FINAL REPORT

CONFIDENTIAL

Contract No.: **SOE1-CT96-1036**

Project No.

Title: **European Comparison of Public Research Systems (EUPSR)**

Project coordinator: University of Sussex, Science Policy Research Unit (USUSS.SPRU)

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Starting date: 1 March 1997 **Duration:** 2 years (+ 2 months extension)

Date of issue of this report: August 1999

TSER Project No. SOE1 - CT96 - 1036

Changing Structure, Organisation and Nature of European PSR Systems
Work Package 3

FINAL REPORT
European Comparison of Public Research Systems

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August 1999

Abstract *(1 page)*

This study compared the changing organisation and structure of public sector research (PSR) in 12 European countries, and developed a methodology to examine how national policies affect researchers at bench level. The results reflect growing convergence among the previously rather distinctive functions of various sectors of PSR, a growth in the importance of university research and a casualisation of Europe's research labour force. PSR has a wide range of functions. In every country there has been increasing emphasis on the promotion of economic growth, innovation and technology transfer. Research collaboration of all types is increasing, including collaboration by the various sectors of PSR within countries, as well as collaboration between countries. There are also common trends in management practices across countries such as evaluation and mechanisms for strategic planning, but diverse results due to the differing characteristics of each national PSR system. Each country can learn from others; but what it learns must be tailored to the specific national PSR system.

The development of the methodology was experimental and an important objective was to test it and make it more robust. The methodology involved a postal questionnaire and in-depth case studies and was applied to the human genetics research community. Lessons were learnt from each approach and are a major result of this part of the project. Analysis of almost 400 postal questionnaires found that research groups could be differentiated by their involvement in four activities: research training, academic pursuits, industrial interaction and relationships with clinical practice. 22% had no marked involvement of any type; 23% focused on traditional academic outputs (training and publications); 22% had strong socio-economic interactions (with clinicians or industry) and 33% engaged in every activity. Neither nationality, sources of funding nor facilities explain the profile of activities. Institutional type had a weak effect. The main result is that the size of the research team matters, but we do not yet understand why. Case studies found that the human genetics research community is implementing the priorities set by European governments. Flexibility in research and career planning, mobility, openness to transdisciplinary and international collaboration and demonstration of socioeconomic relevance are an integral part of most research units' and scientists' strategies. Increasing ìshort-termism“ in research funding may have adverse effects on the quality of research, and discourage promising young researchers from staying in the field. Further work is required to understand how local management practices, and in particular how the allocation of researchers to different duties, affects the activity profiles of research units.

The results of the study suggest the need to correct the current over-emphasis on PSR to promote industrial innovation, which may tend to favour short-term over the longer term research whose potential may only be realised in the distant future. The casualisation of scientific manpower and poor PSR career prospects give rise to concern about negative effects on research quality and the loss of promising young scientists to research careers. Both tendencies may harm industrial innovation, which is also threatened by the decline of specialist sectoral institutes. In particular, universities may lack capability or interest to meet the needs of SMEs. There are also doubts about the ability of disciplinary-based universities based on short-term contract researchers to provide government ministries with the impartial, long-term, in-depth and interdisciplinary background expertise previously on-tap from dedicated research institutions, as the need arose. Finally this study has identified a loss of public trust in the advice of scientific "experts" and recommends that PSR gives more attention to public welfare and safety aspects of science and technology.

1. Executive Summary *(maximum 15 pages)*

1.1 Introduction

This study compared the changing organisation and structure of public sector research in 12 European countries. It also developed and applied a methodology to examine how national policies affected researchers at bench level. The sample of countries involved in the study - Denmark, France, Germany, Hungary, Iceland, Ireland, Italy, Norway, Portugal, Spain, Sweden and the UK - have diverse characteristics and include: EU members and non-members, including one coping with the transition from a planned to a market economy; large and small countries; developed, less developed and rapidly growing economies. The great interest which this project evoked, and its relevance, is shown by the fact that three self-funded partners (from Italy, Iceland and Sweden) joined the six partners funded by the EC.

The main aims of the project were:

1. to gain a deeper understanding of the changing structure and dynamics of PSR systems in a range of European countries, and of how these relate to the wider social, institutional and political context in which those systems are embedded.
2. to use this information to assess on a comparative basis the strengths and weaknesses of different organisational structures of PSR systems.
3. to develop a sound methodology for conducting cross-national case studies of PSR in areas vital to public welfare and safety.
4. to review the relationship between national and supra-national organisations in the support of PSR in this area, and to compare the extent and organisational forms of intra-European and extra-European networking.

1.2 Methodology *(short text)*

The project utilised two complementary approaches to meet these aims. The first, a top-down approach, focused on preparing national reports about the changing organisation and structure of public sector research in twelve countries. When the national reports were completed, a synthesis report was prepared which attempted to map broad-scale similarities and differences between countries. National reports adopted a common definition for public sector research and a common framework of issues to be discussed in the reports. The team adopted the OECD and EU definition of research: "original investigation undertaken to acquire new knowledge in the natural sciences, social sciences and humanities." A new definition was developed for "public sector" to reflect the heterogeneity of the institutions involved and the impact of recent changes to public policy for funding and controlling research. This definition is based on criteria of funding, control and accessibility of results:

> "Public sector" covers those institutions for which the major source of funds is public; and which are in public ownership or control (or have converted to private ownership since 1980); and which aim to disseminate their research. It also covers the organisations of officially recognised charities or foundations which raise the majority of their funds from the general public, and whose main activity is research.

The focus of the national reports is therefore civil research, but includes the civil research of institutions which carry out both civil and defence research, and distinguishes clearly between them.

The second part of the project aimed to complement the national reports by taking a 'bottom-up' approach based on the analysis of research collectives. It aimed to develop a sound methodology for conducting cross national case studies of PSR in areas vital to public welfare and safety. It drew on previous work in science studies which shows that research activity is a collective endeavour and that research units or ìlabs“ are to science what firms are to the economy: the basic units of production. Building upon this image suggests that understanding the dynamics of a given organisation or of a ìnational system“ requires the identification of the main types of production units and the factors which favour, constrain, direct and shape their growth. The specific objective was to undertake a pilot study to develop a "harmonized framework for characterizing research collectives across countries", to test it in a given research field and see how it helped to better grasp common dimensions and specificities of given national research systems. It involved both postal questionnaires and in-depth case studies of human genetics research labs.

Human genetics was selected as the field to study because it was thought to be performed in every country and because it is related to genetics, the field of biological sciences which has been subject to revolutionary changes over recent decades. Progress in knowledge and techniques has led to an explosion of research which is relevant to economic development, to new models or medical practice and is also affecting the organisation of research and education in the biomedical and medical fields. High priority has been given to genetics research since the early 1980s, both by the EC and its Member States, and it is frequently used as an example of the "new mode of knowledge production": it is transdisciplinary, has an applications-orientation to research in which the boundaries between basic and applied research are blurred; and research is performed in a variety of locations under diverse funding arrangements.

1.3 Main results: the national reports (50/60 pages)

PSR systems expanded rapidly in every country, especially during the 1960s. At this time the OECD helped to accelerate investments in public sector research, especially in countries with a poorly developed science base. The European Community has also played a role in the modernisation of countries with under-developed PSR systems.

Public sector research is carried out in a diversity of organisations. The three main sectors are: (i) universities, (ii) non-university research organisations for general or specific functions and (iii) Government laboratories to support policy formation and implementation. These organisations carried out the following functions, with the relative importance ascribed to each of these functions changing over time:

- i) the advancement of knowledge;
- ii) to support policy formation and implementation;
- iii) to support public welfare (e.g. health, the environment, public safety etc.)
- iv) to support economic development (inc. technology transfer);
- v) programmes to build up and support prestige activities and capabilities in "frontier" science.

The proliferation of funding organisations led to weak coordination of PSR in most countries. The last two decades have been a period of extensive restructuring of Government arrangements for PSR. Changes have been made to Ministerial responsibilities for PSR, the organisations which allocate funds, the institutions performing research as well as the functions which PSR is expected to perform and general principles underlying PSR as expressed in Government rhetoric.

There is a diversity of funding arrangements for PSR. Two main approaches can be identified and, within any country, the two approaches may run in parallel. These approaches are the Research Council model in which grants for university research are allocated on the basis of competitive peer review. These grants complement core funding which covers academic salaries (and assumes that a proportion of their time is dedicated to research) and research infrastructure. (French Research Councils, however, support accredited research units and allocate their researchers to these units). The second approach - the block grant system - gives researchers in relevant universities, research institutes and government laboratories a degree of freedom in deciding on the internal allocation of funds. There is a slow but steady erosion of 'block grant' systems in favour of competitive applications for grants, and a growing role, in some larger countries, for regional agencies to act as funders of research. Whatever the system, every sector of PSR is under increasing pressure to raise research funds from external agencies.

There is a marked change in most countries in the distribution of research among different sectors of PSR, with an increasing proportion of research taking place in universities and a decreasing role for research institutes. Governments in every country have put growing emphasis on all sectors of PSR supporting innovation, undertaking 'relevant' research and engaging in technology transfer. The level of autonomy for academic researchers differs between institutions and countries but the self-governance of researchers is being eroded by such demands and the growing proportion of research funds being allocated to research priorities determined by Government.

Government resources for PSR have remained static in most countries and PSR has been encouraged to look for new sources of funds. Additional resources have been provided by the EC's Framework Programmes and Structural Funds, by charitable foundations in some countries and by industry. There has been a general decline in energy research and apparent growth in resources for "applications-oriented" research in new and key technologies, including biotechnology and the environment. National economic concerns also affect PSR expenditure patterns.

Common trends are apparent in management practices across countries such as evaluation, mechanisms for technology transfer and strategic planning in various forms. It seems that management practices are converging because they are easier to implement than putting new institutional arrangements in place. However, the outcomes from these practices differ because there are organisational differences between countries both in the organisation of funding bodies and of university research.

Evaluation is increasing in significance and countries with limited current evaluation activity, plan for it to increase. Evaluation of EC programmes has been significant in spreading learning about these practices and late-comer countries, in particular, are catching up in adopting evaluation procedures.

Many countries are attempting to increase coordination over the PSR system. Efforts focus in particular on incorporating the work of specialised government laboratories or institutes which provide support for ministry functions into national science and technology policy. This seems to be difficult problem which generates friction and debate, especially attempts to achieve coordination across different ministries. Problems are increased in countries where regional authorities allocate funds for research.

Advisory councils traditionally provided advice to governments about the areas of research to be funded, and research funding organisations tended to have a great deal of autonomy in deciding how to distribute funds between the various areas of research for which they were responsible. There is now a slowly developing trend for research priorities to be identified through "Foresight" activities.

A variety of approaches have been adopted to link PSR with wider national economic needs. These approaches involve promoting mutual understanding between science and industry by involving industry in the policy-making process, providing technical support to industry, and by establishing a variety of mechanisms for technology transfer. Public and private technical institutes traditionally supported industry and other important national actors in many countries. There is a discernible tendency, even in countries with government-funded technical institutes, for universities to undertake contract research for industry. Technology transfer is very high on the agenda of most of the countries covered in the study. National rhetoric about technology transfer, however, does not ensure that these initiatives are successful. It is particularly problematic in southern countries where it may reflect the lack of indigenous firms involved in R&D.

Research collaboration of all types has been increasing in most countries. This includes collaboration by the various sectors of PSR within countries, as well as collaboration between countries. International research collaboration has three main components: involvement in (i) large European facilities/programmes (ii) EC research programmes (iii) research with other international partners. If any overall trend is distinguishable, it is the rise in inter-European collaborations, and the importance of participation in EC R&D Programmes to almost every country, no matter what its size, or state of development of its PSR system. International collaboration appears to have been particularly important for the smaller countries in our study.

Tight constraints on public spending in most countries have led to some recent changes to Europe's PSR systems. Political motives, international and EC influences, industrial needs and the emergence of new technologies also had an impact. Political decisions, for instance French determination to develop energy independence, has had a strong influence on the development of PSR throughout Europe. Such decisions are often influenced by the actors involved in advice and decision-making, and the objectives they wish to attain. In Portugal and Spain decisions are strongly driven by the scientists themselves, because of lack of awareness of the strategic significance of science and technology by many of the bureaucrats involved in decision-making. Industry plays a large part in the process in large developed countries. Public actions can also influence the research agenda. For instance, in several countries contributions by the public provide a significant amount of funds for medical research. European collaborative facilities have also provided the potential for individual European countries to maintain expertise in some areas of "big science" where the cost of going it alone is too costly.

The emergence of new technologies has perhaps been the strongest driver of change. Developing research capability in the new fields of IT, biotechnology and new materials at a time of static or falling PSR budgets, demanded the development of mechanisms to identify research priorities so as to redistribute funds from traditional to new fields. Helping industry to compete in the new technologies required that higher education be expanded to train qualified manpower and research staff. Increased links between industry and PSR were necessary to enable industry to access knowledge about the new technologies because traditional PSR sources of expertise for industry often lacked competence in these new fields. The new technologies also enabled the development of more sophisticated scientific instruments, and widened the range of disciplines which required such equipment. Both these trends increased the cost of research, and may explain many of the increased links between sectors of PSR. Fourthly, the pervasiveness of the new technologies across disciplinary fields and government responsibilities demanded methods to better coordinate the research activities of organisations responsible for public sector research. In particular, new technologies are characterised by interdisciplinary research and a blurring of boundaries between basic and applied research and development. This may also apply to other fields, but the process is driven by the new technologies, and creates the need for new organisational structures and funding arrangements.

1.4 Main results: the analysis of research collectives

Research collectives of "labs" were studied in two ways. The first approach focused on analysing birth and growth dynamics and links to the wider institutional PSR framework. It was based on a limited number of in-depth comparative case studies in six countries: Germany, Ireland, Norway, Spain, Sweden and the United Kingdom. The approach to developing the methodology was experimental and an important objective was to test it and make it more robust.

The prioritisation given to human genetics research during the last fifteen years is reflected in the case studies. Most case study research units were established or redirected their research agenda towards human genetics during the late 1980s or early 90s. Even the smallest countries have several active research groups. The time when and the degree to which countries entered the field is explained by three variables: country size, level of economic development and cultural factors. Thus research in the field started first in the larger developed countries before moving to smaller developed countries, and moving finally to those which were either small and/or less developed. All the countries involved had pursued an innovation-oriented research policy for PSR since the late 1970s which involved competitive resource allocation, quality control and a demand for increased social and economic relevance. The transdisciplinary research units, located in a variety of institutional settings, are typical of the "new mode of knowledge production". The problem-oriented character of research seems to promote ìlocational fragmentation“. In neither teaching nor patient care is human genetics recognised as an independent medical discipline, so researchers move between university faculties, research institutes or hospitals to those offering the best research conditions, especially tenure-track positions and a stable resource base.

Specialised skills and technologies play a central role in research. The recruitment of new staff largely determines the composition of disciplinary knowledge and technical skills available in the unit and thus its future research trajectory and success. Research collaboration fills gaps in skills, expertise and techniques, but are also vital for access to blood and tissue samples and access to patient histories.

The impact of national research policy on human genetics researchers is clear. Resource allocation largely takes place on a competitive basis, most researchers are employed on temporary contracts or on a project by project basis and the bulk of research activities is financed by success in winning competitive grants from external funders. Tenure positions and long-term core funding are scarce and where such privileges exist researchers are subjected to regular evaluation.

Research funds are provided by governments and research councils, mission-oriented government agencies and hospitals, foundations and charities (in some countries) and, to a lesser extent, the European Union and industry. Flexibility in research and career planning, mobility, openness to transdisciplinary and international collaboration and demonstration of socioeconomic relevance are an integral part of the identity and self-awareness of most research units and scientists.

The main negative effects of changes in research policy come from increasing ìshort-termism" in research funding. Two or three year contracts are inadequate for producing high quality research, especially for complex and long-term basic research which requires a minimum level of stability. Moreover, promising students and young researchers are discouraged from staying in the field by the lack of career prospects.

Flexibility and responsiveness are central assets in this highly dynamic research area where knowledge, techniques and applications are rapidly expanding and advancing. Research units follow either a niche or a diversification strategy to ensure organisational survival. The former is pursued by units specialising in specific diseases or techniques. They aim to reach a leading position in a particular disease or technique where tacit knowledge, skills and access to blood, tissue and tumour samples and local patient populations are important. The latter concentrates on a specific disease or technique, but broadens the aspects or areas dealt with.

The second methodological approach focused on developing a reproducible method for the characterisation of a large set of research collectives, or "labs". It was based on the pragmatic identification of entities through the use of bibliometrics and the development of a postal questionnaire. Seven countries were involved: France, Germany, Iceland, Italy, Spain, Sweden and the United Kingdom. The results are based on analysis of almost 400 completed questionnaires, which makes this one of the largest studies on labs ever undertaken. The analysis considered "classical" indicators (inputs, institutional and organisational settings); and involvement by labs in academic pursuits, research training, clinical and industrial activities. A global overview of these activities identified four distinct activity profiles. These profiles were linked to the "classical" indicators.

The average size of a human genetics lab is 23 people, made up of senior and junior research staff, technicians, clinicians and doctoral students, with national variances in internal composition. The average is nearer 30 people in the large countries and 20 for the smaller or less developed ones. Over 80% of labs are located in a university or university hospital setting, but only two-thirds are affiliated to these institutions. One-fifth are associated with government research organisations and the remainder are divided between foundations and general hospitals. Labs draw the majority of their funds from competitive sources, with 38% being provided from national project funds and 37% by foundations, industry, the EU and regional funds. Long-term core funding contributes an average of only 25% of budgets. There are significant differences between countries in the proportion of funds received from each source. Germany and French labs receive high proportions of core funding, but Spanish labs get only tiny amounts. Foundations play a very significant role as funders in Britain and are also important in Sweden and Italy.

The analysis of labs activities considered relative involvement in research training, academic pursuits, industrial interaction and relationships with clinical practice. Research training in labs was based on ratio of doctoral students to research staff and the number of PhD theses completed in the last three years. Academic pursuits were based on the average number of publications in academic journal per researchers over a three year period, as well as other activities including networking within the public research system and general involvement in the management of the discipline. The industrial involvement of labs was based on an index constructed from the industrial activities performed, the breadth and nature of links and the industrial share of the budget. Clinical involvement was measured in similar ways, but the third element was relative importance of clinicians in lab staff, rather than budgetary contributions. On average clinical involvement is more marked than industrial involvement and more diffuse. Four main patterns of strong involvement were found: 22% of labs had no marked involvement of any type; 23% focused on traditional academic outputs (training and publications); 22% had strong socio-economic interactions (with clinicians or industry) and 33% (all embracing labs) engaged in every activity. An analysis was next undertaken of the relationship between the four activity profiles and data on institutions, inputs and national contexts.

(i) Does nationality matter? Nationality may matter for the capability of labs to emerge in a given field, but the analysis did not aim to answer this question. It appears to be a crucial question since, once created, there do not seem to be major differences between countries in favouring one or other of the profiles.

(ii) Do institutions matter? Yes, institutions matter, but strikingly enough not because they handle different types of labs differently; it is more probable that they matter because of the wider environment they correspond to and thus the indirect stimuli which derive from it.

(iii) Do sources of funding affect the orientation of labs? The most important sources are competitively allocated national funds and core funds. The aggregate level from these two sources is similar in all four configurations (around 63%). Academic labs receive far less core funding than average (18% against 25%) and far more competitive funds from national sources (48% against an average of 38%). Labs with no marked involvement have above average core funds (35%). National differences cannot be easily related to these findings. The industrial impact on labs remains limited since even the most heavily involved labs receive only 15% of their budgets from industry.

iv) Do facilities differentiate situations? A large percentage of labs used external facilities for their research. Only 2% consider their research is constrained by lack of equipment or lack of access. Facilities matter but are easy to acquire or to access.

(v) Are different human resources required for different types of activities? The average size of lab (23 people) is typical of labs both with no marked involvement and those engaged in all activities. Academic only labs were smaller (averaging 13 people) and socio-economic only labs larger (35 people). The answer to this question is thus clearly yes, but the way in which it matters is not straightforward. There is a strong relationship between size and numbers of research staff (but not to other personnel in the lab). The allocation of research staff to various duties by institutions may explain these findings, but the questionnaire failed to address this issue.

