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TARGETED REVIEW OF ADDED VALUE PROVIDED BY INTERNATIONAL R&D PROGRAMMES

OFFICE OF SCIENCE AND TECHNOLOGY

MAY 2004

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Targeted Review of Added Value Provided by International R&D Programmes

An independent report for the Office of Science and Technology by

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MAY 2004

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Foreword

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Europe has set itself the ambition of becoming the most dynamic, knowledge driven economy in the world by 2010, accompanied by improved quality of life, social cohesion and employment. Achieving leadership in research and technology, together with the necessary innovation performance are vital to achieving this ambition.

Whilst much of the responsibility for improving research and technology performance lies with Member States, the European Framework Programme also plays a central role. It supports leading-edge science and technology and strengthens partnerships with teams across Europe and beyond. The current Sixth Programme is worth €19bn over four years.

Consultations are now beginning on the content and priorities for the next, seventh, Programme. As part of its contribution to the debate, the UK Government has commissioned this independent review of the available evidence.

The report seeks to assess previous evaluations of the Framework Programme. It also takes account of experience with major S&T programmes in other countries that can offer valuable lessons for Europe. In addition to an Executive Summary, the report summarises evidence relating to some key policy questions in a Conclusions section.

The Government will consider this evidence as part of its development of policy on the new Programme and is publishing it as a contribution to the consultation process. A new evaluation of UK experience with the Programme is underway and the findings will be published shortly. Key references to UK and EU documents can be accessed as they become available on www.ost.gov.uk/ostinternational/fp7.

Contents

This report is also available online at http://www.ost.gov.uk/ostinternational/fp7

1 Executive summary

1. This targeted review assesses the 'state of the art' in the understanding of the impacts of the CEC RTD Framework Programmes and their strengths and weaknesses in comparison with national programmes and other international research programmes, particularly from a UK perspective.

2. The general economic literature favours 'technical change' as a primary cause of productivity growth and hence research and development as being an important factor in securing higher living standards in the long term. However care has to be exercised in interpreting this general view in the context of specific R&D programmes.

3. The payoff to higher spending on R&D, and especially basic research, is subject to 'long and variable lags'. As such, in the medium term, the link between R&D and productivity is difficult to demonstrate. Indeed, there were few instances where evaluations had managed to quantify programme impact at all and none that had sought to aggregate such effects to the level of the wider economy.

4. Since the inception of the Framework Programme in 1984, each subsequent FP has increased in scale and scope, with funding rising to Euro 17.5 billion for the current multi-annual programme, the 6th CEC RTD Framework Programme (FP6). This expansion has been accompanied by a broadening of objectives, adding social and environmental factors to an earlier concern with issues of economic competitiveness.

5. This evolution in scale and scope has been accompanied by improving arrangements for monitoring and evaluating programme expenditure. However, the increasingly structured and methodical system of Commission-coordinated reviews and evaluations, comprising annual monitoring and five-yearly assessments of specific programmes, and five-yearly assessments of the overall FPs, has yet to get to grips with programme outputs and impacts.

6. Evaluations involve a trade-off in terms of the timing of the review and the timing of the realisation of wider impacts. Generally, elapsed time is fairly short, so that the typical focus of programme evaluations is a concern to capture information on short term, local benefits such as the degree to which technical or commercial objectives are met, extent of collaboration, publications, researcher training, overall perceptions of satisfaction. Equally, primary data tend to be gathered using participant surveys with few studies investigating effects in the wider research and business communities.

7. Notwithstanding the challenge of evaluating long-term effects, this analysis suggests there is an opportunity for the Commission to strengthen its monitoring and evaluation procedures without adding unduly to the burden on participants. Implementation of new information systems, including online proposal preparation and submission, promises simpler cross-programme reporting and the possibility of this material being published in a more timely fashion to aid insight and learning.

8. A fuller understanding of the impact of EUREKA is emerging from the Continuous and Systematic Evaluation, which may provide a model for FP project evaluation, capturing data on a range of metrics, from papers to patents to events to network formation. This kind of factual material would improve greatly the utility of the Commission's current procedures for independent monitoring and evaluation. There would remain a need however for a more strategic evaluation function, with the tools and resources to examine the effects of Framework on more fundamental issues such as European added value, impacts on science and industry and the interplay of European funding with support offered by Member States.

9. Presently, in attempting to assess long-term effects, there would appear to be no option other than to invoke general econometric estimates of the effects of public research expenditure on the macroeconomy. A recent OECD paper outlined an econometric calculus for estimating the effect of Framework on total factor productivity (TFP), using data on private sector R&D, public R&D and foreign business R&D. Application of the formula generates an estimated annual contribution to UK industrial output of over £3 billion, a manifold return on UK Framework activity in economic terms. While this estimate needs to be treated with considerable caution, it does suggest that the costs of Framework will be repaid many times.

10. The literature makes clear that the value of R&D is not confined to (eventual) commercial outputs. 'Indirect' payoffs such as expanding the supply of trained graduates may be as, or even more, important to business and society. Framework Programme evaluations permit us to understand the range of types of benefits, as well as participant satisfaction. However, they say nothing directly regarding the extent of the Programme's impact on UK (or European) competitiveness. The benefits identified are essentially intermediate outputs (knowledge, skills, tools, relationships, et cetera). Of the many Framework sub-objectives, the evaluations reveal that 'stimulation of collaboration' is being achieved consistently.

11. There are no programmes that directly 'compete' with the Framework Programme in providing public funding for (pre-competitive) collaborative research, conducted at the European level, with the ambition of facilitating social, economic and scientific programmes. There are other international schemes, however, which provide public-sector support to European research. For example, EUREKA funds (near market) research and is similar in scale similar to Framework. Equally, COST (European Cooperation in the field of Scientific and Technical Research) stimulates research cooperation across Europe through support for networking and information exchange, as does Framework. However, while these schemes exhibit some similarities there are important differences too and as such Framework may be said to be a worthwhile addition to the suite of support measures available to European Member States.

12. The US Advanced Technology Program (ATP) adopts a more focused approach and in so doing poses several challenges to Framework. ATP evaluations are at least as positive regarding the impact on business and commerce as are any that have been undertaken for Framework and yet the programme follows a very different approach. ATP achieves critical mass through a highly selective strategy – with funding per project on a similar scale to the FP, but with a much smaller overall programme budget – closer to that of the EPSRC. ATP is pursued at the Federal level while individual States provide more universal assistance. Moreover, in contrast to Framework, collaboration is not an essential requirement – 70% of awards are single-company projects – and where networks are supported they tend to reflect competence and do not have a geographical dimension.

13. The literature deals poorly with the question of 'critical mass,' providing no ready-reckoner to check whether more or better capacity is necessary. However, empirical studies suggest that certain fields of scientific endeavour – space astronomy or gene sequencing for example – are more demanding than are others – social anthropology or history of art for example – in terms of both capital investment and research capacity. The need to seek partnerships beyond national boundaries depends on size too. For smaller European states, recent evidence suggests that international collaboration is vital to maintaining world class capabilities in many areas of S&T.

14. There are few research areas where the UK may be said to lack critical mass, with successful research being possible at the national level in most fields. There are areas where other country's scientists have higher levels of competence (e.g. Germany and the nanosciences) and in these fields UK scientists and engineers may look to international partnerships as a means by which to enhance national capability. Where international collaboration is pursued, it is just as likely to be global as European. Such logic suggests that the Framework Programme offers limited 'value added' to UK researchers in terms of facilitating access to complementary and world-class expertise, compared with national funding, and must be justified in other terms.

15. While UK participants in the Framework Programme value the insight and opportunities deriving from their international partnerships, for most, it is the *availability of public funds*, additional to those available nationally, which is critical to their interest in the Framework Programme.

16. There are areas of S&T activity that seem to be more appropriately addressed at the international or European level (big science, issues of common concern such as environmental protection, cohesion in research capability). On the other hand, there are sectors where national industries remain strictly 'un-Europeanised' and where high-quality Framework proposals have been thin on the ground.

17. In terms of administrative efficiency, while detailed improvements are possible, and the Commission has responded to the Court of Auditors criticisms of its management of FP5 with a long list of detail improvements introduced in FP6, there is no obvious alternative model which holds out the promise of a marked improvement in performance. In an international programme of this kind, there remains a trade-off between the use of lengthy, detailed procedures on the one hand, and faster and less expensive, but less rigorous and focused, procedures on the other.

18. On balance, there is value in retaining *both* national *and* international programmes as instruments of UK S&T policy. The latter offer the scale and scope essential in some technological areas, while the former permit greater exploitation of the UK's National System of Innovation. However, the interplay between national and European support is not very clear, and is nowhere explained in writing.

2 Introduction

This report presents the findings of a literature review to assess the 'state of the art' in the understanding of the impacts of FPs, and their strengths and weaknesses in comparison with national programmes and other European programmes. More specifically, the objective was to inform a set of Key Policy Questions posed by the Office of Science and Technology (OST).

Section 3 outlines the broad approach to the literature review, including its scope in terms of the programmes to be discussed. These programmes are subsequently described in terms of their attributes, and their outputs and added value (as identified in any evaluations and commentaries) – the Framework Programmes are covered in Section 5 while selected other European and national programmes are discussed in Section 6. Section 7 addresses questions of how evaluations are carried out and their limitations, Section 8 discusses issues relating to collaboration and networks, and Section 9 reviews the key concepts of additionality and European Added Value. Section 10 considers the role of Government policy, and lastly, Section 11 presents conclusions from the literature review structured against the Office of Science and Technology's Key Policy Questions.

