formal academic qualification.
- A further need is the removal of existing obstacles to mobility from the public to the private sector. These cover administrative and legal issues but also the cultural gap that exists. Measures to promote inter-sectoral mobility include financial support for

secondments and relaxation or removal of restrictions arising from the civil service status of researchers.

- Continuing support for the science base is an essential precondition for a healthy industrial R&D culture. The need for excellence as a driver for competitiveness is clear. Science creates opportunities for innovation through production of new knowledge and is the most important source of trained people. It also provides firms with a window on the world of research. However, recent analyses have illustrated that despite its many strengths, the science base in Europe lacks the strong concentrations of excellence which can be found in the USA. Loss of economies of scale in equipment and of the critical mass needed for interdisciplinarity are accompanied by a fragmented interface with industry at a time when major firms are seeking to consolidate and focus their academic links into a smaller number of deeper and long-term relationships. The implication is that radical restructuring is needed in some fields towards policies based upon concentration of resources and creation of well-networked "centres of excellence".
- The relationship between an excellent science base and industrial innovation is far from automatic. Continuing emphasis upon the whole range of direct measures that exist to promote industry-science relations is needed, along with complementary measures to train students in entrepreneurial skills and to induce a similarly entrepreneurial culture among researchers in academic and other public laboratories. Training in the management and the exploitation of technology are further priorities for direct measures.

Coordination

- Progress towards the Barcelona target requires a substantial new orientation of innovation policy in Europe towards a demand-side focus on the creation of lead markets friendly to new products, processes and services. This report has emphasised the need for coordinated policies to achieve this. At all levels of governance, the need for such coordination goes well beyond those traditionally responsible for science and technology policy. The way to achieve this depends upon the particular circumstances but in general we expect that innovation policy should have its locus at the centre of government.

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SUMMARY

The European Council in Barcelona set an overall EU R&D investment target of 3% of GDP by the year 2010, with industry asked to contribute two thirds of this figure. To approach these levels, however, dramatic improvements are needed in the effectiveness of policies used to stimulate private sector R&D. The specific aim of this report is to offer suggestions and guidance concerning the design and implementation of direct public support measures to stimulate private investment in research. The report considers the importance of supply side measures, the growing importance and significance of demand-side measures and the role of framework conditions. After reviewing the use of these measures and the factors that affect their effectiveness, the report then presents a series of recommendations for the consideration of policymakers across the EU.