(vi) Does age matter? Is there potential for labs to move between profiles, starting: from no marked configuration and then slowly gaining in involvement and recognition. The results do not confirm this. The average age of labs involved in all activities is greater than that of ìacademic“ labs (13 years against 9), but the latter is similar both to ìsocio-economic only“ labs (14 years) and of labs with no marked involvement (13 years). Thus we are driven to hypothesise that initial phases are crucial and set labs in a trajectory which is then difficult to change.

Our analysis thus found that activity profiles have a limited relationship to labs' national and institutional location. National contexts impact on the way in which inputs are assembled, but it is not clear how much national channels for accessing resources are involved in setting labs on a given trajectory, since we have hypothesised that movements from one profile to another might be neither easy nor numerous. The results also highlight the presence of all configurations in all institutions but, once created, labs appear to develop quite autonomous strategies.

The results from both approaches to studying research collectives have great policy relevance. Significant progress has been made in developing methodologies to explain the relationship between top-down science and technology policy and "bottom-up" responses by PSR researchers. especially the way in which such an approach should be implemented in future. Despite the limitations of the approach adopted we found that some researchers manage to take advantage of policy to promote their own interests. This re-emphasised the need for future projects to be mindful of the role of researchers in shaping science policy

The results of this part of the project are of particular relevance to funding agencies. They emphasise the growing significance of biology, and of genetics in particular, within science and technology budgets in the most advanced countries, in supranational organisations and in foundations. The methodologies developed meet funding agencies' need for instruments to assess the outputs from the research they fund. The tools developed (aggregate indexes and case studies) can also trace the logic behind the actions of the actors involved in PSR and provide new indicators to identify and assess scientists' internal and external research links.

1.5 Conclusions and policy implications

Integrating knowledge from both parts of the project makes a considerable contribution to meeting the aims of the project and identifies a central issue not anticipated at the outset of the project. The findings have numerous policy implications.

The first objective of this project was to deepen understanding of how far the changes to PSR systems are related to the social, institutional and political context in which these systems are embedded, and how far they reflect wider global trends.
Both global and national influences are reflected in our studies. Societal dynamics, the challenges for PSR and political reactions to these challenges are basically the same within all the countries studied. Political goals have converged around six issues: better management of PSR, higher flexibility of PSR, more collaboration within PSR and between PSR and users, more coordination of PSR and of research policy, more political control of PSR through evaluation and related measures, and a strengthening of university research within PSR. Nevertheless countries differ in the specific political measures implemented and in the effects of such measures on the structure and dynamics of PSR.

Measures to shape PSR are often introduced in situations of great uncertainty, when information is rather incomplete, strongly conflicting values are at stake, and time pressure is high. "New institutionalism" explains that in such circumstances actors search for ready-made models of what to do, and often imitate what appears to be a successful measure by someone else in a similar situation. This type of imitation leads to a convergence between countries, which is reinforced by analyses and advice of institutions like the OECD and the EU.

Path-dependence - a country's history and institutional structure - resists any tendencies towards convergence which might be produced by imitation. Path-dependence maintains diversity, and is a kind of international division of risk. Diversity prevents all national systems from making the same mistakes and the differences between national systems open up manifold opportunities for learning. Each country can learn from all the others; but what it learns must be tailored to the specific conditions of its own system of PSR.

A second objective was to assess the strengths and weaknesses of different organisational structures of PSR systems. Every part of this study has reflected the growing convergence amongst the previously rather distinctive roles of various sectors of PSR, a growth in the importance of university research and a casualisation of Europe's research labour force, both in universities and research institutes.

Universities traditionally focused mainly on research for the advancement of knowledge and the training of new generations of researchers. Government laboratories (or special mission-oriented institutes) focused on supporting Government policy formation and implementation, including issues of public safety and welfare. Some institutes had responsibilities to concentrate on supporting industry. These activities were complementary, with each sector drawing on the knowledge and expertise developed in the other sectors of PSR. Every sector of PSR is now in competition for research contracts from Government and industry. Moreover, research for the advancement of knowledge is often restricted to the areas prioritised by Government for support. There is also evidence that boundaries between university research and long-term, mission-oriented government laboratories are becoming blurred.

Universities appear to be gaining from a shift in the balance of funds being distributed to PSR, but are coming under pressure to carry out research to meet government priorities and of relevance to users, as well as trying to ensure that their research results are transferred to industry. Research institutions have reduced budgets forcing them to work as contract researchers for Government and industry.

Our results do not allow us to reflect on the strengths and weaknesses of different organisational structures of PSR systems, but the growing convergence between different types of PSR and the changing location of PSR research raises some important questions? Does PSR require a cadre of full-time, experienced, professional researchers to undertake research and provide a pool of scientific expertise? To what extent will the output of PSR suffer if they are replaced by part-time inexperienced people? Can university researchers provide government ministries with the long-term, in-depth, background expertise previously on-tap from dedicated research institutions, as the need arises? Can research institutes, dependent on contract research funds, act as impartial policy advisers to government. Will the public trust the judgements of scientific experts from PSR institutions carrying out industrial contracts? Institutes generally employed interdisciplinary teams of research staff working on particular missions. Will it be possible to develop stable, interdisciplinary teams when research is organised in disciplinary-based university departments? Is it possible for university departments or research institutes which rely on short-term contract researchers, to accumulate, share and apply the knowledge developed?

The case studies suggest that there are advantages in the flexibility produced by a large percentage of temporary contract staff. Constant turnover of staff allows a continuous influx of ideas, skills and techniques, which leads to success in applying for competitive research funds. Temporary contracts also have negative effects, and threaten programme continuity, research driven by scientific curiosity and the loss of promising young scientists from research careers.

The third objective was to develop a sound methodology for conducting cross-national case studies of PSR. The approach to developing the methodology was experimental and an important objective was to test it and make it more robust. Lessons learnt from the development of each approach, which were far from linear, are thus a major result, if not the main result of this part of the project. Both approaches were fruitful, suggesting the existence of contrasted configurations of research groups and highlighting major organisational dimensions which shape their interactions with the wider national systems. We also found that there can be a major element of complementarity between ìtop-down“ and ìbottom-up“ approaches. A major lesson from both approaches is that the "top down" research must focus on the research field under study. The ‘top-down’ part of the PSR project was not designed as such, and embraced the whole of public sector research. Further work should ensure a coherence between both approaches to take full advantage of their complementarity. The second major lesson was recognising the imperative need for the questionnaire and case study approaches to be carried out sequentially, and to allow sufficient time for this in future projects.

Although this was a very specific case study, it is tempting to speculate that human genetics may offer a good example of the way in which life sciences research is developing. Areas such as general biology, botany, entomology, ecology and taxonomic studies now appear to be moved by the same impulses and constraints, i.e. interdisciplinarity and transdiciplinarity; context of application; changes in institutional, organisational and funding arrangements and the need for more social accountability.

However successful, this first cross-national study raises several questions. We selected a field which we thought would reflect the ìnew“ mode of production. Did this choice affect and constrain our conclusions? Other fields, with more traditional relations both to institutions and to the economic world, e.g. established fields in the health sector or in engineering sciences, should be considered before generalising hypotheses about the role of institutional and national dimensions on the emergence and development of labs. We advocate that another study should be undertaken on a more ìtraditional“ field, a study which would benefit from the methodological lessons derived from this exploratory work.

The fourth objective of the study was to throw light on the relationship between national and supra-national organisations in the support of PSR and to identify any tensions between inward-looking, nationally-networked public research and the potential emergence of a distributed European knowledge production network based on outward-looking and inter-linked national scientists and centres. These are very ambitious aims. Our study indicates that there is extensive PSR networking within countries as well as strong linkages throughout Europe and the rest of the world. It is not clear whether European linkages reflect the potential emergence of a distributed European knowledge production network.

The national reports show that policies to promote collaboration are a common feature of European PSR systems. National and/or regional policies have given increased emphasis to closer links between the various sectors of PSR. The intention appears to be to improve integration and knowledge flow between national researchers working in the same broad fields, as well as to save costs through sharing expensive scientific equipment. The results of the questionnaire and case studies show that these collaborations are central for the majority of human genetics research groups because the field transcends disciplinary boundaries. Collaboration is also demanded because even the largest research units may not have all the resources now required to carry out competitive research. The second type of collaboration is the promotion of closer interaction between PSR and industry, as well as with other users. The intention is for PSR to be more responsive to national needs so that it can strengthen the economy by contributing to industrial innovation, and is also able to provide expertise to address social or environmental problems. The results of the questionnaire on human genetics research groups show that half the research group have long-standing relationships with hospitals and 17% have strong links with industry but 43% have no strong relationship with any type of socio-economic actor.

National policy also supports foreign collaboration and has been especially important in small countries, where researchers would otherwise have difficulty in finding colleagues with complementary interests. The two main factors affecting national policies for international collaboration are firstly, the increasing cost of "big science". Collaborative European laboratories have minimised the heavy costs previously borne by individual countries which tried to maintain national facilities, and helped them to maintain their expertise in these areas. The second influence is the impact of EC's Framework Programmes. These programmes generally require that research be carried out by researchers in more than one country, and/or have an industrial partner. Although EC funds account for only a small part of most countries' overall public sector research budgets, it appears that the availability of funds for these EC programmes is accelerating the growth of intra-European research collaboration. Some national reports note that these European collaborations may be substituting for previous collaborations with the US. What the reports cannot identify is whether these intra-European collaborations would persist in the absence of EC programme funds, or whether US collaborations would be a preferred option, should funds be made available on a similar scale for collaborating with the US.

The case studies in the second part of the project show that scientists in small developed European countries, such as Sweden and Norway, have benefited from national policies which encourage international collaboration. Their scientists have been enabled to maintain close contacts with world centres through study and work abroad, enabling these countries to establish "niches of excellence". Both large and small less developed countries (Ireland and Spain) have yet to develop such strategies. From this point of view, both countries have benefited from the EC's Framework Programs. Participation by Irish and Spanish researchers in joint EC research projects and programmes has provided access to international research networks and the latest knowledge and techniques. The experience of these two countries also suggests that the existence of European programmes provide both the incentives and resources for poorer countries to develop a national research effort in human genetics, hitherto neglected by research policy or funding agencies.

The findings of the study that policy for PSR throughout Europe is privileging industry and the promotion of innovation, led to recognition that lower priority is now attached to its responsibility to act as a "watchdog" in matters concerning research which may affect public safety, the environment, sustainability, and so on. This neglect may be related to governments taking increased control over the governance of PSR at a time when a series of disasters connected with deficient scientific advice has led to public loss of trust in the advice of scientific "experts". It also appears to reflect problems connected with the shift from modern to postmodern paradigms for science and technology policy.

The former paradigm, based on *Science: the Endless Frontier* (Bush, 1945) started to founder in the 1980s. It enshrined unfettered basic science to be performed without thought of practical ends, a disciplinary basis for knowledge production, the autonomy of the scientific community, free diffusion of knowledge, altruism and the use of expert peers as the sole judges of research excellence. The post-modern paradigm is based on new modes of multidisciplinary and interdisciplinary knowledge production and a non-linear, complex and interactive model of innovation. Moreover, it rests on a new social contract where the relationship between government and science is not only more direct but mediated by social and economic demands and needs.

Disasters such as global warming, Bhopal, Seveso, Chernobyl and BSE have raised public concern about the application of new technologies. The public increasingly recognises the shortcomings of science and is unwilling to accept the reassurances of the scientific-political establishment (Beck, 1992; Lash et al, 1996). Beck suggests that these attitudes characterise "risk society" characterised by a preoccupation with technological threats because of the failure to develop effective institutional controls or to recognise the limitations of reductionist science. Ecological modernisation - a more optimistic scenario - describes societies which recognise the shortcomings of scientific inquiry, emphasise technologies that support social learning and promote institutional flexibility. Social capital, or the degree or trust and association between a society's members, and the ability to formulate political consensus around problem situations facilitate the move from risk society to ecological modernisation (Cohen, 1999).

This analysis indicates that governments which fail to give sufficient attention to public welfare and safety aspects of research, or to involve the participation in risk analysis of all interested and affected parties may find their PSR policies increasingly open to public challenge. Moreover, PSR policy which continues to privilege industry may perpetuate "risk society", and hinder rather than promote industrial innovation. This is not the only reason for advocating PSR policies which assist the development of social capital. Lack of social trust, and the growth of risk society may also deter some of Europe's most able young students from studying or pursuing scientific careers, and lead to shortages of trained scientists and engineers for both the public and private sectors.

The results of the project have numerous inextricably linked policy implications.

- There is an urgent need to rectify the current over-emphasis on PSR to promote industrial innovation. More attention should be given to developing social capital by allocating funds to PSR programmes which investigate topics connected with public welfare and safety. Such programmes should not be open to PSR institutions or researchers receiving more than a very small percentage of their income (e.g. 5%) from industry (for industrial research contracts, acting as consultants etc.) There is also a need for science and technology funding agencies to take account of public perception and risk assessment in assessing new bids.
- The convergence of activities and the blurring of the "missions" of the various sectors of PSR carry inherent dangers. In particular there are great doubts about the ability of disciplinary-based universities based on short-term contract researchers to provide government ministries with the impartial, long-term, in-depth and interdisciplinary background expertise previously on-tap from dedicated research institutions, as the need arose.
- There are concerns that the increasing emphasis on economic returns from investment in PSR, and related instruments may concentrate resources on short-term or oriented research and lessen the availability of resources for long-term, uncertain basic research - research for the advancement of knowledge. Trends in this direction may dissuade promising young scientists and engineers from careers in European PSR. Moreover, concentration on short-term issues of current concern to industry may lead to neglect of longer term research whose potential may only be realised at some time in the distant future.
- Technological support for industry and other users was traditionally provided by specialist sectoral institutes. There are doubts about the capability of universities to replace these specialist institutes, and especially about who will take care of the needs of small companies. Universities have not typically been very good at this, and it is uncertain whether universities will be either interested or capable to meet SME needs. A second problem will be the difficulty for users, especially SMEs, to find specific sources of expertise in the widely dispersed university sector.

- The casualisation of scientific manpower may adversely affect the output of PSR, the ability to accumulate, share and apply research results, programme continuity and research driven by scientific curiosity. A more insidious effect of casualisation may be the loss of promising young scientists from research careers, either in the public or private sectors. Policies for training highly skilled research personnel must therefore run in parallel with policies for their secure employment, both in PSR and in industry. In particular, there is a need for policies to encourage commerce and industry to demand such skills, especially in some of the less developed countries. In the absence of such demand-side policies, countries which invest in the training of highly skilled staff may lose them to foreign employers.

The second set of implications concerns the way in which PSR is managed, both at a national and local levels:

- The development of new management practices should take account of national PSR strengths and weaknesses. Each country can learn from others; but what it learns cannot be adopted unchanged but must be tailored to the specific conditions of its own system of PSR.
- Policies to improve coordination of PSR are best served by following several parallel approaches from a variety of relatively independent policy-makers, rather than one unified policy. Diversity can protect the fostering of new initiatives, flexibility in the PSR system and a degree of autonomy for research institutions and researchers.
- Further research is required to understand how several factors (emergence of labs, allocation of permanent staff, existence of external facilities, specificity of national funding mechanisms) have on both the dynamics of public sector research and the policies framing these dynamics. This could be undertaken by enlarging the work undertaken in human genetics, with complementary in-depth studies to be undertaken on ìsimilar“ labs (i.e. labs sharing the same ìactivity profiles“), especially focusing on the issues which both case studies and questionnaire analysis suggested were important to explore.

2. Background and objectives of the project

During the past two decades wide ranging socio-economic and technological transformations have caused European governments to reformulate their policies for public sector research (PSR). Such policies have affected the organisation and location of research, the prioritisation of specific fields, the agencies responsible for funding research, and the mechanisms for allocating research funds. National policy-makers seek to learn from one another's experiences, but often ignore the cultural, socio-economic, political, institutional or legal context within which particular arrangements have been developed. This study aimed to provide guidance to policy-makers by bringing together information about the changing organisation of PSR in several European countries. The results were also intended to provide policy-makers with an understanding of the advantages and disadvantages of different institutional arrangements for PSR, of their relationship to specific national contexts, and of the wider trends affecting PSR systems throughout the world.

It was essential to undertake this task because there was a deficiency of comparable information and analysis on the ways in which countries organise their PSR systems. Available national studies lacked a common basis, were often out of date, and therefore failed to reflect recent far-reaching changes in the organisation of PSR. It was also hoped that the results of the project would complement findings from studies of national systems of innovation and enrich the interpretation of science and technology indicators.

Thus the main aims of the project were:

1. to gain a deeper understanding of the changing structure and dynamics of PSR systems in a range of European countries, and of how these relate to the wider social, institutional and political context in which those systems are embedded.
2. to use this information to assess on a comparative basis the strengths and weaknesses of different organisational structures of PSR systems.
3. to develop a sound methodology for conducting cross-national case studies of PSR in areas vital to public welfare and safety.
4. to review the relationship between national and supra-national organisations in the support of PSR in this area, and to compare the extent and organisational forms of intra-European and extra-European networking.

More specific project objectives were:

1. to provide policy-makers with guidance about the major trends affecting PSR;
2. to identify common features in the changing nature and functions of PSR in specific areas vital for public welfare and safety.
3. to identify any tensions between inward-looking, comprehensive and nationally-networked public research and the potential emergence of a distributed European knowledge production network based on outward-looking and inter-linked national scientists and centres.

3. Scientific description of the project results and methodology

I INTRODUCTION

The project was designed to meet its aims by two complementary approaches. The first, a top-down approach, focused on preparing national reports about the changing organisation and structure of public sector research in twelve countries. A common definition for public sector research and a common framework of issues to be discussed were used as the basis for the national studies so as to aid comparability. The definition and framework is presented in section 2. It also contains an overview and comparison of the main results of the national studies, based on analysis of the twelve national reports and discussions at workshops.

The second, 'bottom-up' approach was designed:

a) to undertake "a pilot" study as the basis for developing a "harmonised framework for characterising research collectives across countries";
b) to test it in a given research field and to identify whether it helped to better grasp the common dimensions or specificities of particular national research systems; and
(c) to determine whether any broad trends were influencing the production of public sector knowledge or the requirements for its production.

The methodology adopted and the results are reported in section 3. The overall results of the two studies and their implications for the objectives of the project are discussed in section 4.

II NATIONAL REPORTS

This section presents the main results which emerge from analysing reports on the changing organisation and structure of PSR systems in Denmark, France, Germany, Hungary, Iceland, Ireland, Italy, Norway, Portugal, Spain, Sweden, and the UK. The methodology for the national studies was developed to solve the many methodological problems connected with undertaking comparative public policy studies (Heidenheimer, Heclo & Adams, 1990). In particular, we used a common definition for the phenomenon being investigated and a common framework of issues to be discussed in the reports. When the national reports were completed, a synthesis report was prepared which attempted to map broad-scale similarities and differences between countries. A brief description of decisions reached about the definition of "public sector" and "research" as well as about the structure and content of the national reports therefore precedes the results derived from mapping similarities and differences between countries.

The Frascati Manual does not define public sector research as an identifiable category. In order to ensure that the national reports be comparable therefore demanded developing a common definition for PSR and an agreed framework of topics to be covered in each report. The following definition for "public sector" employed is based on criteria of funding, control and accessibility of results:

> "Public sector" covers those institutions for which the major source of funds is public; and which are in public ownership or control (or have converted to private ownership since 1980); and which aim to disseminate their research. It also covers the organisations of officially recognised charities or foundations which raise the majority of their funds from the general public, and whose main activity is research.

The focus of the study was therefore civil research, but includes the civil research of institutions which carry out both civil and defence research, and distinguish clearly between them. It was further agreed to adopt the OECD and EU definition of research: "original investigation undertaken to acquire new knowledge in the natural sciences, social sciences and humanities."

This definition of PSR created a new category for which there is no readily accessible statistical data. However, the research team considered it important not to rely on existing OECD definitions, which may be out of date. The complexity of the definition adopted is caused by the heterogeneity of the institutions involved and by rapid changes in public policy for funding and controlling research. It was also agreed that the national studies should focus on PSR at the performing level, and on the public policies and funding for relevant institutions. These decisions formed the basis for drawing up a check-list of issues to be covered in each national report and developing a general reporting framework.