3 The Literature Review

3.1 The study design

This is a report of a desk study to identify and analyse relevant English-language literature from across the world to assess the 'state of the art' in the understanding of the impacts of international collaborative research programmes and their added value over and above that achieved through national programmes. As such, an important aspect of the methodology has been to find ways of 'cutting through' the vast amount of material of potential relevance to the review in order to analyse only that sub-set of documents of especial utility. While addressing the key policy questions raised by OST, the review kept as a central focus the issues of *scale* and *scope* – in the context of international research collaboration – and, in particular, what does European funding yield that national funding does not? Moreover, how, and under what circumstances, might the two be interrelated? These questions go to the heart of the matter, and were borne in mind when considering:

- What social and economic benefits international research programmes deliver
- Their effects on economic growth
- Differences in value added across research fields
- Management of international research programmes

Ex-post evaluations typically involve a trade-off in terms of the timing of the review and the timing of the realisation of wider impacts. If undertaken too soon after the programme is complete, insufficient time will have elapsed for the full range of impacts to be realised, whereas delay reduces policy relevance and the likely quality of inputs from participants. Generally, elapsed time is fairly short, so that the output/impact issues that typically constitute the main body of programme evaluations – such as the degree to which technical or commercial objectives are met, extent of collaboration, publications, researcher training, overall perceptions of satisfaction, et cetera – are short-term. However, these sorts of benefits only constitute a means to an end, and the review has sought to identify a methodology by which one can draw conclusions regarding longer-term issues.

In the light of the above, the review methodology involved:

- Identification of reference programmes, both national and international
- Literature searches of material relating to those R&D programmes, material covering broader and generally longer-term issues concerning R&D impact, and methodological studies
- Construction of analytical frameworks to capture the short, medium and long-term effects of programme outputs, interactions between programmes, and other features of the Key Policy Questions

The literature search was carried out using several different starting points and a wide range of sources in both published and grey literature:

- Expert knowledge from within the study team and other gatekeepers to compile a short bibliography of recent, relevant texts, which was a vital means by which to break into the 'grey' literature
- Bibliographies of recent key references as sources for further searches
- Free searches on the Internet, as well as searches on sites of governmental,

academic and consulting organisations with an active interest in the field

- On-line searches of particular refereed journals, such as Research Policy
- Library archive searches

3.2 Scope of the study

The following programmes were included within the study:

- Framework Programmes 4-6, covering all relevant material – programme structures, evaluations of the Programmes, general methodological analyses
- Other EU Programmes, particularly EUREKA and COST, where important lessons may have been learned from programmes with a rather different focus than the Framework Programmes
- National UK Programmes, primarily LINK and Faraday Partnerships. The primary interest here is twofold: comparisons of costs and benefits of UK participation in these domestic programmes compared with participation in European programmes, and consideration of synergies and relationships between domestic and international programmes
- Major US national programmes, and in particular the Advanced Technology Program. The interest here was to make comparisons with another country operating at a national level, but as a nation whose size is on a par with the EU. Does US experience provide any evidence, for example, on whether any observed advantages/disadvantages to the UK in operating at the EU level are due to the larger scale/scope or to international operation *per se*?
- Major national collaborative research programmes in use in several other large countries, including Japan, France and Germany

3.3 Taxonomy of the literature

While there was a wish to segment the literature in order to facilitate analysis, the study revealed a tendency for published and grey literature to offer insight, albeit partial, on several of the OST Key Policy Questions rather than a single topic. As such, the study did not create watertight segments into which to categorise the literature. Nevertheless, to assist manageability, and to indicate the range of topics being covered, the team used the following taxonomy to organise its archive of documents and associated database:

- *Programmes and their evaluations*:
  - Evaluations of EU Framework Programmes from a national perspective
  - Evaluations of EU Framework Programmes from an EU perspective
  - Evaluations of other EU programmes
  - Evaluations of UK National Programmes
  - US National Programmes
  - National/International programme linkages
- *Methodological studies*:
  - Impact assessment in the context of national R&D programmes
  - Impact assessment in the context of international R&D programmes
  - Evaluation protocols from e.g. DTI or CEC Evaluation Unit

- *Issue-based studies*, concerning primarily:
  - Government-sponsored industry/university links
  - Role of publicly-financed R&D – social returns, spillovers
  - Effects of R&D on economic growth
  - Additionality
  - Collaborative research
  - Training, mobility of researchers
  - Programme management

Literature was collected on each of these topics, and included both mainstream peer-reviewed published material and 'grey' literature. As a result, the study team identified a large number of references to relevant documents. Appendix A lists that bibliography of the sub-set of documents that have been quoted directly.

3.4 Methodological issues

3.4.1 Impacts of international collaborative research programmes

Two key methodological issues arise out of the review of the literature, the first relates to the challenges of identifying, measuring and attributing the flow of benefits to specific policies and programmes. The second relates to the question of 'additionality,' that is the extent to which a given programme will cause socially and economically worthwhile things to happen sooner or more forcefully than would have been the case without government intervention.

In the report, programme impacts are categorised as follows:

- *First-order impacts*: These impacts are realised during, or immediately after, programme activity
- *Second-order impacts*: These impacts tend to be concentrated on programme participants and other associated stakeholders and tend to occur during the course of a programme and continue to accrue in the 2-3 years following the conclusion of the programme
- *Third-order impacts*: These impacts are realised at points outside the programme participants, in the wider economy for example, and are generally longer-term effects that may take several decades to fully emerge

Collaborative research programmes tend to be justified in terms of their third-order impacts, rather than the easier to identify and measure first and second order impacts. Traditionally, third-order impacts have been assessed via econometric rates-of-return studies. However, the bulk of the still rather limited effort to calculate the economic and social rates of return to R&D programmes is based on American data and research, and is most concentrated in areas such as agriculture.

Given the different context, the conclusions from this body of work may not be the best indicator of the extent of the benefits deriving from the fields of endeavour covered by the EU's Framework Programmes. Moreover, the methodology for computing rates of return, which is referred to later in this report, has come to be regarded with increasing scepticism and, to some extent, to have gone out of fashion. A comprehensive review is given in SPRU (1996), and updated in SPRU (2001).

As part of this critique, the SPRU reviews underline the importance of a range of other forms of return to investments in government R&D programmes, including:

- increasing the supply of skilled graduates
- creation of new instrumentation and methods
- development of new networks
- enhancement of technological problem-solving capacity
- generation of new firms
- provision of social knowledge

With the exception of the category of new-firm creation – a focus of recent government attention in the UK and elsewhere, but regarded as relatively inconsequential by the SPRU teams – only limited 'hard' data exist on these potential impacts. It was nevertheless the strong feeling of the SPRU studies *that several of these should be regarded as being as important as the direct economic benefits*.

Without going at length into the evidence, it is worth considering the main line of argument that led to this conclusion. It is drawn from extensive findings and analyses that propose that the accumulation of technological capabilities is basically a learning process, and that the knowledge thus accumulated is embedded in people. Some of that knowledge can be codified and expressed as 'information', although much of it is 'tacit' and may be difficult to codify.

It follows firstly that the exposure of high-quality researchers to means of accumulating useful knowledge is the basic ingredient for success in technology strategy. This may come through such means as formal training, e.g. on doctoral programmes, or through experience in 'puzzle-solving' empirical research, or through contact with national and especially international networks of other researchers and technology developers. 'Learning' in technological accumulation comes through both formal and informal channels, and from sources both internal (e.g. intra-organisational) and external (e.g. collaborative networks).

It follows secondly that 'information', even when widely circulated, still has to become embedded in the behaviour of individuals and the organisations they belong to. 'Learning' involves both 'learning by doing' and 'learning by using'. A peculiarity of knowledge is that higher and higher levels of knowledge are required in order to get maximum benefit from new information. The more knowledge one already possesses of a particular field, the more readily one may be expected to derive insight – and learn – from a new publication in the field (the next increment, so to speak). An implication is that new information is of little value to those in receipt of it unless they have the necessary literacy or 'absorptive capacity' (Cohen and Levinthal, 1989, 1990), i.e. the ability to internalise the information and understand it sufficiently to use it for their own purposes.

The concept of 'absorptive capacity' is critical in assessing the impact of international R&D programmes for national advancement. Involvement in international programmes obviously widens the exposure to progress over a larger front. While this may benefit individual researchers it may be of only limited benefit to their countries unless the countries have the requisite 'absorptive capacity' to make use of the internationally generated information. In other words, national and international programmes, seen from this vantage-point, are complements rather than substitutes. This needs to be borne in mind when trying to decide upon the allocation of resources between national and international programmes.

3.4.2 Added value of international research collaboration programmes

One of the most important considerations in this report is whether, and to what extent, international programmes 'add value' which cannot be obtained through national programmes. The most obvious addition is the ability to tackle problems on the basis of drawing together a much larger pool of resources, both financial and human. Some research problems may involve such costly equipment as to be economically feasible only with international cooperation, as in branches of nuclear physics or space. Others more generally may benefit from 'economies of scale' such that increasing returns are obtained from larger inputs of resources (e.g. bioinformatics).

In addition to the normal 'static' economies of scale, the recent theoretical literature has highlighted 'dynamic' economies of scale. The latter include the ability to achieve outcomes faster by scaling up the projects, and indeed one of the major justifications for international collaboration is the desire to get there more quickly, for example, through subdividing tasks to permit parallel working (e.g. gene sequencing). The idea that international collaboration may work as an accelerant is particularly attractive when the overall programme objective is concerned with boosting 'competitiveness', since competitive products in high-technology industries demand speed to market.

Another branch of the recent business literature has come to emphasise economies of 'scope' as well as 'scale'. In this respect, international programmes offer the opportunity to attack problems in different ways, stemming from the varieties of national backgrounds of the participants, and to attain different forms of outcome. The literature on innovation suggests that variety – and competition among competing studies and approaches – may be essential for eventual success. National targeted research programmes often commit to one particular line of development ('path dependency'), which may turn out to be fruitless or uncompetitive. Given the high degrees of uncertainty attached to any one course of action, the opportunity to operate with a more diverse portfolio, as provided by international programmes working, may be seen as an important safeguard as well as being a healthy source of cross-fertilisation and rivalry.

At the same time, there is a theoretical risk that the attraction of economies of both scale and scope may lead administrations to venture too far down that particular road to the point where such programmes could impede rather than expedite progress. A long tradition in economics, dating back to the classic works of Alfred Marshall, has argued that, while physical economies of scale in production might go on rising as volume increases, at some point managerial 'diseconomies' of scale are likely to arise. In a research context, for instance, those diseconomies may reveal themselves in networks that have grown so large as to have become ungovernable, and to have compromised their very reason for existence. Indeed serious questions are being asked about whether the 'new instruments' of the Sixth Framework Programme (FP6) have created such a situation. Equally, variety in the form of ever widening 'scope' can be taken too far, to the point where research partnerships fragment or fail to cohere. In many instances, there appears to be consent that the extremes of too little or too much are to be avoided. Naturally, the question for decision-makers is at what point these extremes arise.