The main items in the check-list are: the historical development of each national PSR system and its legacy; government arrangements for administration/oversight of PSR; funding organisations; descriptions of each sub-sector of PSR (characteristics, funding sources, research personnel, external relationships, and organisational issues); emerging trends and challenges; and the effects of recent changes.

The national reports concentrate on developments since 1980 but set the historical context for the development of each national research system, since this may affect the debate about research in each country and the issues which policy makers seek to resolve. The reports are based on researchers' accumulated knowledge and documentary sources. Gaps in knowledge were filled by interviews with national experts. Collection of new data on funding, number of research personnel etc. was beyond the scope of this project. However, it was agreed to use the rough approximations provided by OECD data.

An iterative process was used to produce overall results from the twelve national studies. Broad similarities and differences between countries emerged during presentations and discussions at several workshops, and similar debate influenced the shape and content of the "synthesis" report which follows.

2.1 Historical Development and Legacy of PSR Systems

Among the countries involved in this study, France, Germany, Sweden and the UK have the longest established PSR systems. World War II forms a watershed after which PSR systems expanded rapidly in every country, especially during the 1960s. This involved the establishment and expansion of universities, research funding agencies and specialised government research institutions. Similar trends were evident in Hungary, where the communist regime recognised scientific development as a leading force, and expenditure on the science system outpaced economic growth. In France, Germany, Italy, Norway, Sweden and the UK significant resources were allocated to nuclear energy research institutions during this period.

The PSR systems of several countries have been greatly influenced by their political history. Spain and Portugal's PSR systems, for instance, were at a very low level during the period of Fascist Governments and there was no strategic science and technology policy until the transition to democracy. World War II also had important effects, especially upon decisions by some countries to allocate significant resources to defence research (e.g. Sweden). The closure of Norway's only university during the German occupation temporarily halted the development of PSR. Like Iceland, its system forged ahead after World War II, with the return of well trained scientists who had spent the war years abroad.

The influence of the OECD helped to accelerate investments in public sector research during the 1960s, especially in countries with a poorly developed science base. Its debates on "technology gaps" and science policy studies were particularly influential. In Ireland, for example, the OECD promoted awareness of the link between technology and economic expansion, leading to the establishment of a National Science Council in 1967. A 1963 Italian research survey based on the OECD's Frascati Manual showed that Italy compared badly with other OECD countries. Higher education was expanded, funds were made available for applied industrial research, and efforts made to improve planning for science research. Iceland has used OECD evaluations to plan possible changes to its system since the early 1970s. Contacts with OECD were also influential on the promotion of Spanish research although, as in Portugal, Fascist dictatorships retarded development until the transition to democracy during the 1970s. The stress laid by the OECD on governments developing research policies in the 1960s also had an effect on more developed nations; for example it led to the Swedish Prime Minister holding wide-ranging discussions on science policy in the early 1960s. And in Germany the federal research ministry followed the OECD's 1968 recommendations by emphasising research planning and evaluation as instruments for priority setting and the distribution of public research funds. It is anticipated that Hungary's recent membership of the OECD may help to revive its PSR system, which declined during the economic crises of the 1980s and suffered severely during Hungary's transition from a centrally planned to a market economy.

The European Community also played a role in the modernisation of countries with under-developed PSR systems, especially by emphasising the significant role played by PSR in technologically advanced Member States. This effect tended to be related to the date at which countries joined, or considered joining the EC, with impacts on Italy in the 1960s, but not on Spain or Portugal until the 1980s.

2.2 Sectors and Functions of PSR

Public sector research is carried out in a diversity of organisations in every country in our study. There appear to be three main sectors: (i) universities, (ii) non-university research organisations for general or specific functions and (iii) Government laboratories[1] to support policy formation and implementation.

The university sector is an important player in every PSR system, and the most important in some such as Sweden and Ireland. Most countries also have non-university research organisations (research institutes or agencies) dedicated to specific interests such as agriculture, health or nuclear physics, but in Sweden this sector is very small and in Ireland it has almost disappeared, with the universities being regarded as the best place for publicly funded research. Some countries such as the UK, Italy, Germany, Denmark and Spain differentiate between these non-university research organisations and Government Laboratories which have been formed specifically to support policy formation and implementation; in others (e.g. France, Norway and Portugal) the distinction is less clear. Germany has the greatest proliferation of PSR organisations; in addition to universities and Government laboratories, it has four different categories of research institute. Many of the countries (with the exception of France, Ireland the UK and Spain) have institutes specifically involved in carrying out applied, industrially relevant research, and in transferring the results to industry; indeed this is the main character of the modest institute sector in Sweden, and the function of the Fraunhofer Society in Germany. The final form of PSR - charitable foundations carrying out their own research - is evident only in a few of the more advanced countries: the UK, France and Sweden.

Governments appear to have had either explicit or implicit expectations that their investments in PSR would achieve some of the following functions, with the relative importance ascribed to each of these functions changing over time:

i) the advancement of knowledge;
ii) to support policy formation and implementation;
iii) to support public welfare (e.g. health, the environment, public safety etc.)
iv) to support economic development (inc. technology transfer);
v) programmes to build up and support prestige activities and capabilities in "frontier" science.

All of the countries involved in this study traditionally invested in PSR to advance knowledge and to promote economic development, and these activities provided the main pillars for their science and technology policies. If there is a spectrum along which the various countries ranged in their attitudes to these two roles, Sweden and Germany were at the end which laid greatest emphasis on PSR to promote the advancement of knowledge and expertise, Ireland was at the other end, with the main focus on technological development and application to industry, and Hungary fell somewhere in the middle, with a functional division between the Academy of Sciences concerned with the advancement of knowledge[2], and the Industrial Research Institutes which carried out applied research for companies. The other countries were ranged somewhere between these two poles. Since 1980, the promotion of economic growth, innovation and technology transfer have steadily increased in importance in every country.

In several countries - Spain, Portugal, Iceland and Ireland - PSR supported important sectors of economic activity long before its role in advancing knowledge was recognised, and Irish allocations for basic research are still very low. During the 1960s, advocates for basic research in Iceland pointed not only to its relationship with applied research, but also stressed its importance in national cultural activities as well as for "maintaining self-respect and honour". Spanish investments in basic research began to grow in the 1980s, part of its programme of "modernisation" to prepare for entry to the EC.

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[1]Government laboratories are identified by their governance and by their funding. They are in the hands of a specific Ministry which funds the lab to carry out work central to the Ministry's policy needs.

[2]There was no research in universities, which were traditionally involved in teaching only. Involvement in research is a relatively recent activity for universities.

The function of PSR "to support policy formation and implementation" has been recognised explicitly in some countries only. Its recognition in Germany dates back to the end of the last century and in the UK to 1918. In Scandinavia the function is part of a Social Democratic tradition which believes in rational debate and public intervention, and leading professors may participate in policy research and discussions about policy development. It is also routine for experts to participate in policy debate in Hungary. In Norway, a separate Research Council for Social Planning (NORAS) was set up in the 1970s, responsible for funding applied social research and applied and policy-oriented institutes to serve the public sector. In many other countries support for policy formation and implementation is implicit, and apparent in the formation of mission-oriented research institutes or agencies to support government departments in numerous areas such as agriculture, fisheries, health, mining and geology, transport, building, energy or the environment. A major driver behind the establishment of these mission-oriented institutes has been to provide support for innovation in public services. Public welfare and safety were included within these broad policy support functions for many years, but in several countries, such as Germany, public welfare and safety became an explicit goal for PSR in the 1970s.

The fifth function of PSR - to build up and support "prestige" or frontier activities - is prominent in two countries, France and Italy, where it was related to supporting industry and especially "national champions". It is most marked in France, with investments in nuclear energy in the immediate post World War II period. The promotion of large industrially-based programmes for "frontier activities" in aeronautics, space, nuclear energy, computers, deep sea exploitation and telecommunications in the 1960s were supplemented by activities in small PSR institutes. A large proportion of the Italian science budget was directed towards "missions" from the mid 1960s. These focused on space research and, following the 1973 crisis, on energy, but there has been little industrial linkage with these projects.

Germany was similar to France in making commitments to nuclear, aeronautics, space and data processing research in the 1950s and 1960s and these federal priority programs drove the expansion of German PSR during this period. These areas of application-oriented big science were intended to help Germany catch up with leading countries, since knowledge in these areas was thought to be a precondition for economic development. The decision to allocate significant funds to dedicated institutions for nuclear research were to have long-lasting effects on countries such as Italy, France and Germany. In Spain, even in the period of low PSR activity, sectoral institutes (or Government laboratories) were created with the aim of supporting productive or "prestige" activities, i.e. in nuclear energy, agriculture, oceanography, public transport and aerospace. Norway mobilised science and technology to deal with the difficult climatic conditions connected with exploiting North Sea oil and gas. Its success in these endeavours in the 1970s and 1980s has directed attention on potential "missions" for research to support Norway once the North Sea energy reserves are exhausted.

2.3 Coordination of PSR

In every country there have been multiple sources of funds for PSR which include numerous government departments and agencies, as well as not-for profit organisations, industry and the EC. The proliferation of funding organisations has led to weak coordination of PSR in most countries. France traditionally appears to have had the most coordinated system, with central control over general strategy and five-yearly plans until 1981, but implementation and control were delegated to sectoral ministries. Surprisingly there was little coordination of PSR in Hungary during the days of central planning because of the relative autonomy of the individual institutions responsible for implementing Government policy. The decentralised German system of PSR has a low level of *positive* coordination, but nonetheless coordination takes place because many important decisions require unanimity between the l‰nder (or between the l‰nder and the Bund); in addition there is a great deal of informal voluntary coordination at senior levels of scientific organisations.

2.4 Stability of PSR Systems

2.4.1 Government Arrangements:

The last two decades have been a period of extensive restructuring of Government arrangements for PSR in almost every country in our study. Changes have been made to Ministerial responsibilities for PSR, the organisations which allocate funds, the institutions performing research as well as the functions which PSR is expected to perform and general principles underlying PSR as expressed in Government rhetoric.

Two trends are evident in the restructuring of Ministerial responsibilities. The first is related to the widespread expectation that PSR should now contribute to wealth creation. In most countries, therefore, there has been an attempt to merge ministerial responsibilities for science with those for technology and higher education. This can be seen most clearly in the new French Ministry of Education, Research and Technology, German Federal Ministry of Education, Science, Research and Technology, Italian Ministry of Universities and Scientific and Technological Research and Iceland's Ministry of Education, Science and Culture, which has responsibility for science and technology policy. Britain and Portugal divide ministerial responsibilities for science and technology from that for higher education.

Hungary, Norway, Spain, Sweden and Denmark have adopted a variety of other approaches. After the transition, Hungary set up new governing organisations in higher education to administer new functions related to evaluation and competitive funding, but left the rest of the system unchanged. This has resulted in a rather blurred administrative framework. Responsibility for higher education (including science) is separated from the agency responsible for science in institutes, the Academy of Sciences, and from the national agency at the Ministry of Industry and Trade involved in technology policy. Denmark has tried various formats for merging responsibility for Education, Research and Technology since 1988, but with little success. There is a great deal of tension apparent in the relationship between the Ministries of Research, Education and Industry, which currently have divided responsibilities for science, higher education and technology. Following a 1998 election there was further fragmentation, with responsibility for universities being divided between the Minister for Education (teaching) and the Minister for Research (research). Sweden, Spain and Ireland combine ministerial responsibilities for higher education and science, but a separate Ministry has responsibilities for technology policy. In Norway the Minister of Education has a special role in coordinating R&D matters at ministerial level, but there are independent efforts by the Ministry of Industry to stimulate technology development. Countries such as Spain, Italy and Portugal, however, have had limited success with integrating their science and technology policies. It has been suggested that this is due to the absence of large firms or influential economic sectors from the policy arena, which is dominated by public sector scientists.

The second trend concerns attempts to increase coordination of science and technology policies across government. Quite apart from explicit science and technology policies, many government ministries maintain specialised government laboratories or institutes to provide support for ministry functions, as well as commissioning research from other sectors of PSR. Recent years have witnessed largely unsuccessful attempts to incorporate these disparate activities into overall government science and technology policy.

2.4.2 Funding arrangements

There is no single model able to reflect the diversity of funding arrangements for PSR in the countries studied. It is possible to identify two main approaches and, within any country, the two approaches may run in parallel.

> a) *the Research Council funding model*: Research Councils provide grants for university research projects, based on allocation by competitive, peer review. These grants usually complement "underpinning" or "floor" university funding, which provides the infrastructure necessary to carry out research and assumes that a proportion of tenure academics' salaries account for time spent conducting research. This model broadly covers universities in the UK, Norway, Sweden, Denmark, Iceland and Hungary, but even within this group there is a wide diversity in the proportion of academic salaries which is intended to cover research activities. UK academics are given only marginal time for this activity from "floor" funds, compared to Norway, where 40% of academic salaries cover time to undertake research. The University of Iceland has control over funds for research by its faculty, which is larger than the Science Fund allocated by the Research Council. The funds are not very large but give the University some degree of autonomy and control over Iceland's basic research.

France has an idiosyncratic system. Organisations such as CNRS and INSERM,[3] which might be considered as Research Councils, do not fund individual researchers and their projects. They support research units, which are mainly located on university campuses, by selecting and accrediting teams at these units on the basis of proposals. Four-yearly evaluations are conducted to decide whether accreditation should be renewed. Researchers recruited by CNRS and INSERM can then freely join accredited teams. Thus instead of allocating funds to individual researchers and their projects, these organisations allocate research manpower to approved research units.

b) The *'block grant' system:* Under this approach academic salaries cover both teaching and research activities. Universities are allocated block grants for research, and decide independently on the internal distribution of funds. This block grant may be supplemented by grants from national and EC funding agencies, and from collaborations with firms. Universities in Germany, Spain, Italy, Portugal and Ireland are closest to this model. In France, staff known as enseignants-chercheurs are meant to spend 50% of their time on research.

This model of funding is also used for the UK's Research Council Institutes, Hungarian Academy Institutes and the main Spanish Research Institute. It is also applicable to government laboratories in most countries as well as to the so-called institutes whose funding and governance derives from a specific Ministry for which they to carry out research,

In some larger countries the block grant for research is provided both by the state and the regions. For instance, in Germany there is a long-standing tradition whereby exclusive policy responsibilities for education and culture, including science promotion are held by the regions, or L‰nder. This covers both university and non-university research. The German federal state was constituted later than the L‰nder, and has never managed to do more than share responsibility with them for science policy. French and Spanish regional agencies now have some responsibility for funding university research. However, this is not an absolute right and there is always the possibility that these responsibilities could be removed by national government. There are other important differences between the countries in this category. Germany has a Research Council, buts its grants are meant to be complementary to the core funding provided by the federal state and the L‰nder. In Spain the overall university budget, which comes from regional government, provides faculty salaries, incorporating a notional 40% of time spent on research, as well as a small percentage for research projects. Most research is funded by various national and EC funding agencies through competitive peer review.

Charitable foundations also provide funds for PSR in some countries. In the UK, for instance, they provide 20% of universities' research income. They also play a role in Sweden and Portugal, and are of growing significance in France. There is little information on their overall contribution to French PSR but they have been especially active in the medical field and in life sciences. In Germany, charities also concentrate funds on medical research.

There has been extensive reorganisation of the agencies (usually councils) which provide research grants, but no general trends emerge from these changes. Two countries, Norway and Iceland, have now centralised responsibility for basic and applied research funding into one organisation. In contrast, Sweden and Denmark separate the agencies responsible for these two types of research.

Several countries have recently set up new agencies to administer research funds for special purposes. In Denmark the new fund supports basic research. A new French fund, created from pollution-based taxes, finances research into current public issues, such as AIDS, the environment and gene therapy. In Sweden, a large Wage Earner's Fund has been allocated to seven new foundations which will support strategic research in areas including the environment, health care, problem-oriented natural sciences and engineering as well as the humanities and social science. These new foundation will run in parallel with four existing university research councils. In Ireland, structural funds from the EC are being used to fund

[3]These organisations are part of a wider group of Organismes Public de Recherche (OPRs), which are mission-oriented public research institutes each of which is active in a specific field.

two programmes to support industry: Programmes in Advanced Technology, set up at universities around the country, reflect local strengths in advanced technologies and Technology Centres at Institutes of Technology provide services to industry. Portugal has also used structural funds to set up research programmes, but has separated the programmes funding infrastructure for basic research from that which provides technological support for industry.

The main change to various Hungarian and Spanish funding organisations is the allocation of grants on the basis of competitive applications rather than by allocating block grants. The majority of Italian research funds are still allocated as block grants, but an increasing share is distributed in response to grant applications. Growing recognition of the role of research in universities is acknowledged by the Irish university budget containing a notional amount for research; a new investment fund for educational technology and research equipment and facilities; and by the recent establishment of institutional awards to encourage universities to take a planned approach to the development of their research capabilities. New approaches to research funding are also emerging in Germany. The aim is for funding to be more targeted and competitive in selected areas and projects, and to be based on quality and originality.

The main trends which emerge from our national studies are the slow but steady erosion of 'block grant' systems in favour of competitive applications for grants, and a growing role, in some larger countries, for regional agencies to act as funders of research. Whatever the system, every sector of PSR is under increasing pressure to raise research funds from external agencies.

2.4.3 PSR Institutions

There is a marked change in most countries in the distribution of research among different sectors of PSR, with an increasing proportion of research taking place in universities and a decreasing role for research institutes. In Ireland most research institutes have been restructured or closed down. Danish research institutes (and universities) have been restructured so as to concentrate resources. In the UK, the Research Councils have rationalised their research institutes - centres of national expertise involved in long-term research - and reduced their funding. This money has been redirected towards universities which provide more flexibility and the capability to switch research rapidly into new areas as the need arises. At the same time, government laboratories have been privatised and compete with universities and research institutes for contracts for government commissioned research. Italian and Norwegian research institutes have undergone extensive restructuring. Like research institutes in many other countries, they are forced increasingly to earn their keep through contract work. In Iceland, there is also increased pressure on research institutes to seek external funds. There have been very few other changes to the research institutes created in 1965, despite extensive changes to the research environment. There are now calls for the Icelandic system of public research to be revised so as to facilitate collaboration between different fields of science and reduce duplication of research efforts.

There has also been a growth in research activity in French, Spanish[4] and UK universities. In Germany there have been special policies to reverse "an emigration of research" from the universities in the late 1980s, but the universities are generally suffering from stagnation in research resources, and an increase in student numbers, which has eroded the time available to undertake research. The German non-university sector still accounts for almost half of PSR resources, and has better conditions and infrastructure than at universities. However, research-based training universities remain the basis of the German PSR system, due to their disciplinary variety. An Italian reform in 1980 which reinforced university research was recently mirrored in Hungary where, since 1993, universities have been given the right to undertake research. In both countries there are new initiatives for university research to become integrated with research institutes. Collaboration between research institutes and universities is trend visible in many other countries. The evidence from Portugal is contradictory.[5] Higher education has a higher percentage of staff involved in research than Government research institutes, and higher numbers of qualified

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[4]In their evolution, Spanish universities are facing the transfer of political dependence to regional governments. This may lead to uneven development in the higher education sector or to processes of "false" competition between the regions.

[5]The PNP sector accounts for more than 20% of GERD, well above the EU average.

personnel. Current trends show that numbers of research staff are increasing in institutes and dropping slightly in universities.

In the UK, Germany, Sweden and Norway, growth in numbers participating in higher education have led to former colleges of education/polytechnics demanding the right to carry out research, which has increased the competition for research funds. In Ireland pressure by colleges to be upgraded to full university status is being resisted.

It is difficult to find comparative data to demonstrate these trends. Table 1, which should be treated with caution, contains indicative data on expenditure by government, higher education and the private non-profit (PNP) sectors on the R&D performed by each of these three sectors for the years 1989 and 1995. Funds from abroad have also been included, as the main source of such funds is the EC. It has been assumed that the government sector correlates with government research organisations (GROs) and higher education with universities. The data in this table broadly confirms the trends identified above. Some anomalies are caused by countries having varying criteria for classifying government-funded research

Table 1: Gross Public Expenditure on R&D by Sector of Performance in constant $million (1990 prices and purchasing power parities))

	GRO		HEI		PNP		Total	
Country	**1989**	**1995**	**1989**	**1995**	**1989**	**1995**	**1989**	**1995**
Denmark	240.0	295.3	317.9	433.1	14.5	19.2	572.4	747.6
%	*41.9*	*39.4*	*55.5*	*57.9*	*2.5*	*2.5*	*100*	*100*
France	5151.1	4808.0	3176.6	3909.3	162.1	265.1	8489.8	8982.4
%	*60.7*	*53.5*	*37.4*	*43.5*	*1.9*	*2.9*	*100*	*100*
Germany	4041.4	4721.5	4239.8	5523.4	118.3	n.a.	8399.5	10244.9
%	*48.1*	*<46.1*	*50.5*	*<53.9*	*1.4*	-	*100*	*100*
Iceland	19.5	24.4	10.3	18.3	2.7	0.9	32.5	43.6
%	*60.0*	*55.9*	*31.7*	*42.0*	*8.3*	*2.1*	*100*	*100*
Ireland	48.8	61.2	62.6	132.2	4.6	3.9	116.0	197.3
%	*42.0*	*31.0*	*54.0*	*67.0*	*4.0*	*2.0*	*100*	*100*
Italy	2352.1	2099.9	2156.8	2396.2	n.a.	n.a.	4508.9	4496.1
%	*<52.2*	*<46.7*	*<47.8*	*<53.3*	-	-	*100*	*100*
Norway	225.1	224.7	284.0	356.1	n.a.	n.a.	509.1	580.8
%	*<44.2*	*<38.7*	*<55.8*	*<61.3*	-	-	*100*	*100*
Portugal	125.9*	161.8	179.5*	202.8	46.0*	103.0	351.4*	467.6
%	*35.8*	*34.6*	*51.1*	*43.4*	*13.1*	*22.0*	*100*	*100*
Spain	733.2	729.8	616.6	1215.3	14.7	39.2	1364.5	1984.3
%	*53.7*	*36.8*	*45.2*	*61.2*	*1.1*	*2.0*	*100*	*100*
Sweden	151.8	189.7	1192.4	1120.6	3.7	8.4	1347.9	1318.7
%	*11.2*	*14.4*	*88.5*	*85.0*	*0.3*	*.6*	*100*	*100*
U.K	2443.5	2563.0	2754.5	3505.5	341.0	238.9	5539.0	6307.4
%	*44.1*	*40.6*	*49.7*	*55.6*	*6.2*	*3.8*	*100*	*100*

*(1990)
Source: OECD (1998), *Basic Science and Technology Statistics. 1997 Edition,* OECD, Paris.

institutions; in particular the French research council CNRS is classified as in higher education, while similar UK and Italian research council institutes are classified as the government sector (OECD, 1989, 18).

2.4.4 Role of PSR and New Principles Governing PSR

Governments in every country now perceive that PSR is central to innovation, and have demanded that PSR undertake 'relevant' research. One counter-trend, observable in Ireland, where the role of PSR has always been connected with economic development, is recognition of the role of PSR in building capability to keep abreast of global developments in science and technology

National philosophy for PSR has always insisted on autonomy for public sector researchers, although the degree of autonomy could differ between research institutes and universities. Research institutes in most countries have been set general goals and provided with funds to undertake research in keeping with the general mission of the institute and the way this is achieved has been delegated to individual institutions. The level of autonomy for academic researchers differs between countries, but academics have the greatest autonomy over their research agendas in those countries where universities are provided with block grants covering research activities. Even here, growth in student numbers and the teaching burden can crowd out opportunities to undertake research.

Autonomy is still entrenched in Italy for universities and other research agencies carrying out what is known as 'non-instrumental' research, which are free in terms of choice of methods and determination of research topics. In contrast, research agencies carrying out 'instrumental' research have limited autonomy. In Germany, too, there is an emphasis on scientific autonomy for PSR, though pressure to carry out "relevant" research has increased. In most other countries, however, a top-down approach is developing whereby Government places demands on all sectors of PSR to be 'relevant to users', and a growing proportion of research funds is allocated to programmes of strategic research, or to priorities determined by Government.

Autonomy has also been a key issue for Hungarian universities and the Academy of Sciences since the early 1990s. Scientists associate autonomy with freedom from political control and the democratic self-governance of science based on scientific merit. This view seems somewhat outdated, and ignores the need to be accountable to tax-payers.

2.5 Resources for PSR

There are many problems in trying to compare trends in Government funding for PSR among the different countries over time. The main difficulties are caused by coping with fluctuating exchange rates and the different costs of research in each country. Some indicators are provided by the OECD and these are provided in Table 2. These provide rough approximations only, since OECD definitions do not match the definition for PSR used for this project. In particular, OECD data for expenditure on civil R&D include expenditure in firms, which is outside the scope of this project. Thus the data in this table must be treated with caution, since countries vary in the way they allocate civil R&D expenditure between companies and public sector research. Given these reservations, the table shows a declining trend in the annual growth in Government expenditure on R&D,[6] as well as a reduction in expenditure on defence R&D for most countries allocating funds to this activity.[7] The data on civil R&D as a percentage of GDP shows that the countries in this study fall into three main groups. The first group - France, Germany and Sweden - allocate a relatively high proportion of GDP to civil R&D; they are followed by Denmark, the UK and Norway, with Iceland and Ireland not far behind. Italy, Spain, Portugal bring up the rear. There are no comparable OECD figures for Hungary for the period concerned, but national data indicate that *total* Government expenditure on R&D fell below 1% of R&D during the transition period.

[6]The exceptions is Denmark, where there has been some growth.

[7]Except for a very small increase in Portugal

Table 2: Indicators of Government Funding for PSR

Country	Compound annual growth in GERD		Civil GERD as a percentage of GDP		Defence R&D as a percentage of Govt. R&D outlays	
	1991	**1995**	**1991**	**1995**	**1991**	**1995**
Denmark	6.1	6.9	1.7	1.9	0.6	0.5
France	0.5	0.3	2.0	2.0	36.1	30.3
Germany	--	0.6	2.5	2.2	11.0	9.1
Hungary**	--	--	1.09	0.75	--	--
Iceland	18.8	12.0	1.2	1.5	0.0	0.0
Ireland	15.0	15.6	1.0	1.4	0.0	0.0
Italy	--	1.0	1.2	--	7.9	4.7
Norway	1.1	--	1.6	1.6	5.7	5.0
Portugal	11.6*	-1.0	0.6	0.6	0.8	1.3
Spain	5.1	2.7	0.8	--	16.8	10.4
Sweden	-0.9	--	2.7	--	27.3	20.9
UK	-5.1	-0.3	1.7	1.7	43.9	37.0

Source: OECD (1997), *Main Science and Technology Indicators,* No. 2, except Hungary.
*1992
**This data is illustrative only - to show the fall in GERD in the period. It is drawn from Hungarian statistics, which do not yet conform with OECD standards. In particular there is no breakdown between public and private Government expenditure.

The national reports confirm these trends and indicate that Government resources for PSR have remained static in most countries, with small increases in countries like Iceland. The other countries where there seem to have been increases in PSR resources are Sweden and Denmark, where new research funds have become available. It is perhaps too early for Swedish increases to show up in OECD statistics - alternatively, there may be compensating reductions in existing funds. Government support for R&D in Ireland has dropped to 23% of GERD, compared to an EU average of 36%. Ireland, Portugal and Spain have become very dependent on Brussels for R&D funding. More than 40% of total Irish R&D funds comes from Structural Funds and the Framework Programme. The transition to a market economy in Hungary led to an absolute decline in resources for PSR; macro-economic data indicate that the Hungarian economy has just started to recover, but the research sector is in much deeper decline than the economy as a whole.

Faced with static Government resources, PSR has been encouraged to look for new sources of funds. As a result, overall resources for PSR may have been increased by funds from the EC's Framework Programmes, from Structural Funds or from industry. In the UK, EC Funds are not an addition to Government PSR expenditure; under the system of "attribution", EC-funded research, about 5% of total government expenditure on science, engineering and technology, is deducted from the budget for research allocated to each Ministry by the Treasury. In Germany, EC funds are an extra resource but the amount is negligible and the significance of EC funds to Norway, Sweden and Denmark is not clear. In France, EC funds do not play a significant role in overall, national terms. They are, however, becoming significant to specific research units in areas where there are EC programmes. In Iceland, Ireland, Hungary, Portugal and Spain, however, EC funds are a very important addition to national funds. It is thought that had it not been for EC funds, public expenditure on Irish R&D would have declined in the decade since 1987. Structural Funds are especially significant in this respect, having been used to finance special programmes in areas of new technology and it is unclear whether these programmes will continue in 1999, when this source of funds is likely to decline. In Portugal, Structural Funds have also provided the resources for various programmes, including significant expenditure on providing R&D

infrastructure. They have also been used to develop PSR and innovation activities in the less developed regions of Spain and Italy.

Within national budgets, there have been significant re-allocations of funds between areas in the recent past. There has been a continuing decline in defence research (see Table 2). Other general trends are:

- A general decline in resources for energy research, especially in Germany, France, Italy and Sweden[8] which, in the past, dedicated special research institutes and resources to nuclear research. In France, Germany and Italy, the institutes concerned have been asked to redirect their research interests towards industrially relevant research, and are expected to raise a greater proportion of funds from links with industry. In Italy and Germany, these institutes are also involved in environmental research. Sweden has established new establishments for energy research, alongside the scaling-down of energy-research in traditional research agencies. The scaling down of energy research is also evident in Norway and Iceland. In Norway, the research was related to exploitation of North Sea oil and gas, a mission which has now been successfully achieved.

- An apparent growth in resources for "applications-oriented" research in new and key technologies, including biotechnology and the environment.[9]

In addition to these general trends, significant, national economic concerns also affect PSR expenditure patterns. For instance, although Spain has developed priorities to follow international trends in new technologies, other priorities are more closely related to traditional fields of interest like agricultural sciences, food technologies, marine science and technology and chemistry. Portugal and Ireland have adopted a similar approach in promoting new technologies of national relevance, but they also support traditional areas of economic importance. Iceland is shifting resources away from primary sectors (agriculture and fishing) and favouring secondary sectors such as fish processing and other industry. Denmark's PSR seems to favour food and agriculture. Some of the larger, well-developed countries have increased resources for prestige fields such as German and French support for (aero)space, but Sweden is reconsidering whether its aerospace research can continue on a purely national basis.

As well as shifts in allocations between *fields* of research, there have also been changes in the *type* of research funded, but the overall picture is confused. Germany, has increased expenditure on basic and non-directed research. In the UK, the trend is completely in the opposite direction, with an increase in funds for research directed into broad areas identified by the Government and a decrease for non-oriented research.[10] Sweden and Denmark are similar. German and Norwegian political rhetoric often supports basic research. In practice Norway has introduced more modest funding and a "directed", top-down approach to the allocation of research funds. Like Germany, it emphasises basic research but there has been a growth of funds for strategic or applications-oriented research of interest to users. In Italy, oriented research is important in research institutes and the growth of non-oriented research is mainly accounted for by the development of an autonomous university research sector. In Portugal and Spain, the autonomy of university faculty to determine their own research agendas has also reinforced the dominance of basic research, rather than concern with national interests or those of the business sector. In Iceland and Ireland there have been small increases in funds for basic research, but directed research still dominates in both countries. In Hungary there is still no significant Government research policy initiative and the emerging scene is based on the survival strategies of the various PSR actors.

2.6 Targets of New Policy Mechanisms

Policies in most countries seem to focus on four main themes: evaluation, coordination, prioritisation and technology transfer.

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[8]In the UK, this decline occurred in the 1980s with the privatisation of the energy utilities.

[9]Government rhetoric may differ from reality. In Germany, for instance, key technologies account only for 11% of federal expenditure on R&D, with "big sciences" retaining 28%. And expenditure on nuclear research declined sharply in 1981 in parallel with an increase in space and defence research.

[10]However, both types of research are basic in nature.

2.6.1 Evaluation

Evaluation is increasing in significance in many countries. Three groups of countries can be discerned. Those where evaluation is now integral to the PSR system, a second group where evaluation is partial and a third group which has plans to develop the evaluation system.

The UK and France are in the first group. In the UK evaluation occurs throughout the PSR system, and the results of these evaluations are reflected in the allocation of core funding for university research (the Research Assessment Exercise), project funding, in the continuation of research programmes and in research institute activity. There is, however, some doubt about the efficacy of evaluation in relation to the commissioned research undertaken by individual Ministries. In France evaluation is also strongly entrenched, with separate mechanisms to evaluate the research of universities and of Organismes Public de Recherche (OPRs) and other public research agencies. It is not clear how the results of these evaluations affect the institutions concerned. To date, however, there have been few evaluation of research programmes.

The second group of countries includes the Scandinavian countries, Germany and Ireland. In Norway, Denmark and Sweden evaluation has become more common since the 1980, and these activities are most often initiated by Ministries and Research Councils on an ad hoc basis. Evaluation in these countries suffers because members of evaluation panels are seldom independent, and internal criteria tend to dominate these assessments. The impact of these evaluations is somewhat limited, because the strong system of tenure for researchers makes it difficult to introduce any changes. In Germany the Science Council has evaluated specific research areas, Blue List Institutes and all university and non-university research in the former GDR. There is now a demand for Max Planck Institutes and the German Research Society to introduce systematic self-evaluation procedures. A discussion is also currently underway about the introduction of evaluation for academic staff and universities which will form the basis for funding decisions by most L‰nder. In Ireland, evaluation is a recent development, stimulated by the receipt of EC funds. External evaluations are carried out on its Research Technology Development and Innovation programmes, and its EC funded programmes. At first external experts were used, but now Ireland has developed national expertise and the government agency responsible for science and technology policy has set up an Evaluation Group.

The third group of countries, with limited evaluation activity, includes Hungary, Iceland, Italy, Portugal and Spain, but all these countries have plans for it to increase. In Hungary the allocation of core funding for university research is based on evaluation of research potential and that for academic research institutes on their research performance. Government policy now seeks to establish a more transparent system for research grants based on competitive bidding and expert evaluation. Iceland plans to carry out a study to evaluate how the activities of the Research Fund have influenced the Icelandic research environment and another on basic research. Evaluation is rather problematic in Iceland due to the limited size of the scientific community, and it may be necessary to use some foreign evaluators. The lack of an evaluation system in Italy has made it difficult to check for coherence between research programmes and their objectives, both for national science policy and for research institutes. However, new Italian guidelines for the reorganisation of PSR include the establishment of a national evaluation system and instruments are in the process of being developed for widespread evaluation of scientific activity. In Portugal, evaluation is beginning to increase and is one of the main goals of the new Minister for Science and Technology. In Spain, there is some evaluation of the research of tenured university staff which can lead to a considerable salary increase for those who have carried out research for a total of 6 years. In general, however, there is an absence of a culture in Spain for evaluating and monitoring R&D activities as a means of fostering and developing policies for goals and outcomes.

2.6.2 Coordination

The growing importance to PSR of application-oriented or strategic research in most countries demands that governments strike a balance between overall coordination of the public research effort and integration of relevant research within relevant ministries. Coordination is sometimes managed through interministerial committees or is made the responsibility of a single ministry. Attempts at increasing coordination over the PSR system, however, seem to be a particularly thorny problem which generates friction and debate, especially attempts to integrate individual Ministry's research activities with research in universities and research institutes, and in achieving coordination across different Ministries. Problems are increased in countries like Germany, Spain and France where regional authorities allocate funds for research. The pages of the national reports record many attempts to achieve better coordination, but few successes.

Germany has a long tradition of decentralised powers for PSR and numerous mechanisms to promote coordination between the various bodies involved. It is unable to exercise the positive coordination which is possible in a unitary state, where central government can implement reforms by majority decision. German experience has shown that institutionalised coordination, which demands joint and unanimous decisions, may be 'negative', with reforms or controversial issues being shelved, or being solved by compromises acceptable to all participants. The outcome is a very slow decision-making process based on the lowest common denominator. It may be preferable to rely on voluntary coordination, where each actor is free to pursue its own policy if no common agreement can be reached. Thus, whilst coordination mechanisms can provide an arena for diverse public authorities to negotiate, it is important to remember that these attempts may be dysfunctional if those involved cannot reach agreement on new priorities or procedures. Decentralised system without coordination may work better in this situation.

Both Norway and Iceland have attempted to increase coordination by establishing a single Research Council. The Norwegian Research Council has attracted much criticism in its brief life, and Iceland still lacks coordination between its Research Council and the Icelandic government, which allocates most PSR funds and is in overall control of the structure of the PSR system. The UK has attempted to increase coordination by a number of mechanisms which include the annual publication of a *Forward Look,* containing details of each Government Department's activities in research and a longer-term assessment of the portfolio of publicly-funded work best suited to the needs of the country. Concordats have been established between government departments and Research Councils so that Departments use the research sponsored by the Research Councils and Research Councils take account of the needs of Departments. Foresight priorities are yet another mechanism to increase coordination. Research Councils must take account of Foresight priorities in their funding activities, but the influence of Foresight on Departmental activities is less strong.

Apart from the fusion of the federal ministries for education and for research and technology, Germany has had little success at promoting better coordination between federal ministries, or between the national and regional levels or amongst research institutions. Separation between its science and technology programmes is hindering any attempts at coordination in Portugal. The coordination of all R&D activities in Spain was the aim of its National Plan of R&D, set up in 1988, but it has achieved limited success because it controls only a limited proportion of the national budget for R&D, and is unable to control the activities of the autonomous universities or regions. Coordination has traditionally been weak in Italy. The establishment of the Ministry of Universities and Scientific and Technological Research was an important first step to improve coordination and the process may soon be completed by setting up a series of bodies at the Ministry to deal with coordination of national research policy. There has been weak Irish cross-Departmental coordination but the need to increase coordination has now become an important policy concern, with the recent establishment of new interdepartmental structures. The lack of coordination in the Hungarian system is mainly caused by larger problems following the transition to a market economy. But it is exacerbated by the gap which exists between economic policy and science and technology policy, with the PSR system remaining rather closed and riven by competition for financial support and policy influence between the various bodies involved. In Denmark, fragmentation of responsibility for PSR among various Ministries hinders coordination and the multiplicity of research funding organisations is a significant barrier in Sweden.

2.6.3 Prioritisation

Advisory councils traditionally provided advice to governments about the areas of research to be funded, and research funding organisations tended to have a great deal of autonomy in deciding how to distribute funds between the various areas of research for which they were responsible. There is now a slowly developing trend for research priorities to be identified through "Prospective", "Forecasting" or "Foresight" activities. The most advanced appears to be the UK. Its Foresight exercise established priorities which now have a strong influence on research in the UK. France has undertaken public consultation exercises on research priorities over the last two decades; the 1981 exercise was the direct origin of subsequent major changes to PSR. The effects of the 1994 exercise is still unknown. Hungary, whose current priorities for research are not evident, is currently setting up a Foresight programme. Spain has an agency for forecasting developments in science and technology and Italy has attempted some foresight exercises, but never on a systematic basis capable of affecting research policy. Priority research fields have been identified in Iceland, but the approach has not been very systematic. Ireland develops priorities through a top-down process based on widespread consultation with users, scientists and policy makers, and is currently engaged in a Foresight exercise.

Germany has developed the methodology and instruments to take a systematic approach to prioritisation and foresight, but the results of various exploratory studies have had little effect to date, due to the fragmentation of powers between the State and the L‰nder, and to the autonomy of the research institutions. One method it has adopted to develop expertise in important new technology areas has been to establish new institutes to focus on priority areas of research such as biotechnology and molecular medicine. The early effects of foresight exercises have been to increase emphasis on interdisciplinarity and to provide new funds for key high-technology sectors. Portugal is trying to implement prioritisation through special research programmes. France, Germany and the UK have experimented with a Delphi approach to identify research priorities. These attempts had limited success and have been abandoned for future Foresight exercises in the UK.[11]

2.6.4 Linking PSR with Wider Economic Needs

Countries have used a variety of approaches to link PSR to wider national economic needs (not only industry, but also primary sectors such as agriculture, forestry and fishing and other users such as the medical establishment). These approaches involve both promoting mutual understanding between science and industry by involving industry in the policy-making process, and by establishing mechanisms for technology transfer.

It is part of UK policy that "users" of research should be heavily involved in every level of policy formation. Thus industrial involvement in councils providing Government with policy advice, as well as in the Foresight programme has increased substantially when compared to former industrial participation in science policy formation. The organisations involved in allocating research funds have representatives of industry or users acting as Chairmen, and members from industry and other users serve on their councils and committees. These trends are reinforced by programmes for collaborative university-industry research, incentives for academics to demonstrate user interest in proposed research, and for dissemination of research results to potential users.