This discussion of both economies and diseconomies of 'scale and scope' fits seamlessly into policy-makers' concerns about 'additionality' and 'added value', as outlined in later sections of this report. The decision to enlist in – or in some way support – an international research programme can be seen as a desire on the part of national officials to do 'more' or 'different' in order to do 'better'. It will also emerge that the R&D will not be done better if diseconomies of scale or scope take over. A key issue is the integration and cohesion of the activities these international programmes involve, and that necessitates effective administration.

4 The policy context

4.1.1 The origins of the Framework Programmes

The EU's strategy for supranational programmes of R&D was born out of a perceived combination of weaknesses of Europe in the emerging global competition of the 1970s and 1980s. On the demand side, the European market place was seen as being too fragmented to provide a competitive platform for purchasers or suppliers of goods and services as compared with the conditions existing in the unified United States. On the supply side, European countries were seen as losing out in new waves of technological change, especially those revolving around the new technological 'paradigms' of information technology and biotechnology due to the fragmentation evident in the funding of research. Japan and the Asian 'Tigers' were also seen as a growing threat based in part on their more centralised strategies to support innovation and technological change. These perceptions led into the construction of supranational programmes like EUREKA and ESPRIT, and eventually into the sequence of multiannual Framework Programmes.[1]

4.1.2 The EU and the Lisbon strategy

Here we jump ahead to recent considerations, revolving around the strategy that emerged at the Lisbon Summit in 2000 (see Rodrigues 2002). The objective became one of re-creating Europe as the world's foremost region for the knowledge-based economy by the end of the current decade. This leapfrogging is to be pursued through several mechanisms, two of which are of relevance here.

The first is by radically reorienting the conception of the EU from an emphasis on harmonisation to one that would utilise 'open methods of coordination' (OMC). The latter in essence recognised the differentiation inherent in the differing 'national systems of innovation' of the EU's member states.

The second, promoted from Brussels subsequently, was the so-called 'Barcelona target', to raise R&D intensity across the EU from its existing level of about 2% of GDP to a figure of around 3% of GDP. Of this, two-thirds (i.e. 2% of GDP) was expected to come from private rather than public sources. The increase has come to seem ambitious, not only because of the high path-dependency of most 'national systems of innovation', which can make them difficult to lift to much higher levels of R&D commitment, but also because of the process of accession of eastern and southern European countries. These new member states have tended to record much lower levels of R&D intensity than the EU average – with a high-degree of reliance on government expenditure rather than private – although in several cases (e.g. Slovenia) public and private sector investment is growing quickly and has already overtaken the research intensity of several long-established EU-15 member states.

1 ESPRIT, the European Strategic Programme for Information Technologies, was specifically designed on Japan's Very Large Scale Integration (VLSI) programme. ESPRIT was a major European initiative, coordinated by DG Enterprise, addressing the development of information technologies (IT). It was a response to the major US and Japanese programmes running in the 1980s and was an integrated programme of industrial R&D projects and technology take-up measures. After FP4, ESPRIT evolved into the Information Society thematic programme of FP5 and FP6.

A bigger concern of critics was the presumption that raising R&D would achieve the objectives of the Lisbon strategy, which reminded commentators that the conceptual simplicity of the 'linear model of innovation' still has power over many key decision makers. The assumption that more science would feed through seamlessly to some equivalent addition to the rate of technological progress and competitiveness, overlooks both the importance of other ingredients such as investment and absorptive capacity and the dynamic nature of global competition. However a strategy that gave full weight to human capital formation, absorption and the like – for example through the mobility programmes noted later in the present study – could form a coherent package for implementing the Lisbon aims, even if over a longer time-scale.

The case of Sweden and Finland may be instructive,[2] with both Nordic countries having taken a deliberate decision to maintain public research expenditure – and even to increase it – through the recession of the early 1990s, while the majority of member states reduced investment. Equally, the focus and scale of investment of the national technology programmes during the 1980s may have spurred Ericsson (Sweden) and Nokia (Finland) to expand their investment in mobile telecommunications research at a critical point in time. This helped to provide a platform for success in global markets. However, other factors may be as crucial to this success, including the limitations of the domestic market and the incentive this gives to business to pursue global strategies as well as other factors such as an historically high level of investment in education. Lastly, the focus of Sweden's multinationals on more traditional manufacturing sectors – including Ericcson to some degree – has left the economy exposed and productivity and economic growth are languishing despite its position as the number one country in the world, in terms of research intensity. Indeed, Swedish business and trades unions have come together to challenge the utility of this primacy in research statistics and have made a plea for government to change its emphasis on science and ensure that more of the state's efforts in the development of knowledge are coupled closely to the needs of society and business.

4.1.3 Comparisons with the USA

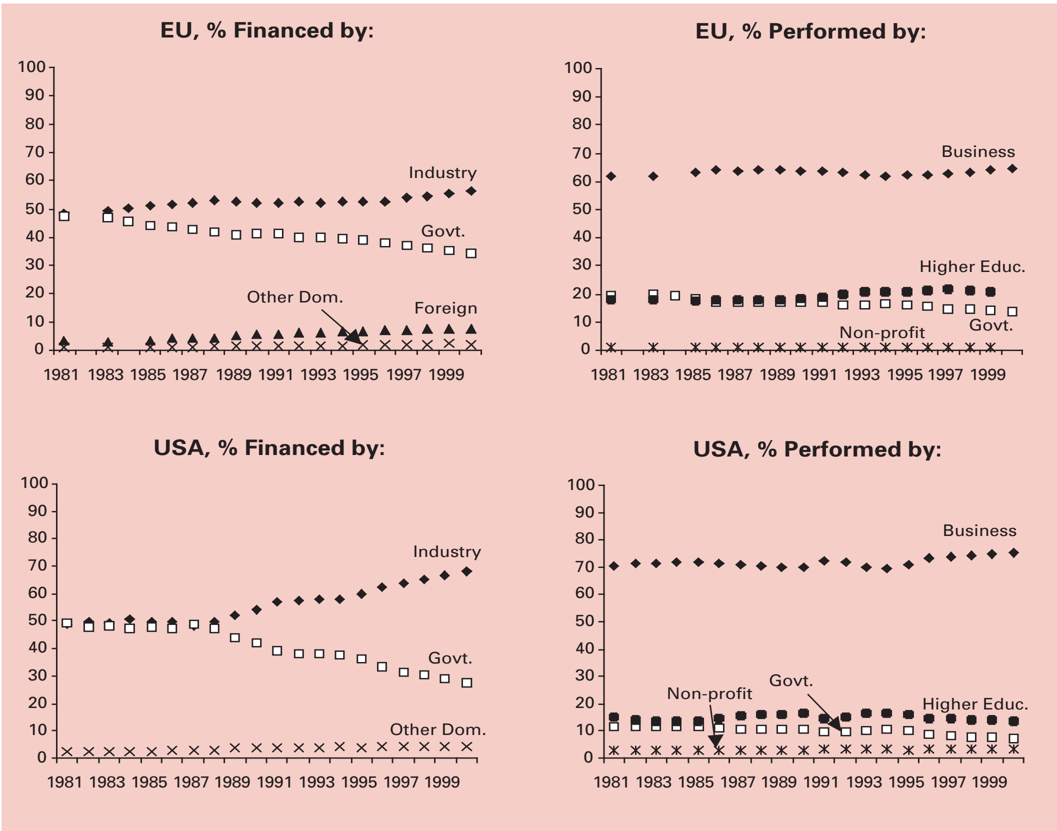
Much of the concern with productivity and competitiveness in the UK, and Europe, stems from a demonstrable productivity gap with the US. Indeed, UK government policy has committed explicitly to close that gap in the coming years through a range of measures, including policies to support research and innovation more generally. However, there remains something of a dilemma in the minds of many policy makers with respect to the most appropriate strategy to be pursued by government.

There is a widespread belief that the US government is much less interventionist than the EU or many of its member states, and that, in particular, business is left much more to its own devices. Although this is often brought into play in the political rhetoric, outside the US as well as within it, the reality as investigated by academics and others on both sides of the Atlantic appears somewhat different. Several large US federal departments and agencies (defence, space and health) make substantial investments in applied research and technology demonstration in order to permit them to sustain and improve their performance as public service agencies. Much of this development activity is procured in the private sector.

2 With research intensity above 3% of GDP, both Sweden and Finland are coming under increasing scrutiny as the rest of Europe reflects on the implications for them nationally of the Barcelona commitment. In almost all cases, and certainly for the larger EU economies of France and the UK, there will need to be a dramatic increase in spending on R&D (by business) in order to achieve an average research intensity for Europe of 3%, by 2010.

Exhibit 1 allocates funding sources (in the left-hand panels) and performing sources (in the right-hand panels) on the basis of published OECD data, with the EU shown in the top two panels and the US federal government in the bottom two. If we look first at the sources of funding, then there is little difference between the EU-15 and the US until the mid-1990s. Over that period industry financed about 50% of total R&D – rather more in the early 1990s – and the government share dropped from close to 50% to under 40%. Indeed in the 1980s the government share fell in the EU-15 but stayed roughly constant in the US. After the mid-1990s the share funded by industry and that funded by government continued to diverge in both regions, but the rise in industry share (and consequent fall in government share) was faster in the US. The figures go up to 2000. What has happened since, with the collapse of the stock market and the dot.com bust, the change of government in the US and the war on terrorism, remains as yet unanswered.