There are superficial similarities between German and UK industrial involvement in policy formation, and German industry is closely involved in policy formation for PSR. It has representatives on the councils of most research institutions, takes a prominent role in all advisory committees and commissions at both Bund and L‰nder level, and contributes to planning the research to be supported by their funding organisations. Industry mainly influences programmes for collaborative research (the main type of funds from the Bund) and the research areas where it has developed close relations with PSR over many years (e.g. engineering). Its influence on most research institutions is small, with the exception of the Fraunhofer Society, which is mainly committed to supporting industry. As in the UK and Germany, Irish industry also makes significant inputs to all aspects of policy for PSR; indeed it is difficult to find any significant development for PSR over the past 10 years which has not involved extensive consultations with industry. France also has a long-standing tradition to include industrial participants on advisory committees and the board of PSR institutions.

Technical Institutes to support manufacturing industry and important national economic activities are public in some countries and in others they are private, and do not form part of PSR. The growth of UK industrial involvement in policy formation for PSR paralleled the ending of Government support for

[11]In France a national Delphi exercise did not provide much help for policy formulation, although it was more successful in the one region in which the approach was performed.

Britain's privately financed industrial research associations, and marked a shift towards universities as a source of technical support for industry, and away from specific technology institutes. The current arrangements for UK PSR to support industry is perhaps closest to that which has always existed in Sweden, where the main focus of PSR has always been the university system and the sector of applied institutes to support industry has been rather weak. However, questions are now being raised in Sweden about whether this is an appropriate balance. Germany differs from the UK in continuing to provide public funds for Technical Institutes to support manufacturing industry.

Technical Institutes continue to receive significant allocations of government funds in Norway, Iceland, and Denmark, whilst universities maintain a focus on non-oriented or basic research. Even in these countries, counter trends are beginning to develop. For instance, Norwegian university researchers are asked increasingly to do research "of relevance to users", whilst Denmark's Technical Institutes now have to secure contract research to survive. It has been questioned whether the ties between sectoral public research institutes in Iceland and relevant industry are as close as they should be. At the same time industrial relationships with the higher education sector are growing. The proportion of Iceland's expenditure on basic research in higher education has almost halved during the last two decades, which indicates increased emphasis on commercialisation, and this trend has been promoted by participation in EC programmes. In order to survive, some of Hungary's Academy Institutes have turned increasingly to the provision of contract research and services and external funding accounts for at least 50% of their funding. While the major function of institutes used to be knowledge production, the emphasis is now on providing industry with access to research equipment and knowledge based services, with increasing institute activity related to exploitation and dissemination.

France is at a transitional stage - in which both and academic and user-oriented sectors of PSR have begun to converge in terms of the type of work carried out and their links with the market. Previously its public laboratories (OPRs) worked directly for important economic sectors in which they were thoroughly embedded. The close relationship has ended, the OPRs have become more academically oriented while still keeping some links with their user communities. At the same time, academic researchers have increased their interactions with industry and with OPRs. Indeed, strong links between French academic research and industry have developed since the early 1980s. They have been promoted by converging linkage mechanisms: valorisation offices in all research institutes, technological programmes and a network of technology transfer centres. Irish universities have developed a strong commitment to promoting technology transfer and to developing long-term relationships with industry. This approach is driven by a lack of resources on the one hand and, on the other, the growth of university research in recent years.

It Italy a significant part of manufacturing industry has relationships with PSR (one quarter of innovating firms). The firms concerned are mainly of medium to large size and links do not concentrate only in high-tech areas. The interchange between industry and PSR concerns a more diverse range of issues. There are several mechanisms to encourage PSR staff in Spain to collaborate with industry. In Spain, as in Portugal, however, industrial involvement with PSR scarcely exists. This may reflect the lack of indigenous firms involved in R&D in these countries.

Technology transfer is very high on the agenda of most of the countries covered in the study. National rhetoric about technology transfer, however, does not ensure that these initiatives are successful. It is not clear how well these mechanisms are working in the Scandinavian countries, or in Italy, Spain or Portugal. The Danish Ministry of Industry is responsible for several technology service institutes which are intended to deliver services to industry on a contractual basis, but fluctuations in core funding have limited their ability to build up and sustain their competences. Swedish PSR contains a rather weak sector of institutes and centres in universities set up to serve various branches of industry. There is some discussion about whether it might be appropriate to strengthen this sector. In Portugal there are strong divisions between public sector science and technology programmes, and between PSR and industry. The schism between PSR and industry has been intensified by the absence of technology 'actors' (large national firms, industrial associations) from the science policy arena. There also appear to have been poor results from a number of national and regional Spanish mechanisms to increase university/industry links and promote technology transfer. Similarly, Italy's schemes to promote technology transfer (e.g. Mission-oriented projects, CNR research areas, MURST technology parks, and consortia) have met with limited success, but some informal cooperation between PSR and industry exists.

In other countries the tradition for technology transfer is stronger. Germany, as well as funding the Fraunhofer Society Institutes to carry out contract research and technology transfer for industry and other public clients, has established technology transfer agencies at universities, put pressure on its research institutes to focus on technology transfer and made collaborative research between universities and industry a central funding area. In Ireland, the needs of industry have formed the basis of PSR policy over many years. Considerable success has been achieved with its programmes for promoting university/industry links, most notably with its Programmes in Advanced Technology. Technology transfer and university/industry links are an integral part of policy for UK PSR system, even in Research Councils mainly involved in basic research, for example the Medical Research Council and Particle Physics and Astronomy Research Councils. Collaborations between the public sector and industry is also promoted through a number of special funding programmes. In Hungary new organisations have been set up to promote technology transfer, and spin-off companies have emerged from PSR as part of the survival strategies of public sector researchers. Though limited in number, these companies represent one of the most flourishing, knowledge rich sectors of the economy. Iceland's participation in EC RTD programmes seems to have increased university/industry relationships, as has the work of an Industrial Liaison Office at the University of Iceland.

In France, the promotion of technology transfer has changed considerably in recent years. On the one hand France has ended its "Grands Programmes" in leading edge industrial technologies which supported French industry and, since 1982, the mission-oriented public research institutes known as EPSTs[12] (e.g. INRA, INSERM, CNRS) have been re-oriented towards basic research. However, these institutes' mission statements include the demand that their research results are valorised and transferred to the economy. Several new mechanisms have been set up to promote links between PSR and industry, including valorisation offices and regional technical centres, as well as technology resource centres (CRITT). Expansion of research in French universities has also been accompanied by a strong growth of industrial research links, and there have been national programmes to promote PSR-industry links in areas of strategic interest, as well as support for French participation in the EC's Framework programmes. French efforts in technology transfer appear to have evolved from a linear model based on concepts of market failure to a network model, where the emphasis is on joint PSR and industry learning and transfer. And direct efforts to support the technological development of industry appear to have be ceded to EC programmes.

2.6.5 Convergence of Management Practices

Common trends are apparent in management practices across countries such as evaluation, mechanisms for technology transfer and strategic planning in various forms. It seems that management practices are converging because they are easier to implement than putting new institutional arrangements in place. However, the outcomes from these practices differ because there are organisational differences between countries both in the organisation of funding bodies and of university research. It is unclear whether mechanisms such as evaluation, Foresight etc. mean the same thing or have the same impacts in various countries. For instance, the outcome of evaluations have less impact in countries where researchers have tenure. Evaluation of EC programmes have been significant in spreading evaluation practices and it seemed that "learning processes" could be involved in implementing these new mechanisms. Late-comer countries, in particular, are catching up in adopting these mechanisms, and tended to have more trust in practices like peer review, because they are still new. Whilst less developed countries have attempted to learn and catch up by imitating the more developed countries, there are time-lags and lack of experience in the application of these mechanisms. It seems necessary to assess the outcomes of these initiatives in different countries. Outcomes could be an indication of whether PSR systems are fixed or flexible, and reflect differences in culture or the embeddedness of the PSR system.

2.7 Trends in Collaboration

[12] Etablissement public ‡ caractËre scientifique technologique

In most countries there is an increase in research collaboration of all types. This includes collaboration by the various sectors of PSR within countries, as well as collaboration between countries. Growth in European collaboration has been promoted by EC Framework Programmes and participation in European "big science" facilities and programmes. The evidence on the education/research interface is rather ambiguous. Research funds have been redirected away from PSR institutions and towards the university sector, including countries where universities were traditionally involved in teaching only. This has not necessarily led to a closer relationship between research and education in the universities and colleges of higher education.

2.7.1 The Education/Research Interface and Collaboration between PSR Sectors

In most of the countries in this study higher education and research have come closer together in recent years. There has also been a significant strengthening of research collaboration between the different sectors of PSR. Evidence from some countries, however, is lacking, and in others it is ambiguous.

Integration between education and research in its "scientific universities", following Humboldtian principles, is regarded as the foundation of German PSR. However, overcrowding of universities and stagnation of resources (both financial and teaching staff) have led to a lessening of university research because teaching obligations, unlike those for research, are a formal requirement. Collaboration between German PSR institutions is increasing, as a deliberate policy response to cope with the decline of research in German universities (see 2.4.3 above). Instruments have been developed to promote joint research between universities and non-university institutes; and share the training of doctoral students. In addition, professors may hold joint appointments at a university and non-university institution, and staff at non-university institutions are taking on university teaching responsibilities.

Research came late to French universities, which mainly served higher education. However, since the mid 1960s the organisation responsible for carrying out basic research in its own "laboratories" (CNRS) has increasingly set up joint associated research units on university campuses where CNRS researchers work alongside their university colleagues. This model has also been adopted by INSERM, the OPR responsible for health research. Other OPRs continue to be self-sufficient, but here, too, there is a gradual emergence of collaboration with university researchers.

The results of some national studies suggest that a close link between higher education and research cannot necessarily be assumed when universities play a dominant role in research. For instance, despite the important role of research in the Swedish university sector, teaching has often been separated from research because firstly, colleges providing university level teaching, were not involved in research. Secondly, it was not expected that the majority of university lecturers would get involved in research. Research has played a central role in UK universities for many years. In the interests of having a more flexible research base than possible in centres of long-term, national expertise, research activity in universities has recently increased. Paradoxically, other policy decisions are having the effect of concentrating research into fewer universities and even here, creating divisions between teaching and research staff. There are policies for staff interchanges between universities and research institutes, as well as some small programmes to encourage collaboration between the different sectors of PSR, but at the same time, increased competition for research funds between different sectors of PSR may hinder such collaboration.

The state provides all Italian universities with resources for conducting research but resembles the UK in the concentration of grants for specific research projects in a handful of universities only. A recent survey found that Italian university staff spend approximately 50% of their time on research, whereas researchers in public research agencies are engaged full-time in research and other activities such as teaching are sporadic, require authorisation and are often performed outside normal working hours. There has been a long tradition of collaboration between universities and public research agencies, with the university hosting this research activity, and it is anticipated that universities' collaboration in collective research activities will grow in the future. This collaboration has been promoted by the need to reduce research costs.

Until recently Irish PSR policy focused on the interface between research and industry, ignoring the interface between research and education. Recent concerns about skill shortages have focused attention on the latter, and especially on the need to help universities to produce the quality and quantity of qualified research personnel required by industry, especially by multinational companies located in Ireland. Special resources have been allocated for modernising the research infrastructure in universities. However, there is no separation within university budgets for teaching and research, because of a perceived danger that funds for research might be redirected towards teaching.

In Spain there is a growing integration between research and education in universities, and this trend is also true for research staff of the Spanish National Research Council (CSIC). Growing collaboration between the universities and CSIC and attempts to develop a common infrastructure are hampered by some conflicts of interest. However there are no links at all between the institutions focusing on scientific research (universities and CSIC) and the government laboratories involved in supporting industry.

The rigid division between research and higher education has been eased in Hungary, with Academy and Institute researchers becoming more involved in teaching, especially in PhD programmes. Deliberate policy and new funding schemes are transforming universities into research universities. In addition, there is growing cooperation between universities and the research network of the Hungarian Academy both in research and education.

There is limited information on trends in the education/research relationship, or on links between sectors of PSR in some of the smaller countries such as Denmark, Iceland and Portugal. In Iceland researchers in public research institutes often teach courses at higher education institutions. Formal coordination meetings between its public research institutions are also held but there is scope for closer research links.

The overall picture which emerges is that integration between higher education and research has been improved both through universities assuming a greater role in research and through research collaboration with other sectors of PSR. In some countries integration is partial because research activity concentrates in a small proportion of universities. Integration between higher education and research may be stronger in countries like France, Spain and Germany where regional provision of research grants to local universities checks any tendency towards research concentration.

2.7.2 European and International Collaboration

There is a long tradition of international collaboration among the more developed countries in this study, with collaboration resulting both from the international character of fields such as AIDS, climate change, space, aeronautics, nuclear physics, molecular biology and oceanography, and from the costs of research exceeding national resources. International collaboration also appears to have been particularly important for the smaller countries in our study. International research collaboration has three main components: involvement in (i) large European facilities/programmes (ii) EC research programmes (iii) with other international partners. If any overall trend is distinguishable, it is the rise in inter-European collaborations, and the importance of participation in EC R&D Programmes to almost every country, no matter what its size, nor state of development of its PSR system.

Many of the countries in this study are involved in the large European facilities/programmes such as the European Space Agency (ESA) and CERN and EMBL, and there has been a slow increase in the proportion of national funds going to these European agencies since the early 1980s. The costs of "going it alone" in big science have become too high and some national facilities (e.g. in the UK) have been closed down in favour of involvement in these European facilities/programmes. Among the countries in our study, only Ireland and Iceland do not participate in CERN.

The UK, France, Germany, Sweden and Spain all have a long tradition of international research collaboration. UK publications data shows that collaborations are important with both the US and Europe; European collaborations, however, are growing more rapidly than those with the US. There is increased German participation in EC Framework programmes, and German priority programmes in key technologies reflect Framework programme priorities. Recent growth of foreign research funds flowing both into and out of the French research system are mainly accounted for by PSR, and EC research programmes are of increasing importance in these flows. Spain's research collaborations have been undertaken to gain domestic recognition by individuals and institutions. Spanish co-authorships in international publications suggest high participation in EC collaborative research projects and an increase in the collaborative production of knowledge. Membership of the EU has boosted Sweden's research collaborations in Europe significantly. In addition to participation in European research organisations and EC research programmes, Swedish research collaborations also focus on links with central and eastern Europe, the Nordic countries and the US. Cuts in national funding for Italy's research agencies have made participation in EC programmes of increasing importance. Although these funds only account for 4% of their total budget, the period from 1990-95 witnessed a quadrupling of contract income from the EC Framework Programmes.

International collaboration appears to have been particularly important for the smaller countries in our study. International collaboration has always been important to Norway because of the location and small size of the research community. Norwegian researchers probably have more study visits to foreign universities than researchers in many other OECD countries. This may result from the traditional rather weak research training in Norway and the availability of research grants for travel and visits abroad. Limited evidence on the geographic location of international collaboration suggests that cooperation within Europe takes most resources. International research collaborations have also been very important for Iceland. Almost all of its researchers have had training abroad, due to limited availability of national postgraduate training. International collaboration is stimulated by the need to gain access to better research conditions and, in some fields, by a high, external demand for specific Icelandic research materials. Most of these collaborations have been informal, small scale projects. Iceland has achieved a high acceptance rate for its applications to EC programmes, participating mainly in agricultural, fisheries and marine programmes. International collaboration is also very important to Hungarian PSR, both from the point of view of funding and of intellectual relations. Indeed half of Hungary's publications are either the result of international cooperation or co-authored by foreign colleagues. Numerous international research agreements support research collaboration, mobility and long-term research projects, but membership in CERN and participation in EC programmes,[13] account for a growing proportion of Hungary's international collaborations. Denmark seeks to strengthen the training of its doctoral students through international cooperation. Thus scholarships are provided for postgraduate studies abroad and funds for visiting scholars to participate in Danish doctoral programmes. Irish international collaborations used to be mainly with English speaking countries, especially the US. European collaboration through the EC's Framework Programmes is now more dominant. These collaborations appear to have improved the quality of Irish research, with citations to Irish publications in international journals now standing above world averages. Among the smaller countries, Portugal has the weakest involvement in international programmes and organisations. Whilst it is increasing such involvement, its participation in the EC's Framework Programmes requires improvement.

2.8 Drivers of Change

During the period under discussion, most countries experienced tighter constraints on public spending, and this is obviously a major driver of some of the changes reviewed in this report. Four other drivers have also been identified: the political dimension, international and EC influences, industrial needs and the emergence of new technologies, which are discussed below.

2.8.1 The Political Dimension

Political decisions have a strong influence on the development of PSR throughout Europe. For instance decisions made to develop energy independence in France, particularly nuclear energy, have had a significant impact of the current shape of French PSR. However political decisions are often influenced by the actors involved in advice and decision-making, and the objectives they wish to attain. In Portugal and Spain, for instance, decisions are strongly driven by the scientists themselves, because of lack of awareness of the strategic significance of science and technology by many of the bureaucrats involved in decision-making. In the UK, France and Germany industry plays a large part in the process. In Ireland,

[13] It has been more involved in these programmes than any other Eastern European country, taking part in COST, EUREKA, PECO, COPERNICUS and PHARE

concern to attract foreign direct investment, and awareness that this depends on the availability of highly skilled researchers, has led PSR, and in particular basic research, being strengthened in universities. Thus, we need to recognise not only the political decisions made, but to know who was involved in the policy-making process, their level of knowledge about science and technology, and the rationale behind the decisions.

There is also evidence from several countries that public actions can have an important influence on the research agenda, and this applies particularly to medical research. In Britain, and France, charitable contributions by the public are an important source of funds for this type of research.

2.8.2 International/EC Influences
International trends and the influence of organisations such as the EC and OECD play a particularly important role for countries with a poorly developed PSR system and for small countries. Especially in these countries, there is a process of imitating external patterns, whilst it may be more appropriate to focus on a specific country's cultural heritage, natural resources, industrial structure and the appropriate PSR system to exploit its strengths and overcome weaknesses. However, as pointed out in the Icelandic case study, there is a danger that focusing too narrowly on short-term, national problems will lead to neglect of longer-term research relevant to future developments. It is precisely in this sphere that a national body, able to coordinate PSR and prioritise between various research fields comes into its own.

The EC has been and is a major driver of change. EC R&D programmes, though providing a small percentage of most countries' research budgets are influencing national research priorities, supporting the collective production of knowledge and enabling smaller countries, especially those outside the EU, to overcome the limitations of their small size. There also appears to be a general trend for growth in European collaborations at the expense of those with other countries around the world. Structural Funds for small less developed countries within the EU seem to have been more important than participation in EC R&D Programmes and have helped to build up weak PSR systems. In Ireland these funds have not only strengthened PSR, but also helped to foster expertise in undertaking evaluation. In Portugal they have provided the infrastructure necessary for undertaking research.

European collaborative facilities have also provided the potential for individual European countries to maintain expertise in some areas of "big science" like space, nuclear energy and particle physics research, where the cost of going it alone is too costly. Perhaps this should be the model for all European "big science" research, with joint funding and use of large-scale and costly facilities.

However, in an environment where collaboration of all types is increasing, and where researchers increasingly wish to interact with colleagues working at the frontiers of knowledge wherever they are located in the world, it is important to identify the influence of EC programmes. Does the expertise developed in EC research programmes help European scientists to collaborate with international experts in their fields. Alternatively, does the focus on EC collaboration drive out the international collaborations which would help European scientists keep abreast of major development around the world?

2.8.3 Industrial needs and technology transfer
The needs of industry and the role of PSR in supporting innovation have now emerged onto the agenda for PSR in almost every country in this study. This concern has manifested itself in a wide variety of mechanisms both to involve industry/users of research in decisions about research priorities and funding decisions, but also to promote closer interaction between PSR and industry. However, these policies have tended to fail in countries such as Spain, Portugal and Italy where the industrial base is largely made up of SMEs, traditional firms which have low interest is PSR knowledge and/or technology or companies which depend on in-house R&D. Ireland has fared rather better, perhaps because of its attraction as a location for English-speaking multinational companies which require a foothold in Europe's Single Market.

2.8.4 Emergence of new technologies
The fourth and perhaps the most important driver of change has been the emergence of new technologies, which have had multiple effects. Strong budgetary pressures were created by the need to

develop research capability in the new fields of IT, biotechnology and new materials at a time when most countries placed tight constraints on public spending. Static or falling PSR budgets, and the need to redistribute funds from traditional to new fields demanded the development of mechanisms for identifying research priorities. Helping industry to compete in the new technologies demanded that higher education be expanded to train qualified manpower and research staff. It also demanded increased links between industry and PSR, to enable industry to access knowledge about the new technologies and the traditional PSR sources of expertise for industry, the institutes, often lacked expertise in these new fields. Thirdly, the new technologies enabled the development of more sophisticated scientific instruments, and widened the range of disciplines which required such equipment. Both these trends increased the cost of research, and may explain many of the increased links between sectors of PSR. Fourthly, the pervasiveness of the new technologies across disciplinary fields and government responsibilities demanded methods to better coordinate the research activities of organisations responsible for public sector research. In particular, new technologies are characterised by interdisciplinary research and a blurring of boundaries between basic and applied research and development. This may also apply to other fields, but the process is driven by the new technologies, and creates the need for new organisational structures and funding arrangements.

2.9 Emerging Issues

Four main issues emerge from this analysis and raise a number of questions about the direction in which European PSR is evolving. These issues concern an apparent convergence between the roles of non-university research organisations and universities, increasing coordination of PSR policy, convergence of management practices and the wider implications of the growing emphasis on industrial relevance.

2.9.1 Institutional Convergence

The types of PSR in each country depend on a number of variables including local history, the industrial structure and so on. The effects of regionalisation, globalisation and EC funds also differ between countries. Given these differences, there is evidence in many countries of a blurring of boundaries between the roles of university research and the long-term, mission-oriented research institutes/government laboratories which constituted centres of expertise in specific areas and sources of policy advice for government. Universities appear to be gaining from a shift in the balance of funds being distributed to these sectors of PSR, whilst the goals of mission-oriented institutions are being redefined, and more emphasis is being put on their links with the university system and with increasing their income from contract research.

Research institutions, set up to focus on specific topics, now appear of decreasing relevance. They tend to have ageing research staff with permanent tenure as civil servants, and recruit little "new blood". They may lack expertise in pervasive, new technological areas which are of increasing relevance to every sector of the economy. Several governments, struggling to find a solution to deal with the cost and inertia inherent in funding research in research institutes, regard universities as a more flexible research resource. It cannot be assumed, however, that universities are more flexible research performers than the institutes. The German Fraunhofer and Max Planck Institutes have shown that institutes with a high proportion of temporary scientific staff can be as flexible as university departments. Moreover, the apparent flexibility of university research may not exist in countries funded through the block grant mechanism, where it is assumed that a significant proportion of academic time will be devoted to research. Teaching duties, and oligarchic university arrangements where full professors are permanent civil servants may impede attempts to allocate funds to new thematic priorities. This may explain why some countries continue to set up new research institutes in response to the need to focus on new areas of technology such as new materials or biotechnology.

In Ireland, institutes have been closed down. In the UK, some institutions have been privatised, others have been rationalised, with many staff taking early retirement and an increasing proportion of incomes derived from contract research. Norwegian and Danish research institutes are suffering from a reduction in core funding and increasing dependence on contract research. The French, German and Italian research institutes have remained reasonably stable, but awareness of environmental issues, together with concern about the risks connected with nuclear energy after Chernobyl, have led to the research agendas of nuclear research institutes being redefined to focus on environmental issues, including alternative sources of energy and energy efficiency. They have also have forged closer links with university research. Italian institutes are increasingly dependent on contract research funds. Spanish and Portuguese research institutes/government laboratories with sectoral interests are also refocusing their research agendas and successfully competing for funds, while continuing to provide support for the ministries on which they are dependent. Some of them are also strengthening their university links.

It is very difficult to change organisational structures, and that is why they tend not to change. EC Structural Funds have made it easy to set up new research institutions (as in Portugal) or set up new programmes without new institutions (as in Ireland). It is much more difficult to close down large research institutes - which has only happened in the UK, Ireland and Eastern Germany. That is why there has been a tendency to try to redirect the research within research institutes in countries such as Italy, Germany and France. These general trends affecting European research institutes raise a number of questions. How successful are established research teams in research institutes at building up expertise in new areas? Is this the best way to develop knowledge in important new areas such as environmental protection? Are links with university research helping to reinvigorate the institute sector?

Our studies suggest that there is a general trend around Europe - more advanced in some countries than others - for a convergence in the previously rather distinctive roles of various sectors of PSR, a growth in the importance of university research and a casualisation of Europe's research labour force, both in universities and research institutes. If PSR structures are evolving without any evident underlying strategy, are gaps appearing in national competence to fulfil the various roles expected of PSR?

The growing importance of university research may be driven not only by the need for greater flexibility in research, it may also mark growth in the demand for highly qualified personnel with doctoral level qualifications, and the university may be the most appropriate location to provide research training. Does such training require concentration of research activity in a few locations, or is it more appropriate for every university to be fully involved in research?

In many countries there now appears to be a casualisation of scientific manpower, with a movement away from the full-time professional and experienced researchers who worked in the institutes, to part-time researchers/lecturers, staff on short-term contracts and young inexperienced research students. Does PSR require a cadre of full-time, experienced, professional researchers to undertake research and provide a pool of scientific expertise. To what extent will the output of PSR suffer if they are replaced by part-time inexperienced people? What are the implications of this trend for research manpower? Policies for training highly skilled research personnel must run in parallel with policies for their secure employment, both in PSR and in industry. In particular, there is a need for policies to encourage commerce and industry to demand such skills, especially in some of the less developed countries. In the absence of such demand-side policies, countries which invest in the training of highly skilled staff may lose them to foreign employers. This has happened in Spain and Italy because of the lack of appropriate employment.

2.9.2 Coordination

A second issue concerns the widespread attempts by governments to improve coordination of PSR. The reason for these attempts vary between countries. For instance, in Britain it is linked to centralisation, while in France and Spain it is linked to an explosion of decision-making powers for R&D at the national and regional level. The following list implies no ranking, but tries to identify the main factors driving coordination:

(a) to improve the strategic management and guidance of government efforts in PSR, by incorporating R&D policy and budgets into the Government agenda at a horizontal and cross-cutting level.

(b) to cope with big new programmes, big science or national priorities which may not fit pre-existing institutional and disciplinary borders. It is also indispensable when science has to provide advice on important problems related to social issues, to cope with global issues (e.g. climate change, AIDS) or national problems (e.g. BSE or pollution in Spain's Parque Nacional de DoÒana). The emergence of new technologies and efforts to cope with global issues and national disasters demand Government coordination to steer and develop the PSR system so that it can move away from old areas and/or organisational forms and shift resources into new ones.

(c) improving efficiency in distributing no-growth budgets for PSR, especially when faced with the challenges in (b)

(d) to cope with diversity which has been created by the growth of new autonomous PNP funding organisations, the activities of regional authorities, and the EC's Framework programmes. The old hierarchical system of decision-making is being challenged by the degree to which the research agenda is determined by regional or international actors. Diversity is also inherent in new technologies, with almost every Ministry now needing to integrate R&D in its activities. At the same time pervasive new technologies may make it difficult to find a rationale for the division of labour in the system. There may be a conflict between political guidance and scientific criteria about which sectors should take care of new issues. There appears to be a growth in the extent to which Government is attempting to manage the issues being addressed by PSR and the work undertaken by scientist, but scientists also want to be involved in the decision-making process. Coordination in such situations can serve as a mechanism to facilitate negotiations for managing diversity.

It is important to recognise that whilst lack of coordination may provide flexibility, it can also hinder attempts to foster the new initiatives that are possible with steering. On the other hand, policy-makers' attempts to improve coordination may lead to less autonomy for researchers and research institutes, and it is not clear that this is always desirable or functional. It may be more appropriate to have a more loosely coupled assortment of policies from a variety of relatively independent policy-makers. For situations of high uncertainty, the avoidance of failure may be better served by following several parallel approaches, rather than one grand coordinated policy.

2.9.3 Increasing Emphasis on Industrial Relevance

There are concerns that the increasing emphasis on economic returns from investment in PSR, and all the related instruments - Technology Foresight, prioritisation, evaluation, initiatives, university-industry links and so on - may concentrate resources on short-term or oriented research and lessen the availability of resources for long-term, uncertain basic research - research for the advancement of knowledge. Trends in this direction may dissuade promising young scientists and engineers from careers in European PSR. Moreover, concentration on short-term issues of current concern to industry may lead to neglect of longer term research whose potential may only be realised at some time in the distant future. Technological support for industry and other users was traditionally provided by specialist sectoral institutes. Several questions are raised about the capability of universities to replace these specialist institutes, and especially about who will take care of the needs of small companies. Universities have not typically been very good at this, and it is uncertain whether universities will be either interested or capable to meet SME needs. A second problem will be the difficulty for users, especially SMEs, to find specific sources of expertise in the widely dispersed university sector.

A second, and perhaps more worrying trend, is that Governments' current emphasis on PSR as an instrument to increase the technological capabilities of firms appears to have crowded out the concept of its role to protect the public interest. There is a widespread obsession with technology, SMEs and supporting national champions, but aspects of public safety and welfare appear to have dropped to a low position on the agenda of many Governments. In part this reflects the ability of institutions to survive by getting contracts from industry, but these efforts appear to have deflected PSR from fully meeting its responsibilities to act as a "watchdog" in matters concerning research which may affect public safety, the environment, sustainability, animal husbandry and so on. The public has responded to disasters such as BSE, Chernobyl, climate change and environmental degradation by losing trust in PSR, because of a perceived failure of public sector scientists to warn about potential risks. It is unclear how far this failure is related to increased control by governments over the governance of PSR. Increased dependence of research institutes on winning contracts for commissioned research from government or industry may deter them from making critical information available because potential clients will not like the results. On the other hand, such critical information may be suppressed by governments to protect vested interests. Attention needs to be given to providing PSR with more independence so that it can be seen to provide "objective" scientific advice. There is also a growing need to allocate more research funds to topics such as risk assessment, and particularly to public safety connected with emerging applications of science and technology. Such research should recognise the central importance in risk analysis of subjective value judgements, and the consequent need for active participation in analysis by all interested and affected parties.

III AN APPROACH TO PUBLIC SECTOR RESEARCH THROUGH ITS RESEARCH COLLECTIVES

This part of the project aimed to complement the national case studies by taking a 'bottom-up' approach based on the analysis of research collectives. It aimed to develop a sound methodology for conducting cross national case studies of PSR in areas vital to public welfare and safety. It is based upon work done in science studies which have shown that research activity is a collective endeavour and that, to propose a provocative image, research units or ìlaboratories" are to science what firms are to the economy: the basic units of production. Building upon this image suggests that understanding the dynamics of a given organisation or of a ìnational system" requires the identification of the main types of production units which are present and the factors which favour, constrain, direct and shape their growth. The specific objective was to undertake "a pilot" study to develop a "harmonised framework for characterising research collectives across countries", to test it in a given research field and see how it helped to better grasp common dimensions and specificities of given national research systems, in "identify(ing) broad trends which are influencing the production of public sector knowledge and the requirements for its production".

3.1 Methodology

A five step process was followed to undertake this test

(i) select a research field for the test
(ii) identify 'labs'
(iii) define the process and criteria for characterising 'labs'
(iv) undertake an in depth study of a subset of labs for analysing their articulation with the national system
(v) derive lessons: (a) related to the parallel study on a European comparison of PSR; and (b) the "wider applicability of the methodology developed".

The following sections present a summary of the work undertaken and the results achieved. It is of necessity very condensed, so as to provide the reader with an overview of the dynamics of this experiment and of the major results achieved.[14] It contains a synthesis of the results of two complementary projects undertaken and the methodological lessons learned from these projects.

<u>3.1.1 Selecting a Research Field</u>
The selection of a research field for the test was relatively simple since the project focused only on areas of "general interest", likely to be present in all countries. Participants rapidly converged on the health sector and, within it, on a "Mode 2" type field, i.e. problem oriented, requiring collaborations between actors from heterogeneous backgrounds (both disciplinary and institutionally) and witnessing the emergence of 'new' productive configurations. Human genetics appeared all the more relevant in that it also had two complementary dimensions: one practical (the 'traceability' of productive activities through papers, since all applied dimensions - industrial and clinical - give rise to papers) and the other 'economic'

[14]For full results see P. LarÈdo, U. Schimank and M. Winnes (1999), *An Approach to Public Sector Research through its Research Collectives - Overview.* Interim Report B., ARMINES/CSI, Paris and Max-Planck-Institute for the Study of Societies, Kˆln.

in terms of the relevance of the field to established pharmaceutical firms, as well as to start-ups and high tech firms.

3.1.2 Developing the Approach

A theoretical background paper was produced by the Centre de Sociologie de l'Innovation of the Ecole des Mines de Paris (CSI) based on results from science studies. It proposed a two stage approach, first identifying the main "strategic profiles" or "configurations" of labs in human genetics, then undertaking, on given configurations located in different institutional contexts and different countries, in depth case studies to analyse the interactions between labs and the national systems. The work demanded that decisions be reached on which factors were to be taken into consideration, on which 'procedural, material and metrological' devices were to be followed, on how inter-actions should be analysed, and which criteria, descriptors or indicators of these inter-actions could be mobilised. A lively debate arose on two major issues.

- The appropriate level of analysis. The French suggested that the level of analysis should be research groups or "units" (labs), and the Germans preferred "institutes", a more firmly established institutional definition. The debate was broadened to consider university "departments", which are especially strong in Sweden.

- The feasibility and usefulness of a mailed questionnaire to capture relevant features of selected units of analysis. Furthermore, due to an anticipated low return rate (because of the length and complexity of the proposed questionnaire) it was uncertain whether the data collected and "configurations" or profiles" identified would be truly representative. It was therefore decided to split the two objectives and to undertake the two stages in parallel, the second stage also being devoted to solving the issue about the relevant unit of analysis. This was reinforced by the limited duration of the project (two years) which made it impossible to adopt a sequential approach.

The first approach focused on identifying the relevant unit of analysis, and analysing birth and growth dynamics and their articulation to the wider institutional PSR framework. It was based on a limited number of in-depth comparative case studies in six countries: Germany, Ireland, Norway, Spain, Sweden and the United Kingdom. The selection of entities was made along two lines: to cover the different institutional settings in each country, and selecting examples from which lessons could be derived about successful trajectories. The protocols for conducting the case studies were established to ensure linkages with 'data' and 'indicators' used in the second approach. The Max-Planck-Institute for the Study of Societies were in charge of this approach.

The second approach focused on developing a reproducible method for the characterisation of a large set of research collectives, or "labs". Seven countries were involved: France, Germany (undertaken from France), Iceland, Italy, Spain, Sweden and the United Kingdom. It was based on two building blocks: the pragmatic identification of entities through the use of bibliometric analysis and the development of a postal questionnaire. CSI were in charge of this approach.

Both approaches have much in common, and three partners have undertaken both approaches in their countries. A continuous exchange of ideas has taken place between the partners. This has proved very fruitful, especially in the joint definition of the questionnaire and the case study protocols, both of which represent a heavy investment[15]and constitute a major achievement. In their further development, both approaches confronted methodological difficulties which are normal for this stage of exploratory work. Implementing the methodology provided lessons for improving both approaches, and these lessons appear in section 4.3. The results of the two studies are summarised in section 3.3.

[15]They took half a year and involved all teams as well as the two in charge of the respective approaches. Numerous exchanges, bilateral meetings and two consortium meetings were necessary to arrive at them.

3.2 Human genetics in perspective

The general features of human genetics make the field suitable for studying the dynamics of public sector research in response to the changes in its external environment. Firstly it is related to genetics, the field of biological sciences which has witnessed one of the most revolutionary changes in the second half of the century. This change has been driven by progress in knowledge about the structure of DNA, genetic codes, protein synthesis, regulatory mechanisms and by unprecedented technical advances, including new enzymes, PCR reaction, techniques for separation and identification and characterisation of macromolecules. New knowledge and technical advances result from an explosive growth of research in the area since the early 1980s, which uses multidisciplinary approaches based on classical biology, biochemistry, molecular biology, physical-chemistry, organic chemistry and thermodynamics.

- Genetics is at the core of the explosion of the so-called ìmodern“ biotechnology, the realm where biological sciences are becoming instrumental for economical developments in agriculture, industry and the service sector.
- The introduction of human aspects into genetics is revolutionising models of medical practice. New models are evolving which pay increased attention to primary care and preventive medicine. Genetics is playing and will play an even more central role as the genetic base for common diseases are identified.
- The organisation of research and education in the biomedical and medical curricula is undergoing deep modification under the influence of human genetics. Human genetics, and in particular genome sequencing, is incorporating ìbig science“ into the domain of life sciences.
- New subdisciplines such as bioinformatics and new fields of applications like genomics (understanding the function of genes and using this knowledge as the basis for developing new pharmaceutical drugs and medical treatments) are emerging both in academia and industry.
- New medical services and new firms with diverse strategies (small knowledge-based firms, and big multinationals based on mergers and outsourcing) result from the emergence and evolution of human genetics research.
- New and significant ethical and social issues are arising from developments in human genetics research, with implications for both new forms of medical treatment and for social applications e.g. employment, insurance.

Through this evolution, the field of human genetics now appears to be typical of the biomedical research realm. It not only provides a paradigm for the current organisation of biomedical research but is also representative from the cognitive point of view. There has been a clear shift in medical research from the traditional descriptive-based studies of disease or from ìarchitectural“ modes of treating disease (uses of surgical or therapeutic treatments which greatly alter the identities of human bodies) towards an approach based on molecular medicine to explore (and understand) disease mechanisms. The most optimistic visions see a happy marriage between clinical research and molecular medicine (i.e. a genetics based approach) – see for instance Bell, 1999.

High priority has been given to life sciences and genetics research since the early 1980s, by both the EU and its Member States. The ìtake off“ of human genetics as a fast growing research area in government appropriations for research has coincided with important changes in national research policies. The changes include a shift from institutional funding with permanent posts towards temporary and competitive resource allocation. Secondly, mechanisms of quality control and evaluation have been introduced or strengthened. In addition, the special emphasis placed on the social and economic relevance of research privileges human genetic research because of its essential role in transforming and advancing public health care. Thus, human genetic research is particularly well suited for studying the effects of public sector research policy because its institutionalisation and growth largely took place during the new regime for national research policy.

Another general feature suggests that human genetics is a research area of central interest to the overall project, because it is frequently used as an example of the ìnew mode of knowledge production“ (Gibbons et al. 1994). In contrast to the traditional mode, characterised as disciplinary-based and academic, following the social norms and cognitive interests of a particular discipline which is relatively stable and hierarchically organised, the main elements of ìMode 2" are described as (1) transdisciplinarity, (2) a ìcontext of application", which means a blurring of boundaries between basic and applied research and an problem- or application-oriented organisation of research, and (3) heterogeneity and flexibility concerning the sites where and the organisational and financial arrangements under which research is performed. The debate about how relevant the Mode 2 thesis is, to what extent it changes the ìsocial contract" between science and society and what this means for public research was therefore a second reason why human genetics was selected for the case studies.

3.3 Results of the studies

3.3.1 The Case Studies

The prioritisation given to human genetics research in national and European science and technology policy agendas during the last fifteen years is reflected in the case studies. Most case study research units were established or redirected their research agenda towards human genetics during the late 1980s or early 90s, a population age which is confirmed by the results of the questionnaire. Even in the smallest countries like Ireland and Norway several active research groups in human genetics now exist and institutionalisation has set in during the nineties. In this context, one can observe considerable national variation with regard to the time when and the degree to which the individual countries joined the bandwagon of human genetics. These differences are mainly explained by three variables. Country size and the level of socioeconomic development have a strong impact on the thematic breadth and national research capacity in the field, while cultural factors have had a supporting or delaying influence on the development of genetics research in individual countries. Thus an interesting ìdiffusion pattern“ has emerged with a pattern of movement from the larger developed countries (UK; Germany) to smaller developed countries (Norway; Sweden) which finally reaches those which are either small and/or less developed (Ireland; Spain). Only the first group could provide the critical mass of human and financial resources to develop human genetics on a broad base, and a strong pharmaceutical industry and large public health system created public and private demand for genetics knowledge and services. In Sweden and Norway small, but well-funded and internationalised research communities have been enabled to join the bandwagon of human genetics in selected fields, especially where their comprehensive health system produced a concurrent demand. Finally, economic prosperity and rising living standards also expanded government support for science in Spain and Ireland and allowed the build up of a public health care system which provided a favourable environment for human genetics research. For the latter two groups of countries access and contacts with the leading international research centres and networks have played an important role in enabling the import of skills, resources and technologies from abroad which were required to establish competitive research capabilities.