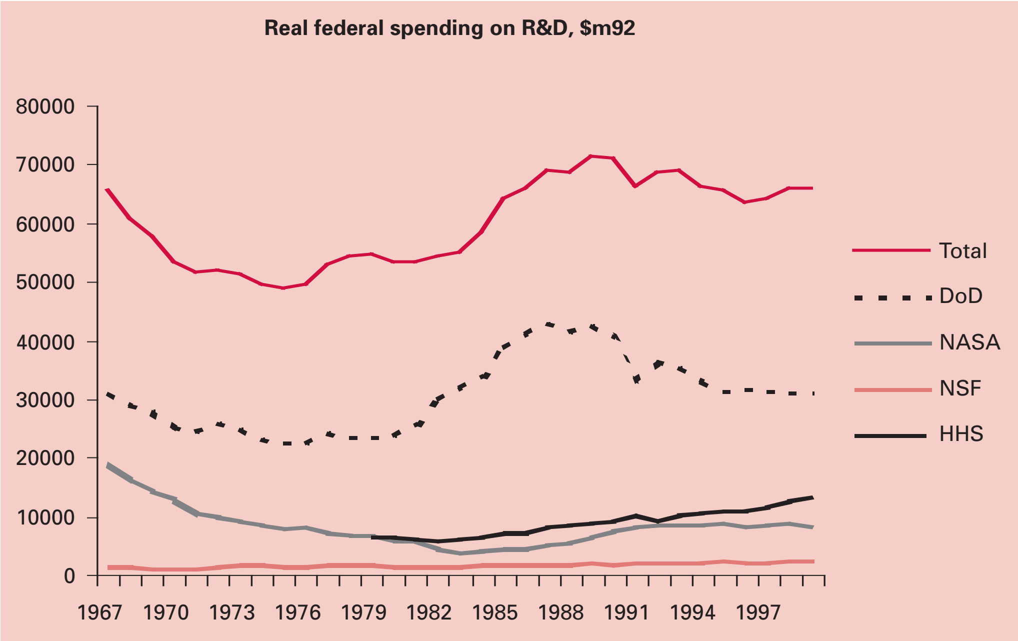
Exhibit 1 Financing and performing sources of R&D, EU and USA, 1981/2000



The right-hand panels show that the share of R&D performed by business in the EU-15, at just over 60%, was close to 10 points lower than that for the US, throughout the period. Conversely, the shares for higher education (HERD) and government (GOVERD) were lower in the US. These figures need to be seen in conjunction with the research *funding* patterns in the left-hand panels. Since the shares of gross expenditure accounted for by industry and by government were roughly the same in the two regions up until the 1990, the difference in the shares for research *performed* means that government support for research in business was higher in the US, in relative terms. In 1981 the business sector in the EU performed 28% more of total research by value than it financed, whereas in the US the figure was 44%. By 2000, the respective ratios were 15% for the EU and 10% for the US.[3]

3 The US figures, unlike those for the EU, exclude capital spending on R&D, and it is possible that government may be more involved in such capital spending.

Exhibit 2 US expenditure on R&D



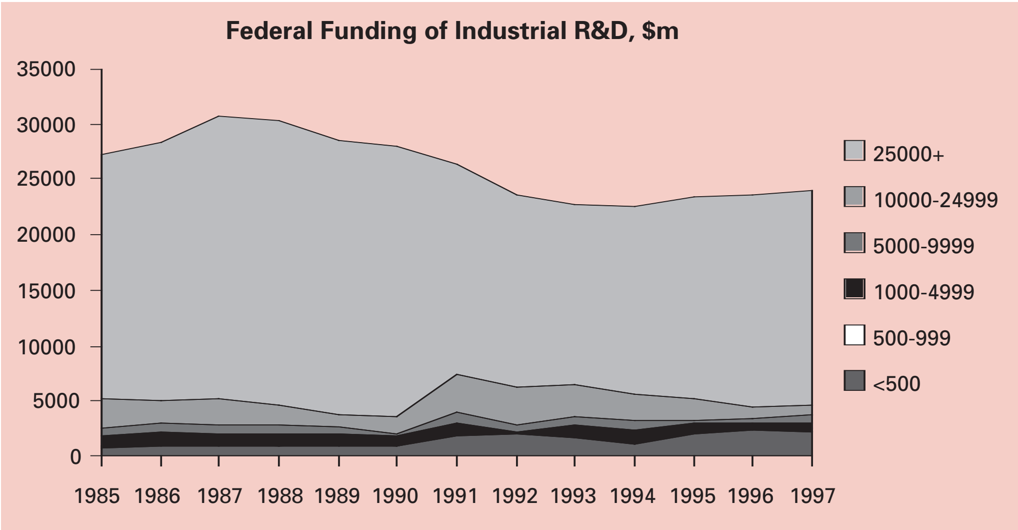
Source: NSF, *Science & Engineering Indicators*, *2000*, Table A2-36.

Exhibit 2 shows US federal government research expenditure, adjusted for inflation, across a 30-year period (in 1992 $ million), by source of funds.4 The diagram shows the dominance of defence expenditure throughout the period, and the growing importance of Health and Human Services (HHS). In addition, it reveals the rapid rise in government spending in the 1980s, a period associated with the rise of neo-liberalism in the US, occurred at a time of cutbacks in UK government research expenditure, civil and military.

The real amounts going to the National Science Foundation (NSF) for academic research rose slowly, and remain small by comparison with other national agencies. Indeed, the programmes of defence, space and health together account for more than 80% of total government expenditure on R&D. The prevalence of the applied research echoes the arguments of Mowery & Rosenberg (1989), who suggest that US commercial success in several major technologies (e.g. ICT and biomedicine) can be linked in part with massive US federal government R&D expenditure (in national labs and in industry) during the formative years of those technologies.

4 These figures include capital expenditure.

Exhibit 3 US R&D funding of industrial R&D



Source: NSF, *Science and Engineering Indicators, 2000*, Table A2-55.

Exhibit 3 considers the 'subsidy' element from federal funding to industrial R&D more explicitly, in this case broken down by size of company affected. The figures here are in current prices. The 'peace dividend' of the 1990s has been associated with a declining share going to very large companies (those with over 25,000 employees), although company size in general also fell over this period of 'downsizing'. Smaller firms – those employing fewer than 500 – is the only size band that has gained over the period: it can be supposed that many of these are dedicated high-tech companies.

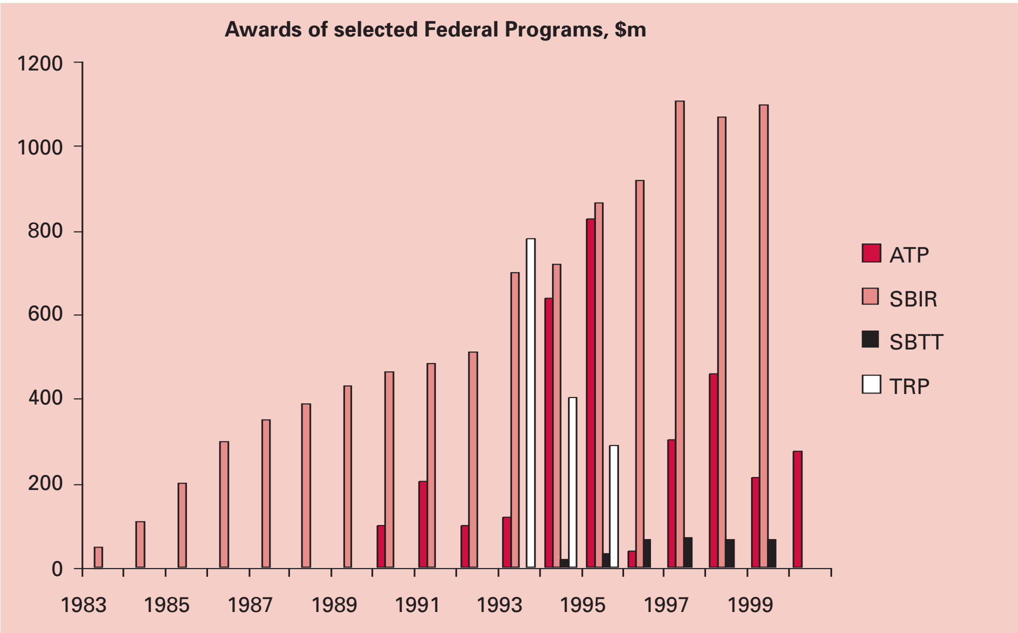
The trends in the statistics are in line with the conclusions reached by a team of American researchers coordinated from the Kennedy School of Government at Harvard University, which assert that there was a major redirection of US government R&D programmes from the late 1980s (Branscomb and Keller, 1999). The old policy environment they associate with the Cold War is given here in the left-hand column of Exhibit 4 presents the team's characterisation of the 'old' and the 'new' policy regime, with the former 'purchasing' new technologies while the latter supports business' innovation efforts. The language is unchanged from the original.

The model is not in active use by policy makers, and as such there is no comprehensive data on its individual components. Equally, the US academics have yet to evaluate the extent to which the new model has proved to be a success. However, there are data on individual business support programmes. The Advanced Technology Program (ATP) is discussed at length in Section 6.4.2, and there are expenditure figures for the Small Business Innovation and Research (SBIR) programme and the Small Business Technology Transfer (SBTT) programme, as well as for the Technology Reinvestment Program (TRP, for 'dual-use technologies') that ran from 1993 to 1995; these are charted in Exhibit 5.

Exhibit 4 Changes in the policy environment for US federal government technology programmes

Cold War era environment	New program environment
Federal financing and control by contract	Consensus management by cooperative agreement
Technology transfer to industry assumed or required	Technology adoption by internalisation of R&D
Single goal defined by engineering objective	Expanded scope; goal is industry transformation
Principal risks are technical or market uncertainty	Complementary assets are important to success
Pipeline innovation model	Recursive innovation model
Emphasis placed on pre-competitive R&D, plus development for government uses	Technologies for design, process, and quality are important
Danger of constituency capture of program	Difficult to create constituency for program
Firms are selected by contract competition on fulfilment of government specifications	Firms are selected by competitive negotiation on likelihood of commercialisation

Exhibit 5 US Awards of federal programs



Sources: NSF, *Science and Engineering Indicators, 2000*, Tables A2-44, A2-61;
NSF, *Science and Engineering Indicators, 2002*, Tables A4-36/8;
Branscomb and Keller (1999), p 181.

The chart shows an erratic pattern of funding for ATP, driven by budgetary constraints, but a more sustained growth from SBIR. Other important branches of the 'new' policy environment, like the Manufacturing Extension Partnership (MEP, which applies agricultural extension concepts to manufacturing) or the CRADAs (Cooperative Research and Development Agencies, mostly with the National Institutes of Health or Department of Energy), are not covered. The combined annual expenditure is comparable with that for the EU Framework Programmes.