Human genetics research units seemed particularly well suited for a study of the effects of the innovation-oriented research policy at the performing level. We found that such policy has been pursued in all the countries covered since the late seventies and comprises three main elements: (1) competitive resource allocation, (2) quality control and (3) increased social and economic relevance of public sector research (PSR). Due to its relative newness as a research field and its potential benefits for health care and economic development human genetics should reflect these policy changes and allow an informed preliminary assessment of the relevance of the "new mode of knowledge production" proposed by Gibbons et al (1994). The main findings are summarised in the following paragraphs:

Transdisciplinarity and a variety of institutional settings for research units are a common feature of most research units studied, corresponding to the expectations of the Mode 2 model. In addition, the problem-oriented character of research focusing on specific diseases or methods for resource acquisition seems to promote ìlocational fragmentation“. In neither teaching nor patient care is human genetics recognised as an independent medical discipline, so researchers move around the university faculties, research institutes or hospitals which offer the best research conditions, especially tenure-track positions, and a stable resource base. Tacit and ìpersonalised“ knowledge is of particular importance in human genetics due to its transdisciplinary and problem-oriented nature. Students and technicians often need training on the job to learn specific methods and techniques, and specialised skills and technologies play a central role in the work of many units. This makes recruitment of new scientific staff one of the most important strategic decisions for group leaders. It is the recruitment of new staff which largely determines the composition of disciplinary knowledge and technical skills available in the unit and thus its future research trajectory and success. Research collaboration is a second instrument used to deal with gaps in skills, expertise and techniques without having to incorporate new researchers into the unit. Collaborations are also vital in human genetics research because of the importance of blood and tissue samples and access to patient (histories) which are normally controlled by hospitals. This explains why many research groups are located in clinical settings or maintain close links with clinicians.

Human genetics research has to operate in a ìturbulent environment“ characterised by fluctuating resources and a corresponding lack of institutional stability and predictability in research planning. In this respect, the impact of national research policy on the micro-level of research performance is clearly visible. Resource allocation largely takes place on a competitive basis, most researchers are employed on temporary contracts or on a project by project basis and the bulk of research activities has to be financed through the acquisition of external grants. Under these conditions quality control is ensured almost automatically by the grant procedures of funding agencies through permanent competition with other research units for scarce resources. Only high scientific productivity ensures attractiveness for research sponsors and the access to research networks necessary for survival. Protected niches where scientists can rely on tenured positions and long-term core funding are largely absent and where such privileges exist researchers are subjected to regular evaluation. External income is often provided from a variety of sources, under different arrangements and there is diversity among the funding agencies which play a significant role in the promotion of human genetics research. Besides the classical sponsors of PSR - governments and research councils, mission-oriented government agencies and hospitals - foundations and charities (in some countries) and, to a lesser extent, the European Union and industry also contribute to research financing. The dependence on third-party-funds creates opportunities for external actors to direct research towards social and economic needs, while incentives are set for scientists to become more responsive to external interests. Thus, one could say that the priorities of European research agendas have been successfully implemented in human genetics. Flexibility in research and career planning, mobility, openness to transdisciplinary and international collaboration and demonstration of socioeconomic relevance are an integral part of the identity and self-awareness of most research units and scientists.

However, there are also significant negative effects of changes in research policy and for the Mode 2 debate. Interestingly, external direction of research is regarded as a rather secondary concern in this context. Almost no scientist reported that funding agencies had an undue influence on actual research activities. Where this issue plays a role is in the selection of research areas and topics, but the priority setting necessitated by the scarcity of resources is accepted so long as there are also opportunities for undirected curiosity-driven basic research. The increasing ìshort-termism“ in research funding is, however, sharply and almost unanimously criticised. Two or three year contracts, grants and scholarships which now prevail in most countries are seen as inadequate for producing high quality research in human genetics. This applies especially for complex and long-term basic research which needs a minimum level of stable human and financial resources. In addition, promising students and young researchers are discouraged from staying in the field by the lack of career prospects and an increasing amount of working time has to be devoted to grant acquisition activities which tend to have declining returns. Another related complaint concerns the lack of or reduction in general government grants for which project funding is no adequate alternative. ìWell-found“ laboratories providing basic infrastructure and the resources to develop new ideas and research themes into concrete project proposals are considered to be a prerequisite since funding agencies do not pay for equipment and overheads and tend to favour established over innovative, but risky, research.

The structural features that characterise the environment in which human genetics is embedded are reflected in the internal organisation, external relationships and strategies of the research units studied. They can be conceived of as small scientific enterprises or ìprofit centres“ operating in a densely populated and highly competitive market. The degree of formal organisation in all research units is low or absent, but two types of governance structure can be distinguished. The first is centralised and hierarchical control by the head of the unit, while other researchers play only a secondary role in research planning and decision making. The second could be termed leadership by competence and consensus formation. This can be observed in larger research units where direct hierarchical control is less workable. While the group leader reserves final authority in central matters like the recruitment of new staff for her- or himself, these matters are discussed and arranged with other researchers. Positive effects associated with this collaborative leadership style are a high level of information exchange and interaction within and between groups from which new ideas and projects often emerge.

To stay at the forefront of one’s research area is the prerequisite to secure adequate funding and attract productive and promising students and researchers which in turn ensure the survival of the research unit.

For this reason flexibility and responsiveness are central assets in a highly dynamic research area where knowledge, techniques and applications are rapidly expanding and advancing. Two general and combined strategies can be distinguished by which individual research units try to ensure both their organisational survival and their capability to carry out competitive research of scientific interest. Which strategy is chosen or how they are combined is influenced by the topic and the institutional setting in which the research unit operates. The first strategy can be termed niche strategy. This strategy is typically pursued by units specialising in specific diseases or techniques and aims at a ìcognitive domain monopoly" by reaching a leading or even dominant position in a particular disease or technique where tacit knowledge and skills and the access to blood, tissue and tumour samples and local patient populations are important. The second strategy can be termed diversification strategy which aims at a ìcognitive domain expansion" and is often combined with the niche strategy. This can be accomplished in two ways. Firstly, by concentrating on a certain disease or technique, but broadening the aspects dealt with. For such a research strategy, however, the level of human and financial resources and infrastructure required is normally only available in large research institutes. A second variant of the diversification strategy is specialisation in a certain research technique that can be applied to numerous areas and offered as a service to external research groups.

3.3.2 The Postal Questionnaire

Results produced from the analysis of the 392 completed questionnaires consider:

a. "classical" indicators - the inputs, institutional and organisational settings which highlight important national differences.
b. the activities undertaken by labs and typical patterns of involvement in academic, research training, clinical and industrial activities.
c. a global overview of labs' activities which identifies four major and very distinct activity profiles.
d. linking the four activity profiles to the data on institutions, inputs and national contexts. This provides results which differ from those in (a) above, and demands further work to be undertaken about relations between institutional frameworks and productive patterns in public sector research.

(a) Global characteristics of labs - the role of national contexts: The average sized lab in human genetics has 23 people, equally shared between senior research staff, junior research staff, technicians and clinicians, and finally doctoral students. This average is around 30 people in the three traditional ìlarge" countries (UK, France and Germany) and less than 20 in the three ìsmaller" ones (Italy, Sweden and Spain). Furthermore, though they share the same average number of staff, French, British and German labs widely differ in their internal composition.

Over 80% of labs are located on a University campus or in a university hospital. Location on a dedicated research site is quite rare, less than one lab in seven. This is partly mirrored in their primary institutional affiliations. One third of lab depend on a university, and another third belong to a university hospitals. 20% are affiliated to a government research organisation (GRO), while the remainder is split between foundations and general hospitals. There are wide national differences in these primary affiliations. It would however be misleading to consider only the primary affiliation since in more than a third of the cases, joint affiliations tend to blur these strong national differences. France and Germany clearly illustrate this point: in France, two thirds of labs mention a GRO (CNRS or INSERM) as their first affiliation, but in 80% of cases the same labs are also affiliated to universities and/or university hospitals, thus in everyday life being not very different from their German counterparts where double affiliations are rare.

Institutional affiliation however is not adequate to describe the financial situation of labs since long term core funding only represents 25% of their sources of funds. Labs in human genetics have to find the vast majority of their budget from competitive sources. Clearly national funds allocated on a project basis still play the main role (38%), but not more than other sources (37%). Within these other sources, foundations, charities and patient associations play an outstanding role (16%, featuring in labs sources of funds as often as core funding!). Industry (8%) is more important than EU programmes (6%) and regional funds (5%). Once more, there are wide differences according to the national context. In France long term core funding is more important (44%) while national funds and foundations share the same relative importance (17% against 15%). Spain relies on national competitive funds (with very limited core funding) and on regional funds. In contrast, foundations have an outstanding role in the UK (35%) completely counterbalancing the weakness of national competitive funds and of regional ones. Foundations also play an important role in Sweden and Italy. And in German labs obtain 75% of their budgets through core funding and national funds (with a far more limited role both for regions, foundations and industry).

A study limited to identifiers and inputs (as in traditional OECD approaches) would thus just draw conclusions about far ranging national differences and the wider role of national ìsystems" in the dynamics of labs. Such information must be taken into account, since it highlights the important differences in the national ìcontexts" in which labs operate. But it remains to be seen whether these differences accompany wide variations in activities performed by labs, and thus in their ìactivity profiles".

(b) Labs' activities: an analysis of typical patterns of involvement: An analysis of labs' activities was then specifically developed following the approach based upon the ìresearch compass card" model.[16] It drove to assessing labs' involvement in four activities: research training, academic pursuits, industrial interaction and relationships with clinical practice.

Relative involvement in research training is based on two central indicators: the presence of doctoral students in labs (seen through the ratio to research staff, on average 90%) and the number of PhD theses delivered in the last three years (similarly assessed through the ratio to research staff, on average 60%). This produces five main groups of labs (excluding 7% which did not answer): 19% of labs have no or marginal involvement (with on average 1 doctoral student to 7 researchers). On the contrary 21% have an ìimportant" involvement (on average 1 doctoral student per member of research staff) and 18% a ìstrong" involvement (with on average 2 doctoral students per member of research staff). In between there are two groups with around 1 doctoral student per 2 researchers, highlighting ìsecondary" (11%) and ìsignificant" (24%) involvement, the difference lies in the balance between past (PhDs delivered) and present activities (doctoral students currently in labs).

The central indicator for involvement in academic activities is the average number of publications in academic journals per researcher over a three year period. The average figure is 6. It differentiates three main groups of labs depending upon their ìproductivity": more than 8 articles (24%), between 3 and 8 (34%), less than 3 articles (31%, labs which did not answer representing a further 10%). For further differentiation, other dimensions of involvement have been looked at: they deal with the importance given to academic networks (as manifested by co-authored articles and longstanding relations with public research), and the participation of lab members in the management of scientific affairs (looking at researchers' involvement in their discipline, in their national system, and in the international and European scenes). This builds a ìcomplementary academic index" which gives an average value of 11 (out of a theoretical maximum of 30). This index is not correlated to publication ratios at all: it is not because you publish heavily that you become involved in strong partnerships which allow the coauthoring of a large share of your articles. And there seems to be little relationship between publications and involvement in disciplinary, national or international scientific life. Taking the publication ratio and the complementary academic index together build 5 quite distinct profiles. 24% of labs witness a ìstrong" involvement with an average ratio of 14 articles per member of research staff in 3 years. A similar number of labs (28%) is only marginally involved with less than 1 article per researcher per year and a low ìcomplementary academic" involvement. Both groups of labs share the same lab size (respectively 19 and 17 persons). Labs with ìsecondary" involvement (i.e. with a low publication profile and a high complementary academic involvement) are by far the largest in size (40 persons) (13% of labs). Labs with a ìsignificant" (21%) or an ìimportant" involvement (13%) share a similar median publication profile (5 articles on average) but differing positions on the complementary academic involvement index.

The industrial involvement of labs is measured via the construction of an index based upon three central elements: activities performed, spread and nature of links established with industry, and share of industry

[16] P. LarÈdo & P. Mustar (1996), 'Laboratory Configurations: an Exploratory Approach", Paper presented to EASST/4S Conference, Bielefeld, October.

in budget. It thus mobilises 11 different basic indicators. This index highlights very different involvements. One quarter of labs (24%) have no industrial involvement whatsoever (index=0) while the average index stands at 6.4 points (out of a theoretical maximum of 40). Involvement remains ìsecondary" (i.e. at most equivalent to the average index) in a further third (35%). On the contrary involvement is important or strong (i.e. 10 and over in the composite index) in a quarter of labs (29%). Two important lessons can be derived from the analysis: (i) contracts (and share of funds from industrial sources) make up the difference between those with only marginal and secondary involvement and the others. But it is not enough to differentiate between the labs involved (since in whatever form, the industrial contribution to lab budgets amounts only to between 15 and 20%). What makes the difference between ìsignificant" and ìimportant" involvement lies in the nature and spread of links (i.e. percentage of articles co-authored, existence of longstanding relations and the provision of advice/expertise to companies). Similarly all these dimensions are nearly doubled when moving from ìimportant" to ìstrong" involvement: 70% of labs with strong involvement have applied for patents and half consider it as crucial for the lab's life, 80% of the articles they mention have at least one industrial co-author, and they send one third of the PhDs they deliver to work in industry. 65% have longstanding industrial relations, 75% are consulted by companies and a third is involved in the creation of high tech companies. More than any comment, these figures tell us about the breadth and strength of links with the economic world!

Clinical involvement is considered along similar lines as industrial involvement, with the building of an aggregate index based on three sets of indicators. The first two sets - indicators of activity, indicators of relations - are similar to those for industrial involvement, while the third set is not built on budgets but on lab composition, taking the presence and relative importance of clinicians in lab staff. On average clinical involvement is more marked (the average index is 10 compared to 6 for industrial involvement), and more widely spread: only one lab in six (16%) witnesses no clinical involvement at all. In addition a larger number of labs are significantly (22% against 12%), importantly (17% against 16%) or strongly involved (22% against 13%), the index thresholds taken being quite similar for both industrial and clinical involvements.

Differences between classes are first linked to the presence of clinicians in labs: they are present in 25% of labs with significant involvement, in half of labs with important involvement and in over 80% of lab with strong involvement where they are nearly as numerous as researchers (the ratio being 77%). Being involved in clinical activities accompanies (as soon as involvement is significant) longstanding relations with hospital clinicians and practitioners. The more labs are clinically involved, the more importance they give to the development of new methods for diagnosis, new therapies or new drugs, the more often they participate in the development of protocols, in epidemiological studies and in clinical trials, as well as in providing expertise at national policy level.

(c) Labs' activities: four main profiles: The simple analysis of typical patterns of involvement highlights a first result. It is difficult to be simultaneously ìimportantly" or ìstrongly" involved in all 4 activities. On average, labs witness 1.5 such involvements. To analyse how these patterns were assembled: (i) we have focused on 'specialisations', i.e. important or strong involvements. This highlighted a first configuration with ìno marked involvement" of any type (22% of labs). (ii) 'Traditional' dimensions of public research, i.e. training and academic visibility, were considered together and then connected to 'socio-economic' involvements (i.e. joint involvement into clinical and industrial activities). This simple analysis helped to identify three other profiles. Labs focusing on traditional outputs – thus called ìscientific only" labs – represent 23% of the sample, labs centred on socio-economic relations – thus called ìsocio-economic only" labs – have a similar share (22%), while a third of the sample had both scientific and socio-economic involvement – thus their denomination of ìall embracing" labs. In interpreting these results, mention should be made of Granovetter's findings (1973): if ìstrong ties" determine current strategies, ìweak ties" should be accounted for since they are the main source of potential redeployment or strategic shifts.

- Labs with no marked involvement (configuration 1) can be defined as having similar involvements to the ìweak" ties of specialised labs. Their academic involvement (2.7 publications per research staff over a three year period) as well as their training involvement (0.3 doctoral student per research staff) is equal to

that of ìsocioeconomic only" labs (configuration 3), while their clinical and industrial involvements mirror those of ìscientific only" labs (configuration 2).
- ìAll embracing" labs (configuration 4) exhibit stronger involvements than ìspecialised" labs in two dimensions (academic & industrial) while the two others stand at similar level.
- There is a wide difference between ìweak" and ìstrong" involvement in all indicators except for the ìcomplementary academic index". Heavy involvement is on average four times stronger for research training, three times for publications and industrial activities and 2.5 times for clinical activities.

(d) Relating activity profiles to other characteristics of labs: The conclusions reached by linking the four activity profiles to the "classical" data on institutions, inputs and national contexts re-opens some questions about the role of national systems of innovation, and within them of formal institutions.

The conclusions reached by linking the four activity profiles to the "classical" data on institutions, inputs and national contexts re-opens some questions about the role of national systems of innovation, and within them of formal institutions.

(i) Does nationality matter? Nationality may matter for the capability of labs to emerge in a given field. Facilitating and favouring the emergence of labs in a new field such as human genetics was not a question this analysis aimed to answer. Still it appears as a crucial question since, once created, there do not seem to be major differences between countries in favouring one or other of the profiles. We have witnesses only second order level differences.

(ii) Do institutions matter? Yes, institutions matter, but strikingly enough not because they handle different types of labs differently; it is more probable that they matter because of the wider environment they correspond to and thus the indirect stimuli which derive from it. This hypothesis is arrived at by comparing the two following results.

- There is no difference in the relations between labs and their parent institutions (evaluation, modes for allocating core funding, rules for applying for external funds, etc.) depending upon the type of activity profile.
- Even so, there is a significant bias towards having more of a certain type of activity profile within given institutions. The main difference is observed between universities and university hospitals, labs from the latter more often being clearly socio-economically involved than labs from universities. Interestingly, labs from GROs are also less often strongly involved in socio-economic activities than average. However these quantitative differences should not hide the significant presence of all configurations in all institutional settings.

(iii) Do sources of funding play a major role in the orientation of labs? A first well known issue deals with the role of funds from industry which could drive labs towards the short term and less risky side of the research agenda. Clearly industry only has an impact on labs with marked ìsocio-economic" involvement, but such impact remains limited providing on average 15% of the budget of those heavily involved.

- The most important source by far remains ìnational funds allocated to projects on a competitive basis" (38% on average) along with core funding (25% on average). In all four configurations the aggregate level of these two sources varies only slightly around the average (63%). However, differences exist within the two profiles with no marked socio-economic involvement: ìacademic only" labs have far less core funding than average (18% against 25% and 35% for labs with no marked involvement) and far more competitive funds from national sources (48% against an average of 38%).

- Finally it should be noted that foundations, charities and Patient Associations (16% of total average budgets) provide almost equal shares to all four configurations.

Too simple notions about steering are clearly not at play here! Furthermore none of the wide national differences can easily be related to these findings.

(iv) Do facilities differentiate situations? We face a field which, according to some analysts, is developing a new type of big science, especially in human genome sequencing. This may well explain why we observed such a large percentage of labs with researchers using external facilities for their research. Still it is also a striking feature to witness the very limited number of labs which consider their research activities to be constrained by lack of equipment or lack of access (only 2%). Facilities thus matter but they are easy either to acquire or to access, without any major differentiation related to institutional affiliation.

(v) Are different human resources required for different types of activities? Average size clearly differs depending upon configurations: from 13 in ìacademic only“ labs to 35 in ìsocio-economic only“ labs, the average (23 people) being shared by the two other configurations (labs with no major involvement and ìall embracing“ labs). The answer to this fifth question is thus clearly yes, but the way in which it matters is not straight-forward. These differences are partly due to the process through which configurations were constructed, but only to a limited extent for two reasons: (a) in socio-economic involved labs, clinicians only represent around 10% of total staff, thus accounting for less than 20% in the difference between ìacademic only“ and ìsocio-economic only“ labs; (b) doctoral students play an even smaller role in explaining this difference (7%). This is due to the fact that strong involvement in research training is not related to higher numbers of doctoral students being present in labs, since the average size of the research staff in ìacademic only“ labs is one third of that in ìsocio-economic only“ labs (6 against 19). Thus difference in global size is first and foremost linked to differences in the numbers of research staff. How can this finding – the central role of researchers (and not doctoral students, clinicians or technicians) be related to the differences observed – with a limited management role for institutions? One potential answer lies in a major limitation of the questionnaire, namely in failing to address the issue of allocation of research staff by institutions. This could lead to further reconsideration of the hypothesis made about the reasons why institutions matter.