In conclusion, from a government perspective, the supranational contribution of the EU and the federal contribution of the USA do not differ greatly in scale or in scope (although the biomedical facet in the US appears to be greater than in the EU). The US has largely abandoned the 'linear model' approach other than in a few key programmes, while there is some danger that the EU is returning to it via the 'Barcelona target'. US business research expenditure is growing faster than in the EU, however the changing balance between public and private contributions to gross expenditure on R&D has been driven in large part by the decline in defence-related expenditure. This may have slowed or even reversed more recently.

4.1.4 Comparisons with Japan

Until the 1990s Japanese government policy was often held up as an exemplar for other nations. In particular, the VLSI program (Very Large Scale Integration) for semiconductors, which was at its peak in the late 1970s, was seen as a model of how to redirect the economy to a modern knowledge-based structure. However subsequent flagship programmes, such as the Fifth Generation Computing project and the SIGMA project for software failed to achieve their (rather ambitious) targets, and indeed to show many evident outcomes of a positive kind. In part this arose from factors that had emerged in earlier programmes, such as the tension between a relatively weak government sector and a strong corporate sector, with its own views about competition. And to tensions between academia and industry that dated back allegedly to the Second World War. Above all, the Japanese economy entered a long period of seeming stagnation and, in parallel, one might say a decline in the fashion among policy makers for seeking to emulate all things Japanese.

The structure that had seemed to work well for the VLSI project had relatively low government involvement (about 22% of the funding) and was concentrated on the laboratories of well-known corporate groups. Japan continues to show a relatively low share of government funding compared to the EU or US, but the subsequent economic stagnation does not signal an overpowering case for imitating this situation. Even its still high level of private R&D intensity (relative to GDP) does not seem to have generated much real growth. From a UK standpoint, the strength of corporate R&D in Japan is also somewhat in contrast with the UK position.

From the mid-1990s, Japanese governments tried to turn around R&D policy. A law of 1995 became the basis for new strategies. Five-year plans were introduced for 1996/2000 and later for 2001/05 and evaluation frameworks were agreed in 1997. Japanese equivalents of the SBIR were introduced in 1999 and of ATP (known as NEDO – New Energy and Industrial Technology Development) for 2003; thus in effect scrapping the old Japanese model and instead copying the US model.

The current five-year programme for 2001/05 has a budget of around $185 billion, and prioritises nanotechnology (especially), the life sciences, IT and the environment – i.e. similar to the Framework Programmes etc., albeit with a different balance. It is under the control of the umbrella ministry, MEXT (Ministry of Education, Culture, Sport and Science & Technology). MEXT also drew up proposals for success in the new knowledge-based economy – similar to the EU's Lisbon strategy – in 2002. Given its large constituency, issues like mobility of researchers and reform of the university system were emphasised. Within the limited government budgets, restricted by the stagnation and constraints on raising government revenue, the Japanese government has tried to upgrade expenditure on science and technology, but is still awaiting clear evidence that the policy is working.

5 The Framework Programmes

5.1 Inception and evolution of the Framework Programmes

The multi-annual Framework Programmes (FP) represent the medium-term planning instrument for Research and Technological Development (RTD) at EU level. The first Framework Programme (FP1) was launched in 1984, but only ten years later (after the Single European Act and the Maastricht Treaty, ratified in 1993), were EU institutions given full powers with regards to research and technology.

In the early days, the primary objective was to increase the competitiveness of European industries (not individual participating companies) by improving their technological capabilities. The intention was to bridge the perceived technological gap between Europe on the one hand, and the US and Japan on the other. A further motivating factor was the perceived excellence of Europe in the quality of its basic science, but its apparent inability to translate this into commercially successful products (Luukkonen, 2000).

Although some have questioned the extent and nature of the supposed gap (Pavitt, 1998),[5] there was high-level concern about the threat to the very existence of the European electronics industry. ESPRIT, the European Strategic Programme for Information Technologies, was specifically designed on Japan's Very Large Scale Integration (VLSI) programme, and became the model for subsequent EU programmes such as RACE (telecommunications), BRITE (industrial technologies) and later Framework Programme initiatives.

The introduction of publicly-supported collaborative research also seems to have coincided with increasing theoretical emphasis on market failures arising from imperfect information flows rather than from the difficulty that firms experience in appropriating all the benefits of their R&D activities (Luukkonen, 2000).

The basic characteristics of the Framework Programmes are that they involve collaborative research by firms and research institutes from at least two EU countries, on a shared-cost basis (with industry meeting at least 50% of the cost), and are 'pre-competitive' (concerned with generic or general research, rather than being product- or process specific). Technical experts and user groups advise the Commission on broad priorities, and peer-group assessment is used to assess suitability for funding.

Specific RTD objectives for Europe were enshrined in the 1987 Single European Act (SEA) and the Maastricht Treaty of 1993, both of which supported a strengthening of Europe's S&T capabilities and promotion of its international competitiveness. Maastricht also introduced the objective of 'cohesion', i.e. the reduction of disparities in wealth between EU regions. These Treaties and objectives validated and reinforced the continuation and expansion of the Framework Programmes.

5 Pavitt argues that, with the benefit of hindsight and improved statistics, it is now clear that R&D expenditure, sales and productivity in European (and in Japanese) firms were growing more quickly than in the US. He suggests that the important gaps are those between European countries themselves.

Indeed, the evolution of Framework Programmes reflects the debates and overall evolutionary processes concerning EU institutions and transfers of powers and policy instruments from Member States to European bodies. The political opposition by Member States such as the UK and Germany to a stronger EU role in the realm of technology and, more generally, industrial policy, remarkably affected the first Framework Programmes, which were systematically downsized compared to the original design. Not even for the negotiation of FP4, which benefited from the EU technology policy of the SEA, was there political agreement on a qualified majority voting system. The Commission's proposal for adopting more flexible decision procedures was strongly rejected by the British government and the Framework Programme's overall budget remained subject to unanimous voting on the Council.

The idea of a comprehensive EU policy framework, which pulled together the Community Programmes and gave them greater coherence, dated back to the early 1980s. The First Framework Programme represented little more than the re-listing of the projects that were already set-up. Nevertheless, there was an important effort to establish general criteria for EU support, which guided the subsequent stages. Preference was indicated for research that was:

- conducted on a *large scale*, for which single Member States cannot provide the necessary financial means and personnel, or which can benefit financially from being carried out jointly
- *complementary* to national programmes
- addressing *common interests*, and could be best tackled through joint effort
- likely to contribute to the *cohesion* of the common market, promoting the unification of European science and technology, and
- contributing to the establishment of *uniform laws and standards*

From the outset, issues of scale and scope were placed at the forefront, but reined in by intentions of integration and cohesion as seen from a European-wide standpoint.

Exhibit 6 describes the evolution of FP budget and priorities up to the institutional and dimensional 'structural break' of FP4. Competitiveness has remained the primary goal of European technology policy, but a wider set of objectives has been added over time, such as reducing unemployment, accelerating structural changes, and ensuring greater cohesion. Accordingly, successive Framework Programmes have addressed wider areas of intervention. In particular, the latest FPs have shifted the emphasis from supply-side factors, central in the design of the first policies, to include diffusion-oriented actions and the increase of learning skills and knowledge among Europeans.

In the *First Framework Programme*, priority was given to the energy sector, to which half of the entire RTD budget was assigned, mainly absorbed by EURATOM related research. The proportion of funding devoted to energy steadily declined, following the subsequent negotiations, up to FP4, when new investments for the development of non-nuclear energy were planned.

Exhibit 6 RTD Priorities in Framework Programmes

Framework Programme Years	I 1984-1987	II 1987-1991	III 1990-1994	IV 1994-1998
Total Million ECUs*	3750	5396	6600	12300
		Budget share (%)		
Information and Communication Technologies	25	42	38	28
Industrial and Materials Technologies	11	16	15	16
Environment	7	6	9	9
Life Science and Technologies	5	7	10	13
Energy	50	22	16	18
Transport	-	-	-	2
Socio-Economic Research	-	-	-	1
International Cooperation	-	2	2	4
Dissemination and Exploitation of Results	-	1	1	3
Human Capital and Mobility	2	4	9	6
Total	**100**	**100**	**100**	**100**

Note: *adjusted to 1992 prices

Source: European Commission (1994)

The *Second Framework Programme* (1987-1991) was designed to coincide with the SEA and reflected its emphasis on the realisation of the Single Market. The RTD budget increased, though it still amounted to less than 3% of total government RTD spending and about 1% of all (public and private) RTD spending. ICT received a much larger share of funding, mainly through ESPRIT, becoming the most prominent area of EU research investment. The effort devoted to the ICT area responded to high-level policy concerns regarding EU competitiveness vis à vis the US and Japan.

In the *Third Framework Programme* (1990-1994), which overlapped the Second by two years to ensure continuity of research for ongoing projects, the budget share of the ICT area fell slightly, but increased in absolute terms and remained the highest, whereas relatively more funds were assigned to *Human Capital and Mobility* programmes and *Life Science and Technologies* themes.[6]

The *Fourth Framework Programme* (1994-1998) represented the first fully legitimised EU political plan in the RTD area. The SEA and the Maastricht Treaty had given an official political mandate to EU institutions in the area of technology policy, though the effective power of the Commission in setting budget priorities has always been limited by the requirement of unanimous voting.

The new institutional set-up marked a significant upward trend of the European Commission's RTD budget, which almost doubled. The existing sub-programmes were reinforced and emphasis was placed by the Commission on the need to employ the FPs to serve broader EU objectives, going beyond the strict realm of technology policy. The Maastricht Treaty introduced the notion that medium-term planning should concern all EU RTD activities. Synergy was to be sought in various fields, such as environment, transport and energy. Moreover, the RTD policy was to be linked to regional development policies and to the more general aim of social and economic cohesion. Hence, the objective of reducing the scientific and technological gap between Member

6 The funding of "life science" research pursues several objectives: improving basic knowledge in biology, accelerating its agricultural and industrial application in the areas of health, nutrition and environment, increasing the effectiveness of R&D in medicine and health in Member States (European Commission, 1994).

States gained priority. In this respect, an important political momentum for EU technology policy was given by the Delors' White Paper on 'Growth, Competitiveness and Employment' (1993), which envisaged a critical role for innovation in recovering from the early 1990s recession. It pointed to the need for rethinking the use of EU funding systems and for placing more attention on the *contents* of the interventions rather than the size of the budget. In particular, 'background' measures were emphasised, such as education, training, risk capital and technology transfer, measures that are integral to the idea of 'absorptive capacity'.

The design of the *Fifth Framework Programme* (1998-2002) was the outcome of a 'new approach,' which explicitly aimed at adapting the planning instrument to the context created by the launch of the single currency, the future enlargement of the EU and the persistent high level of unemployment. In particular, the preparatory documents acknowledged that employment creation represented the major challenge in Europe and effective measures needed to address high-tech, high-growth sectors and the use of new technologies by traditional sectors and SMEs.

The new Framework Programme attempted to rationalise the existing range of projects, introducing more selective criteria. Therefore, it concentrated resources on a limited number of key actions responding to "priority needs" and paid particular attention to the potential for applying the results.

Exhibit 7 describes the Programme funding, which was structured into four thematic areas, concerned with RTD itself, complemented by Horizontal Programmes, which were broadly intended to promote cooperation and dissemination (especially among SMEs), and training and mobility of researchers. The budget increase was devoted particularly to the areas of quality of life[7] and human potential.

Objectives have been modified over the years. In particular, there was a switch from the 1980s emphasis on *producing* new technologies to an emphasis in the late 1990s on enhancing European abilities to *use* new technologies (Peterson and Sharp, 1998). Also, the range of objectives has widened, with increased emphasis on social and environmental factors (including cohesion, quality of life and sustainability).

7 Projects under the heading "quality of life" relate to health and nutrition, environment, natural and man-made hazards, transport safety, and conservation of Europe's cultural heritage.

Exhibit 7 Funding of the Fifth Framework Programme (1998-2002)

	MEURO	%
RTD Areas	**11822**	**79.0**
Quality of life and management of living resources	2413	16.1
User-friendly information society	3600	24.1
Competitive and sustainable growth	2705	18.1
Energy, environment and sustainable development	2125	14.2
Nuclear Energy	979	6.5
Horizontal Programmes	**2118**	**14.2**
Confirming the international role of Community research	475	3.2
Promotion of innovation and encouragement of SMEs participation	363	2.4
Improving human research potential & the socio-economic knowledge base	1280	8.6
Direct actions (Joint Research Centre)	**1020**	**6.8**
Total	**14960**	**100**

Source: EC (2000)

5.2 The Sixth Framework Programme

The *Sixth Framework Programme* introduced dramatic changes in all these respects. In the documents paving the way to negotiations, the European Commission called for a significant change in approach, demanding more concerted effort for the development of a truly European Research Area, in place of the existing 15+1 configuration (Member States plus Brussels), characterised by fragmentation, compartmentalisation and disparity of administrative and regulatory frameworks across Member States. The new approach seeks to produce structuring effects, *changing the organisation of research* in Europe in total, rather than simply pooling resources and facilities in a corner of public expenditure. In this perspective, the focus of European programmes is to change from direct support for a large variety of projects and organisations, that may overlap national schemes, to a more limited number of priorities and measures that exert a '*co-ordinating, structuring, and integrating*' effect on European research (European Commission, 2002). As such, the policy is to focus selectively on stimulating resources and expertise to converge on strategic areas, creating "excellence clusters", whose self-organisation is expected to follow.

The premise of such an approach is that, in a wide range of research fields, excellence exists at European level, but needs further support, better structuring, greater scale, and international visibility, if it is to become dominant and underpin the region's social and economic ambitions. That is, the Commission rhetoric presumes that in Europe, existing national centres of excellence may be constrained from realising their full international potential by size constraints, and that they are loosely connected and inadequately recognised across scientific and industrial communities, especially by firms, which could usefully join forces with them. Therefore, EU policy is to be aimed at mobilising a *critical mass* of resources in strategic areas and to promote the connectivity of centres of excellence. These arguments regarding scale and scope are not rooted in any empirical evidence, and at the time of this review it was rather too early to come to any kind of view on how well these political ambitions are likely to be met in practice.

FP6 comprises seven thematic priorities and 3 blocks of activities. The themes are:

- life sciences, genomics and biotechnology for health
- information society technologies
- nanotechnologies, materials, new production processes and devices
- aeronautics and space
- food quality and safety
- sustainable development, global change and ecosystems
- citizens and governance in a knowledge-based society

These themes cover the first 'block of activities', and a budget of Euro 16.3m is earmarked for them. The second block relates to 'structuring the ERA' (Euro 2.6m) by integrating research and innovation, supporting human resources and mobility (Marie Curie actions), promoting the development of research infrastructures, and promoting dialogue between the scientific community and society at large. The third block ('strengthening the foundations of the ERA', Euro 0.3m) is concerned with the coordination of research and innovation policies in Europe ('ERA-NETs'). Exhibit 8 reports the indicative summary budget breakdown for FP6.

Exhibit 8 Budget breakdown for FP6

	M EURO
Focusing and Integrating Community Research	**13345**
Life sciences, genomics and biotechnology for health	2255
Information society technologies	3625
Nanotechnologies, materials, new production processes and devices	1300
Aeronautics and space	1075
Food quality and safety	685
Sustainable development, global change and ecosystems	2120
Citizens and governance in a knowledge-based society	225
Policy support and anticipating scientific and technological needs	555
Horizontal research activities involving SMEs	430
Specific measures in support of international cooperation	315
Non-nuclear activities of the Joint Research Centre	760
Structuring/Strenghening the European Research Area	**2925**
Structuring the ERA	2605
Strengthening the foundations of the ERA	320
Euratom Framework Programme	**1230**
Priority thematic areas of research	890
Other activities in the field of nuclear technologies and safety	50
Nuclear activities of the Joint Research Centre	290
Total	**17500**

5.3 Researcher training and mobility in the Framework Programme

In the attempt to support the human potential in Europe and encourage young people to take an interest in research and in pursuing a career in science, the EC has introduced in the Framework Programme a programme of *support for training and mobility of researchers*. The programme will contribute to the realisation of a European Research Area through the following general objectives: stimulating training of young researchers, especially those in the early stages of their professional career, promoting equality of opportunities between women and men, promoting trans-national cooperation between research teams and scientific and technological cohesion, particularly with respect to less-favoured regions.

The European Commission has been supporting the training and mobility of researchers through several FPs. Within FP5, it is possible to identify two schemes in the *support for training and mobility of researchers: Research Training Networks* (RTN) and *Marie Curie Fellowships* (MCFs):

- The primary objective of RTN is to promote training through research, especially of young researchers at pre-doctoral and post-doctoral level, in the framework of high-quality trans-national collaborative research projects
- The aim of MCFs is to ensure that more efficient use is made of Community funding for the training of young high-quality researchers through awards for either *individual fellowships* or *host fellowships*, i.e. awarded either to individual researchers or host organisations

5.3.1 Marie Curie Fellowships

Marie Curie fellowships were implemented throughout the range of FP5 research areas, with a total budget of Euro 556.2m (EC, 2003). On average, there were between 1500 and 2000 eligible proposals for individual fellowships per year (EC 2002). A total of 6888 proposals for individual fellowships and 2857 host fellowships were considered eligible in FP5. It should be noted that in the case of individual fellowships there was a constant increase in the number of proposals.

Of a total of 2857 eligible Marie Curie host fellowship proposals 42.8% involved industrial applicants. The success rate for SMEs was 25.5%, compared with 55.2% for larger companies. A major reason for the lower success rate of SMEs was the specific orientation of the Fellowships towards researcher training, for which many applicants did not have the required abilities and/or infrastructure. In total, the 6888 applications came from applicants of 66 different nationalities. Indeed the Marie Curie Fellowships have offered the opportunity to carry out research throughout the whole of Europe, in Member states, Associate States and Candidate Countries. 50% of applications (both received and successful) came from France, Spain and Germany. However, the most popular host country by far was the UK (34.4%) followed by France (18.4%) and Germany (11.4%). Overall, the success rate of applications was 41.4% for individual fellowships and 38.3% for host fellowships. The success rate varied across different specific programmes, ranging from 33% in energy/environment in host fellowships, to 76.5% in nuclear energy in individual fellowships. However, for each call success rates not only depend on the number of proposals but also on its indicative budget.

The area is now included under the Sixth Framework Programme within the "Human Resources and Mobility" sub-programme of Block 2 'structuring the European Research Area', which covers a range of Actions to promote the development and transfer of research competencies, consolidate and broaden researchers' career prospects, and promote excellence in European research. These are known collectively as Marie Curie Actions. RTN has been included within Marie Curie as *Marie Curie Research Training Networks*.

There have been no independent evaluations undertaken of the Marie Curie scheme, and as such there is no literature regarding the outcomes and impacts of the programme. The Commission launched a major pan-European study in 2003 to evaluate the programme (FP4 and FP5), which is due to report in summer 2005[8]. The main reference

8 IMPAFEL: http://impafel.apre.it/

point has been the Commission's own monitoring and evaluation reports[9] including for example the most recent five-year assessment report (*Improving human research potential and the socio-economic knowledge base*, EC, 2000) which looked briefly at Marie Curie and came to strongly positive conclusions on the scheme's impact on researcher mobility.

5.4 SMEs and the Framework Programme

5.4.1 SME participation in FP

SMEs comprise the majority of employers, and as such are a critical element of the EU economy. As such, government policy in the UK (and the EU) has sought to identify a number of measures by which to improve the interface between this large number of innovative businesses and the public sector research base. The Framework Programme is no exception to this and has sought to encourage participation of research-active SMEs within the thematic programmes, and innovation-active SMEs (with no or limited internal research capability) within SME specific schemes.

Peterson and Sharp (1998) consider that 'SMEs present a particularly difficult problem for the Framework Programme.' They point out that some (particularly in software and biotechnology) are highly innovative, although in Europe there is a relative dearth of such companies. But their role is crucial in production supply chains:

> SMEs are important players, not only in the *development* of new technologies, but also, and even more crucially, as *users* of new technologies. Diffusion as a policy goal essentially involves stimulating SMEs to acquire skills and capabilities in new technologies. [But] SMEs have not so far been major players in the Framework Programme.

The challenge of attracting contributions from SMEs is revealed in the participation statistics. SMEs accounted for around 20% of the total participations in FP4, rather less in financial terms, while they account for 98% of European employers and two thirds of European employment.

FP evaluations suggest that small firms have different motives and derive different benefits as compared with larger firms. SMEs participate in FP with a view to short-term commercial considerations, to increase business or to better tailor products to customers, and that these motivations are much more pronounced than they are for larger firms (Luukkonen, 2000).

This view is borne out by the experiences of other programmes. In the U.S., for example, evaluative studies conducted on behalf of the Advanced Technology Programme have found that small firms tend to benefit most in the short run (1-2 years), while larger firms benefit more in the longer run, as indicated by the volume of patents granted over time. Case studies suggest that where public support for research is focused on generation of innovations, then larger companies benefit from participation in consortia to a greater extent than do smaller companies.

Commission assessments have concluded that the FP is not an especially attractive proposition to smaller businesses. In practical terms, the pre-competitive nature of the programme, project time frames of 3-5 years and substantial administrative overhead are all disincentives. Financial rules and payment terms are problematic too.

9 EC (2003), Final Report on Marie Curie Fellowships in FP5 (1999-2002).

On a positive note, the trend in the statistics on SMEs participation has been improving consistently, albeit starting from a low base and would suggest that the Commission has had some success in its ambition to involve European SMEs in research activities. Increased budgets for specific SME measures, SME quotas and dedicated SME calls have all been introduced in FP6. The 5-year Assessment[10] (2000) reported that SME participation had increased from 19 % of all participations during FP3 to 21 % during FP4 and up from 35 to 45% within the industry segment.

In FP6, the Commission has set a target of 15% in terms of the total share of funding (Thematic Priority Areas) intended to be spent with SMEs, which is around EUR 1,700 million. In addition, EUR 430m is available for *SME Specific Activities*. The main routes through which SMEs obtain support, are:

- Calls for proposals for the Thematic Priority Areas
- Separate calls for Integrated Projects issued by the Thematic Priority Areas, and directed to SMEs specifically (via dedicated calls)
- SME Specific Activities, including Cooperative Research Projects (CRAFT) and Collective Research Projects

5.4.2 Co-operative Research (CRAFT)

The bulk of FP expenditure on specific measures to SMEs has gone through the Co-operative Research (CRAFT) initiative, which uses intermediate research and consulting organisations as a route to innovation-active SMEs that do not have the capacity or inclination to perform formal R&D.

CRAFT is quite distinctive when compared with the rest of the FP programme areas and is not replicated directly within the portfolio of UK innovation support measures. However, the DTI sector research and innovation programmes do provide support to research and technology organisations conducting what may be termed ‘club research’ dealing with generic issues of concern to a wide range of sectoral interests, and especially SMEs. The main features of CRAFT are:

- SME Proposers: Minimum 3 from 2 different countries
- RTD Performers: Minimum 2 from 2 different countries
- Other enterprises may participate
- Typical project duration: 1 – 2 years
- Typical project cost: Euro 0.5m – Euro 2m
- CRAFT awards cover 50% of costs of SME contributions to research and 100% of management costs (up to a ceiling of 7% of total costs)
- Awards cover 100% of the costs of the research performers

5.4.3 Collective Research

Collective Research is a type of research carried out by RTD performers (for example, research centres, universities, etc.) on behalf of industrial associations or groupings in order to expand the knowledge base and improve the overall competitiveness of large communities of SMEs. The scheme evolved from five pilot projects funded by the European Commission under the Fifth Framework Programme. Collective Research projects are usually large-scale, Europe-wide initiatives and include a ‘core group’ of SMEs who are involved in all aspects of the project, from the definition of the research

10 Mandl C. (2000), Five-year assessment report related to the specific programme: Innovation and Innovation-SME, covering the period 1995-1999.

to the dissemination of the final results[11]. The main features of Collective Research are reported below:

- Minimum 1 European Industrial Association or 2 National Associations from different countries
- RTD Performers: Min 2 from 2 different countries
- SME Core Group: Min 2 from 2 different countries
- Duration: 2 to 3 years
- Cost: Euro 2m – Euro 5m
- Support
  - 50% for research and innovation
  - 100% for training
  - 100% for management (up to 7% of contribution)
  - RTD Performers are 100% funded

5.5 Impacts of the Programmes – evaluations and analyses

There are two main sources of information on the impacts of the Framework Programmes; Commission-organised 5-Year Assessments (introduced in 1995) and impact studies, most of which have been specified and financed by individual member states[12]. For FP5, the Commission introduced schemes for annual monitoring and 5-yearly assessments of specific programmes by expert panels, which inform the 5-yearly assessment of overall FPs.[13] Prior to 1995, there were many sub-programme evaluations by independent experts, but these were somewhat ad-hoc and tended to lack overall coherence (PREST et al., 2002). Evaluations of impacts on particular member states are carried out under their own individual initiative.

Unsurprisingly, given that both the 5-yearly studies and national evaluations are typically carried out during or shortly after completion of the programme activity, they are concerned almost exclusively with first-order impacts. The Independent Expert Panel conducting the 5-year assessment for the overall programme (EU, 2000) – executed midway through FP5 – considered evidence from parallel 5-year specific-programme assessments, complemented by a questionnaire survey of participants in FP4 and FP3 projects. There is scant material regarding programme outcomes or impacts in the overall – or supporting assessments – and the ‘main message’ from that evaluation was rather more polemical and was concerned primarily to expand on the need for greater integration of research policy with other policy tools and dimensions:

> Our main message is that if the European Union wants to face the challenges of the new economic situation and attain the goals outlined by Heads of Government in Lisbon, the Framework Programme alone is not enough to implement European research and technological development (RTD) policy. It needs to be complemented by other tools.

Other main conclusions were broadly positive, and were that:

- The focus on collaborative RTD was appropriate, giving both a practical dimension to academic work and a theoretical underpinning to technological development

11 The intellectual property rights belong exclusively to the industrial associations/groupings, however, the SME core group and RTD performers may benefit from the exploitation of the results.

12 Some detail of the history of evaluation within the Commission is given in Durieux and Fayl (1999)

13 5-year assessments to date are EC (1997) and EC (2000).

- The secondary focus on thematic networks and the training and mobility of researchers was also appropriate
- The programmes strengthened S&T capability across Europe
- They rarely led to short-term commercial exploitation, but were expected to underpin future competitiveness

On the negative side, the panel concluded that:

- Outputs and results of potential relevance to other policy goals were not adequately communicated or utilised, due to inadequate links between research and policy communities
- There was considerable criticism of certain aspects of management and administration of the programmes. In particular:
  - application procedures were widely considered to be difficult to follow, with inadequate accompanying documentation
  - delays between calls for proposals and project start-up were excessive, particularly with regard to the length of negotiations over contracts
  - costs and risks associated with proposal development were high, particularly in the context of low acceptance rates
  - there were delays in receipt of funding.
- Regarding FP5, there were 'early indications' of a need for urgent clarification of the concept of 'European Added Value' for participants and proposal evaluators

National impact studies are variable in frequency and extent. The most recent UK study (DTI AU No. 39, 1999)[14] surveyed a sample of FP3 projects on benefits and impacts, and reached broadly similar conclusions to the five-year assessments from 2000, albeit in this case regarding the impact of the FPs in the UK, namely:

- low levels of commercialisation
- significant generation of new scientific knowledge
- significant acquisition of technical knowledge and capabilities
- improved access to technical networks by one-third of participants, although most of these represented a development of existing networks
- an improved profile with customers for 15% of interviewees

More generally, the study concluded that most participants considered that the benefits of participation outweighed the costs. The European dimension was felt to be either 'essential' or as conferring 'significant benefit' by 64% of interviewees, although the number of responses is rather small (88) given the size of the total number of project and participations. Project aims and scope were felt to be increased through the typically relative large size of FP projects, with the involvement of more partners. Also, 'the contribution of foreign partners is valued by UK participants, *but for most the availability of a subsidy is an important factor given widespread recognition of the costs which trans-national collaborations give rise to'*.

The reviewers concluded that levels of additionality generated by FP funding were in line with those generated by national collaborative research programmes.

The results of this 1999 study are broadly similar to those of earlier FP impact studies undertaken in the UK, and mirror the findings of a much larger number of studies performed on behalf of other member states (e.g., Austria, Finland, Flanders, Germany

14 DTI Assessment Unit Report No. 39 was produced by Segal Quince Wicksteed (SQW) Limited for DTI and OST and is available online http://www2.dti.gov.uk/iese/aurep39.html.

and Ireland). Georghiou et al. (1992), in a review of the impact of FP2 on the UK, found that:

- academics were overwhelmingly positive in their assessment of the experience of EU participation – 84% positive compared with 5% negative. Corresponding figures for industrial participants were 67% positive, 21% negative
- most partnerships stemmed from previous links
- the most commonly cited benefit for industry was enhanced skills
- reasons given by firms for *not* participating were a perception that involvement restricted flexibility, led to loss of control over results, or that the research was too long-term or not in the firm's area

More wide-ranging studies, drawing on several programme evaluations, have tended to confirm the conclusions set out above. Peterson and Sharp (1998) comment that of the five issues they identify as the main objectives of the Framework Programmes – improved competitiveness (primary), a strengthening of the S&T base, stimulation of collaboration, training of young scientists and engineers, and promotion of cohesion – *stimulation of collaboration* is the goal that has most clearly been achieved. Luukkonen (1998) also observes that the primary impact of EU research programmes has been on the promotion of 'infrastructural' matters (such as skills and training of personnel) rather than on the promotion of competitiveness. Intriguingly, and in light of this finding, she goes on to suggest that

> Targeted research programmes may not be the best option in this respect. Rather, programmes which are more broadly defined, contain fewer targets with less detail, and those which apply bottom-up principles might better serve the objective of enhancing infrastructural matters.

Luukkonen raises a new question therefore, which relates to the means by which one chooses programme strategy and design parameters in order to best match the nature of the challenge (programme mission), in an efficient manner. There is then the unresolved issue as to how best to measure and compare the efficiency with which different programmes translate into tangible societal benefits.

The majority of the evaluation studies have focused on the rump of Framework investments, its projects and thematic programmes. Neither CRAFT nor the Marie Curie Fellowships have been subject to a formal, independent evaluation. However, the schemes have been assessed in some degree through the work of the five-year assessment panels (e.g. for Marie Curie, *Improving human research potential and the socio-economic knowledge base* [EC, 2000]).

The overall conclusion on Marie Curie of this EC panel was that the programme had been a very effective mechanism for:

- creating a small but significant population of mobile, high quality young and experienced researchers with trans-national experience and for retaining these researchers within Europe
- building inter-institutional links among research institutions
- stimulating networking and creating meeting points for European researchers (research networks, European infrastructures)

According to the panel, both RTNs and MCFs were regarded as having been extremely effective mechanisms for providing researchers with trans-national experience and keeping these skilled individuals within Europe, and noted the high prestige now associated with MCFs. The impact of these schemes is as yet relatively small, but the conclusion is that a significant beginning has been made.

6 European and national R&D programmes

6.1 Introduction to reference programmes

The review has sought to assess the 'state of the art' in the understanding of the impacts of Framework Programmes, and their strengths and weaknesses in comparison with national programmes and other European programmes. Accordingly, this section presents an overview of selected reference programmes, both European and national (from larger countries).

There are no programmes that directly 'compete' with the Framework Programme in providing public funding for (pre-competitive) collaborative research, conducted at the European level, with the ambition of facilitating social, economic and scientific programmes. There are other international schemes, however, which provide public-sector support to European research. For example, EUREKA funds (near market) research and is similar in scale similar to Framework. Equally, COST (European Cooperation in the field of Scientific and Technical Research) stimulates research cooperation across Europe through support for networking and information exchange, as does Framework. However, while these schemes exhibit some similarities there are important differences too and as such Framework may be said to be a worthwhile addition to the suite of support measures available to European Member States.

At a national level, the review has looked briefly at collaborative research programmes in the larger EU member states, including France, Germany and the UK. This assessment suggests that most Member States operate large national programmes with very similar remits to the Framework Programmes, albeit with programme goals couched in terms of benefits accruing to the Member State rather than Europe.
The UK government funds several industry-science collaborative research programmes with a combined annual expenditure of around £250 million. LINK is one of the larger industry-science schemes within this funding landscape and its objectives, while expressed in national terms, are very similar to Framework, as are the perceived benefits its coverage. The Faraday Partnerships is another flagship UK scheme with broadly similar objectives to the Framework Programmes, in terms of its ambitions with regard to productivity and competitiveness, except that public support is provided for 'virtual' technology centres rather than for programmes and projects. If LINK can be seen as the UK counterpart to Framework, Faraday Partnerships may be argued to be the UK counterpart to EUREKA.

At international level, the US and Japan are the two countries where one can find collaborative research programmes of a comparably size and remit to the Framework Programme. The US Advanced Technology Program (ATP) for example is a partnership between federal government and private industry, interesting from our perspective in that, while a single nation, the US economy is of the same order as that of the EU. ATP poses several challenges. In contrast to the Framework Programme, industry-science collaboration is an option rather than an *essential* requirement – 70% of awards have been for projects proposed by single companies – and high technical risk is the key criterion, which means that the programme is highly selective. The average project award, at around $3 million, is comparable with that for the Framework Programme, however the high-risk criterion is highly discriminating and the overall budget for ATP is an order of magnitude smaller.

Japan has a long tradition of government support to research collaboration, going back to the immediate post-war period. For much of the period, Government concentrated that support on a few strategic sectors, particularly electronics and machinery. Since the early 1990s, however, Japan has attempted to extend public support to a wider range of economic sectors and has latterly been moving towards a more programmatic and competitive model of funding, comparable with that found in the EU. Despite widely reported success of Japanese support for high-technology sectors, there have been few evaluations of the national plans and associated technology programmes.

Exhibit 9 Outputs of selected international and national collaborative R&D programmes

	Source	Innovation Outputs	Research Outputs	Other outputs
ATP	Various at www.atp.nist.gov	Very high number of patents generated (800 for 1433 participants, 1990 – 2001)	Leveraging private R&D investment	
COST	PREST (1997)		Positive impact on research activities	Facilitation of scientific and technological collaboration
EUREKA	EUREKA Impact report 2002/03	Patents (10% of surveyed org.), new products/processes (40/50% of surveyed org.)	Acquisition of new knowledge	Excellent/good technological achievements of participants
Faraday Partnerships	PACEC (2003)			Positive impact on the increase of the range of networks
FP2 UK	Peterson and Sharp (1998), Georghiou (1994)	High generation of new products, processes and prototypes; modest generation of patents	Acquisition of research skills	Large impact on acquisition of technical knowledge
FP3-4 UK	Segal Quince Wicksteed (DTI AU No. 39, 1999)			Large impact on acquisition of technical knowledge
Japanese programmes	Sakakibara and Cho (2000)		Leveraging private R&D inv.	
LINK	Technopolis (2002)	High incidence on innovation outputs (patents, prototypes,…)	Higher than average papers' citation rate	Very important knowledge-oriented goals

Exhibit 9 summarises the major outputs of surveyed national programmes, sorted alphabetically on programme name. A more detailed analysis of the evaluation of each programme is reported in the following sections.

6.2 Other European collaborative research programmes

6.2.1 EUREKA

Eureka, a French initiative, was introduced in 1985, shortly after commencement of the first Framework Programme, but has significantly different characteristics: it is concerned with 'near-market' research, most of the public funding is provided by national governments rather than the EU, and research organisations are themselves responsible for designing projects (Peterson and Sharp, 1998).

EUREKA's main objective is to strengthen European competitiveness, by promoting 'market driven' collaborative R&D. Projects need to be high-tech and involve at least two EUREKA members. EUREKA is by far the largest non-EU collaborative programme in Europe – by the mid-90s it was only marginally smaller than the Framework Programme. Although the number of projects was rising, their average size was declining. It is also one of the most evaluated. Peterson and Sharp (1998) find that national evaluations 'mirror quite directly the extent to which member state technology policies have made EUREKA a national priority'.

Two major evaluations have concluded that:

- the programme has built upon established patterns of collaboration rather than stimulating the creation of new ones
- participants express a high level of satisfaction
- only about 40% of all projects appear to be 'truly additional'

These conclusions might imply the programme provides something rather close to a direct subsidy. There appears to be little 'spillover', and little integration or harmonisation of national technology policies, with a good degree of furthering individual national policies to suit existing goals (Peterson and Sharp, 1998).

Projects with SME involvement tended to be closer to market than others, however SMEs expressed lower levels of satisfaction as compared with larger firms and other categories of participant.

The 2002-03 EUREKA Impact Report noted that some 1300 projects had been completed over the programme's 19-year history, at a total cost of over Euro 14bn. The report claims an average 6-fold rate of return on public investment, and to have identified 11000 'newly created or safeguarded jobs, with an expectation for a further 15000 within three years.'

6.2.2 COST

COST (European Cooperation in the field of Scientific and Technical Research) was established in 1971 to coordinate pre-competitive research, initiated by participants themselves at the national level. COST 'Actions' typically last 3-4 years and are funded nationally, there being a minimum of centralised administration and EU funding limited to helping to meet coordination costs. A COST Action is subject to a Memorandum of Understanding signed by at least five partners, and has its own management committee composed of representatives of the signatories, and is described as 'bottom up'.

COST's stated objectives are to:

- provide a flexible framework for European cooperation in basic and applied scientific and technical research, including the creation and implementation of research projects of European significance, without formal constraints on particular research areas to be covered

- encourage and implement international R&D activities corresponding to clearly focused needs, which are best conducted through such flexible coordination
- promote pre-competitive R&D cooperation between industry, institutes, universities and national research centres, and to expand interdisciplinary approaches to R&D cooperation
- create scientific networks and to promote and encourage new scientific talents

The COST budget derives from the international cooperation budget line of the Framework Programme, and amounts to around Euro 15m annually. However, when looked at in terms of the volume of national funding associated through COST, the figure increases exponentially to more than Euro 1.5bn, which is comparable with Framework. An average of around Euro 60,000 per Action is available for coordination depending on size and activity of the Action. This expenditure represents on average 0.5% of the overall national funding of the related work being pursued by the network members, and paid for by member states. Coordination costs are used as contributions to workshops/conferences, travel costs for meetings, contributions to publications and short-term scientific missions of researchers to visit other laboratories.

Compared with the Framework Programmes, COST is seen to have a low entry threshold, to be more open thematically and to have greater potential for supporting large networks. The evaluation considered that:

> COST is neither a substitute for the Framework Programmes' major research initiatives, nor is it something that has been rendered obsolete by them. In many ways it complements these initiatives, and can be justified in part simply as providing an alternative, flexible, bottom-up mechanism – avoiding having all of one's eggs in one basket, for a rather modest outlay.

With funding from the EU Sixth Framework Programme, it supports more than 160 networks of researchers in 17 scientific and technical domains. It underpins the European Research Area and its Actions (networks) have catalysed substantial research funding, FP6 networks of excellence, and contributed to the setting of norms and standards. COST adopts a different approach to both Framework and EUREKA in financing the interaction of scientists and engineers whose research work is paid for by Member States or other international research programmes, including Framework. It is designed to facilitate knowledge exchange rather than joint research, and as such arguably it would not be viable as a standalone programme. As with EUREKA, and in marked contrast to Framework, COST favours a "bottom-up" approach to cooperation with geographical partnerships looking very different from one project to another. Its programme budget, which is two orders of magnitude smaller than Framework, derives from Framework. It is governed by the Committee of Senior Officials (CSO), which brings together the representatives of the Member and associated countries. The CSO secretariat is located in the General Secretariat of the Council of Ministers. Operationally, COST is supported by the ESF-COST Office.

An evaluation of COST was carried out in 1997 (PREST et al., 1997). The general conclusions were that it benefited from its flexibility and diversity, and 'adds considerable value to nationally-funded research programmes.' However, while COST was seen as 'clearly successful' in terms of facilitating collaboration, it is 'not always equally successful in incorporating a wider range of participants, acting in *some* instances more as a club for insiders than as a medium for wider participation.' COST collaborations were found to typically build upon pre-existing research networks,