(vi) Does age matter? One major question concerned the potential for labs to move between profiles: one would start with no marked configuration and then slowly gain in involvement and recognition, defining thus a move towards one and then more strong involvements, and possibly towards a balanced coverage of the research compass card. Our results do not confirm this. If the average age of ìall embracing“ labs is far greater than that of ìacademic only“ labs (13 years against 9), this is not the case of ìsocio-economic only“ labs (14 years) and of labs with no marked involvement (13 years). Thus we are driven to hypothesise that, as in innovation processes, the dynamics of technological programmes or for the growth of start-up firms, initial phases are crucial and set labs in a trajectory which is then difficult to change. This is reinforced by the fact that growth patterns do not differ much between configurations: it is not because you are in a less visible configuration that growth will be more difficult or more staggered. Similarly factors central to this growth do not differ widely between configurations: all are pushed by a combination of results obtained, diversification and collaboration strategies, resources accessed, and organisational change. This set of factors is more revealing about the shared attributes of the entities we are looking at, rather than about their differences. And these shared attributes have much in common with those usually used to describe autonomous strategic entities, or to take an economic image, they tend to describe research ìenterprises“.

(vii) Is there a need for differentiated management practices? It is often considered that different institutions are required to handle different types of missions, thus the very revealing OECD terminology of mission-oriented institutions and the notion of government labs. As mentioned in point (ii), we did not find any significant difference in the way different types of labs relate to their institutions though all types were present, in different numbers, in all institutions. This suggests a first conclusion: institutions have not yet recognised any need for treating labs with different profiles differently.

Still, there seems to be significant distinctions in the way labs in different configurations are organised, especially in their internal management (presence of management and/or scientific committees) and in the way they relate to external sources of funds (sharing responsibilities between the head of the lab, the team leaders and the researchers).

This question is left open. Does a ìMode 2“ type of field, such as human genetics, require different institutions. Or rather, does it require any given institution to follow different modes of treatment for its constituent units, so as to follow, monitor and interact with these units' strategic choices?

4. Conclusions and policy implications *(maximum 30 pages)*

This project had very ambitious objectives and has produced results which go a long way towards meeting them. The results depended upon collaboration by a team of experts on PSR in twelve European countries. The team had never worked together previously and a major benefit of the project was the growth of trust and cooperation between the members of the group and of knowledge about how to cooperate in an interdisciplinary social science project. Various constellations of the group are continuing to work together on subsequent projects for the EC, and to have discussions about future international collaboration.

National reports and discussions were an important method for the group to partake in in-depth learning about PSR in the other countries. Moreover, debates among the members of the team about the way to carry out a cross-national study expedited the development of the methodology. A third important benefit from the partnership was the collective contribution to understanding the results produced by the two work packages.

This section will first present the results of the project in terms of its contribution to the advancement of knowledge and methodological development aimed for in its objectives. Next, it will turn to an issue not anticipated at the start of the project - the implications of the relative neglect by PSR of public welfare and safety aspects of research. It will conclude by discussing the policy relevance of our findings and the policy implications which emerge.

4.1 Explaining the changing structure and dynamics of PSR systems

One of the objectives of this project was to deepen understanding of how far the changes to PSR systems are related to the social, institutional and political context in which these systems are embedded, and how far they reflect wider global trends. The analysis of the national studies shows that national public sector research systems are immune neither to global nor national influences.

We can see global influences at work in the similarity of the mechanisms being adopted to manage PSR in various countries. In particular five major trends are evident: an apparent convergence between the roles of non-university research organisations and universities; increasing coordination of PSR policy; a convergence of management practices; growing emphasis on industrial relevance; and concentration on fashionable new areas of high technology, often to the neglect of local needs. There are also global and national aspects of the political context. At a global level, both the OECD and EC helped to accelerate investments in PSR during the last thirty years. In more recent years, EC Framework Programmes have encouraged the development of European collaborations both within PSR and with industry. In some countries collaborations within Europe are now growing more rapidly than those with the US. However, the national studies reveal that political history has had a strong effect on the development of PSR in each country, and current practices in the distribution of responsibilities for PSR (between the regions and the state, or between Ministries) also determine the way in which the system in each country evolves, and its room for manoeuvre.

In consequence, the overall picture of public sector research (PSR) which emerges from reading the national reports is, on the one hand, of important country-specific features and, on the other, of significant features which are common to a number of countries, and sometimes even to all of them. Thus, we have three kinds of phenomena: those which exist in one of the countries studied only; those which exist in some, but not all of them; and those which exist in every country.

To give just two examples of the first kind of phenomena: in Ireland there has been a recent emphasis on basic research at universities. This has been justified by the argument that basic research is necessary to improve teaching to provide the Irish skilled labour force with the qualifications demanded by high-tech industry. Similarly, many aspects of Hungarian PSR can be understood as a consequence of the country¥s overall transformation after the demise of the socialist regime. These and many other ìidiosyncrasies“ of a particular country cannot be ignored.[17] But if all our findings were country-specific, a comparison would not make sense. All we could provide would be a collection of non-comparable ìindividuals".

However, this is clearly not so. Among the PSR systems of the countries covered in this study, groups of countries can be identified which show the same pattern with respect to a specific feature of their PSR. For instance, three groups of countries can be distinguished by the energy put into the evaluation of PSR and its impact. In some countries evaluation has high priority and significant consequences; in others a moderate involvement in evaluation can be detected, whereas in the remainder evaluation mainly takes the form of rhetoric. Such groupings can be made for quite a number of aspects of PSR, as will be seen in the main body of this synthesis report.

An understanding of the co-existence of total diversity - the first kind of phenomena - and partial diversity - the second kind of phenomena - can be drawn from analysing the development of the third kind of phenomena: patterns which are common to all countries studied. Several factors can be identified which have led to a convergence in practices between countries. In particular, two aspects of broad societal dynamics have had enormous impact on PSR:

The first of these is the economic problems suffered by all the countries during the period studied,[18] such as declining growth rates, rising unemployment and so on. These economic problems have created fiscal problems for the state. The second has been a growing awareness of several negative economic externalities concerning, for example, environmental problems or certain deficiencies in public health and welfare.

These societal dynamics have confronted PSR with three challenges. The first results from fiscal problems and for PSR, as well as for other policy areas, the period of fast growth is over, and has been followed by scarcity. The second challenge concerns the need to make PSR more relevant to the economy. It is perceived that economic problems can be overcome and a new period of growth initiated by technological innovations, especially basic innovations based on scientific research. The third challenge is related to the negative externalities, which increase the political relevance of PSR because many of these externalities are expected to be remedied by the state. In carrying out these functions, the state often requires specialised scientific advice and assistance.

Two broad political orientations towards PSR have appeared in reaction to these challenges. The first results from having entered a period of scarcity and is a demand for more efficiency. The other political orientation arises the second and third challenges outlined above - the requirement for PSR to contribute to innovation and to support the state in coping with negative externalities - and has led to a demand for effectiveness of a specific type. Research policy has developed a clear priority for user-orientation and applied research instead of curiosity-oriented basic research, with industry as well as the state, the health care sector and other areas of society as legitimate customers of PSR. Researchers and institutes are not now expected to totally neglect their inner-scientific reference groups, but relevant extra-scientific reference groups have to be given more emphasis than previously.

These political orientations have been translated into a number of more specific political goals, including: better management of PSR, higher flexibility of PSR, more collaboration within PSR and between PSR and users, more coordination of PSR and of research policy, more political control of PSR through evaluation and related measures, and a strengthening of university research within PSR. All these points are discussed in detail in specific sections of this report.

Societal dynamics and the challenges they imply for PSR, the political orientations emerging in reaction to them, and the political goals arising from these orientations have basically been the same within all of the

[17] Two kinds of country-specificities must be distinguished. In the narrow sense, a phenomenon is country-specific if it exists in one country only. In a broader sense, which is our understanding here, something is treated as country-specific if it can be found only in one country among our selection of cases. The Hungarian example is clearly of this kind, since Hungary shares many transformation phenomena with other ex-socialist countries.
[18]With the possible exception of Ireland, which has been growing rapidly in the past five years.

countries studied. Nevertheless the countries differ greatly in the specific political measures which are agreed and implemented to achieve the political goals, as well as in the effects of such measures on the structure and dynamics of PSR. In consequence groups of countries can often be identified which adopt similar measures to implement a particular political goal, but sometimes countries exhibit peculiarities which they share with none of the others. An analytical framework which combines ideas from sociological new institutionalism and economic theories about path-dependence can explain, on the one hand, the great convergence between the political orientations and goals of countries, and on the other, the divergence between political measures and outcomes.

It is reasonable to assume that political actors adopting measure to shape PSR have usually done this intentionally and with an ambition for rationality. But rationality is very bounded in situations of great uncertainty, that is when information is rather incomplete, strongly conflicting values are at stake, and time pressure is high. One of the insights of new institutionalism is that in such circumstances actors search for ready-made models of what to do. They often imitate what appears to be a successful measure by someone else in a similar situation. This kind of behaviour betrays the many illusions on which it is based, because at least three assumptions are made which are by no means always true: firstly, that in the model imitated there is indeed success and not just make-believe or wishful thinking; secondly, that if there is success it is the result of the measure being copied and not of other causes; and thirdly, that if the measure being imitated is indeed the decisive factor for success, that it will be as successful under the different circumstances of the imitator as in the situation where it was initiated.

When this kind of imitation happens, it leads to a convergence of policy-makers' belief systems. The political perception of problems, orientations and goals become more and more similar between countries. ìNew public management“ is a good case in point. Institutions like the OECD and the EU reinforce this tendency because their descriptive and prescriptive assessments of what happens and what is to be done influence national debate everywhere in the same way. Ironically bounded rationality, which often influences the measures imitated, becomes invisible as soon as every country acts in this way, because no alternative or better way to handle the situation practised anymore. So, what everybody does becomes the best way to act because everybody does it - a self-fulfilling prophecy. If every country, for example, has finally jumped on the ìevaluation bandwagon“, evaluation obviously is the thing to do. At least, policy-makers can be sure that they will not be blamed for what they have done, and since blame-avoidance is often a powerful consideration for policy-makers, this again directs them towards imitating others.

If this were the whole story, however, all national systems of PSR would look alike. But path-dependence resists any tendencies towards convergence which might be produced by imitation. Path-dependence means that each formation of a system¥s structure - its past - leads to a structural commitment, a pre-selection of what is possible, feasible, and rational in the future. Step by step, the system¥s dynamics shape institutional arrangements, interests and power constellations, and the substantial tasks carried out. In systems of PSR this means, among other things, that commitments made to certain scientific fields like nuclear energy rule out other possibilities and can only slowly be abandoned. Another example can be funding arrangements such as the German joint funding of extra-university institutes by federal government and states. This makes nation-wide evaluation exercises as in Great Britain almost impossible.

Numerous other phenomena of this kind could be found; and some important ones are discussed in section 2. A general point about the rigidities implied by the path-dependent character of PSR must be made. Often, especially in the eyes of reform-minded policy-makers, path-dependence appears to be rather negative. It seems to be the hardest and sometimes insurmountable obstacle to their ambitions. Many political measures which seem highly desirable are impossible to realise, taking into account the historic intertia of the PSR system; other measures which seem to be possible fail when implemented; still others bring about unforeseen and unwanted effects instead of what was intended. On occasion, path-dependence may work in this destructive manner. However, bearing in mind the highly illusory character of political rationality described above, path-dependence may also be rather healthy in preventing a system from the harmful effects of political measures. The path-dependent character of a national system of PSR can be assumed only to be completely dysfunctional under the assumption that policy-makers always know best what is good for it. The possible functionality of path-dependence can be appreciate by taking into account how much superficial imitation in the design of policy instruments is unjustified by the facts.

This functionality exists not only for one particular system of PSR but also for the whole family of European or even world-wide systems of PSR. Path-dependence maintains diversity within this family, and is a kind of international division of risk. Diversity which cannot be eclipsed by the convergent belief systems of policy-makers prevents all national systems from making the same mistakes. Instead, different national systems have their own strengths and weaknesses which open up manifold opportunities for universal but specific and restricted learning from each other. Each country can learn from all the others; but it can learn only certain things from each specific country; and what it learns cannot be simply adopted unchanged but must be tailored to the specific conditions of its own system of PSR. Flexible adjustment capabilities of this type can counteract the influence of path dependence and are evident in some countries. Ireland, for instance, has made positive use of the results of evaluation studies to adjust programmes providing support for R&D.

By pointing out this dialectic interplay between policy-makers¥ intentional shaping of PSR, which often does not go beyond simple imitation of seemingly more successful neighbours, and the system¥s rigidities originating from its path-dependent character, a certain reading of the following presentation of our comparison of twelve national systems of PSR is suggested. Policy-makers as well as their advisers from the science studies field should learn to become more aware about the type of learning just sketched. Paradoxical as it seems, greater recognition of the limitations of imitation in political thinking, rhetoric and decision-making might lead to its abandonment, in favour of adaptive imitation. Policy-makers might learn that they could do better if only they tried hard enough. By understanding the specificities of other countries¥ systems of PSR, and by keeping in mind the characteristics of their own country¥s system, policy-makers might become more cautious in their measures, and this may turn out to be more successful than fine rhetoric followed by much less impressive performance.

4.2 Strengths and weaknesses of different organisational structures of PSR systems

Every part of this study has reflected the growing convergence amongst the previously rather distinctive roles of various sectors of PSR, a growth in the importance of university research and a casualisation of Europe's research labour force, both in universities and research institutes. The evolution of PSR structures without any evident underlying strategy, may lead to gaps appearing in national competence to fulfil the various roles expected of PSR.

Universities traditionally focused mainly on research for the advancement of knowledge and the training of new generations of researchers. Government Laboratories (or special mission-oriented institutes) focused on supporting Government policy formation and implementation, including issues of public safety and welfare. Some institutes had responsibilities to concentrate on supporting industry. These activities were complementary, with each sector drawing on the knowledge and expertise developed in the other sectors of PSR. We now have a situation where every sector of PSR is in competition for research contracts from Government and industry. Moreover, research for the advancement of knowledge is often restricted to the areas prioritised by Government for support.

Secondly, there is evidence in many countries of a blurring of boundaries between the roles of university research and the long-term, mission-oriented research institutes/government laboratories which constituted centres of expertise in specific areas and sources of policy advice for government. In an environment of low or no-growth budgets for PSR, universities appear to be gaining from a shift in the balance of funds being distributed to these sectors of PSR. But university researchers are coming under pressure to carry out research to meet government priorities, and of relevance to users, as well as trying to ensure that their research results are transferred to industry and other users. Research institutions, set up to focus on specific topics, appear to be of decreasing relevance. They have been closed down or rationalised in some countries, privatised in others or had their research agendas redefined. In every country, they have strengthened their links with university research and reduced Government budgets have forced them to derive an increasing proportion of their incomes from contract research for

Government and industry. They tend to have ageing research staff with permanent tenure as civil servants, and recruit little "new blood".

These findings were mirrored in the results of the human genetics questionnaire, which showed very little difference in the profiles of the research activities undertaken by research groups in different institutional contexts.[19] This result may be explained by the convergence of missions between different sectors of PSR. The questionnaire was unable to help us go beyond this simple explanation because it failed to address the issue of the allocation of research staff to various duties by institutions. Yet questionnaire results hint that the way in which research staff are allocated may have a more important effect on research activities than the institutional system.

We are unable to reflect on the strengths and weaknesses of different organisational structures of PSR systems, but it is clear that the growing convergence between different types of PSR and the changing location of PSR research have their own inherent dangers. Does PSR require a cadre of full-time, experienced, professional researchers to undertake research and provide a pool of scientific expertise? To what extent will the output of PSR suffer if they are replaced by part-time inexperienced people? Questions are also raised about the location of expensive research equipment and technicians able to maintain that equipment. Who will be responsible for training researchers in the use and potential applications of such equipment and on what basis will access to the equipment be arranged? Can university researchers provide government ministries with the long-term, in-depth, background expertise previously on-tap from dedicated research institutions, as the need arises? How far will research institutes be able to act as impartial policy advisers to government, if they become dependent on contract research funds? (This question is raised in the recognition that institutional funding does not necessarily guarantee independence. Ministries may suppress results which do not support their policies and it is not unknown for Ministries to close down institutes whose results challenge Government policy. Awareness of these potential hazards has also served to restrict institutes' independence.) Will the public trust the judgements of scientific experts from PSR institutions carrying out industrial contracts? Institutes generally employed interdisciplinary teams of research staff working on particular missions. Will it be possible to develop stable, interdisciplinary teams when research is organised in disciplinary-based university departments? Is it possible for university departments or research institutes which rely on short-term contract researchers, to accumulate, share and apply the knowledge developed?

Some answers are provided by the case studies. Heads of research units do not deny the advantages of flexibility produced by a large percentage of temporary contract staff. The constant turnover of staff ensures a permanent influx of ideas, skills and techniques and serves to adapt the research programme to new developments in the field. Such turnover leads to success in applying for competitive research funds, and it is relatively easy and cheap to dissolve unproductive units. But the system also has negative effects. The short-termism inherent in temporary contracts may adversely affect programme continuity and research driven by scientific curiosity unless units have adequate core funds. Without this funding there is a danger that scientific excellence may become secondary to extra-scientific criteria such as meeting time or budgetary limits, irrespective of whether such criteria are consistent with research needs. A more insidious effect of short-termism may be the loss of promising young scientists from research careers, either in the public or private sectors.

4.3 A sound methodology for conducting cross-national case studies of PSR

This exploratory work aimed to test a new approach to address the issue of the shaping of public research sectors. The case studies have confirmed that ìlabs“ – however loosely defined this entity may be – constitute a strategic entity, i.e. a place where autonomous choices are made about the nature and direction of research activities. The image derived from the case studies is striking since the authors compare them to ìsmall research enterprises operating in a densely populated and highly competitive

[19]There were some slight differences between universities and university hospitals, with the latter having more socio-economic interaction than the former. This result is probably related to the field of research studied. The finding that research groups in government research organisations have below average socio-economic involvement may relate to historic "missions" which excluded such interaction.

market“. Lab analyses are able to provide a complementary entry point to the presently dominant ìinstitutional“ approach. Especially when taking into account the results of the questionnaire survey (with answers from 392 labs, this exploratory work appears as one of the largest studies on labs ever undertaken). It has enabled the identification of four main activity profiles which bear a limited relationship to labs’ national and institutional location. If national contexts clearly impact on the way in which inputs are assembled, it still remains to be seen how much national channels for accessing resources are involved in setting labs on a given trajectory, since we have hypothesised that movements from one profile to another might be neither easy nor numerous. The results also highlight the presence of all configurations in all institutions and it appears that, once created, labs develop quite autonomous strategies. The question about the role of institutions remains open. However, we have identified factors (emergence of labs, allocation of permanent staff, existence of ìexternal“ facilities, specificity of national funding mechanisms) which point to the role of the wider embeddedness of labs in their trajectories.

Further studies are required to strengthen these hypotheses and the effects they may have both on the dynamics of public sector research and the policies framing such dynamics. This could be undertaken by enlarging the work on human genetics. with complementary in-depth studies being undertaken on "labs" which share the same activity profiles, and which focus on the issues which both the questionnaires and case studies identified as being important to explore.

Although this was a very specific case study, it is tempting to speculate that human genetics may offer a good example of the way in which life sciences research is developing. Areas such as general biology, botany, entomology, ecology and taxonomic studies now appear to be moved by the same impulses and constraints, i.e. interdisciplinarity and transdiciplinarity; context of application; changes in institutional, organisational and funding arrangements and the need for more social accountability.

However successful, this first complementary study raises several questions: How far can we generalise from this work? We voluntarily chose a field which we thought would reflect the ìnew“ mode of production. Did this choice affect and constrain our conclusions? The issue is such that other fields, with more traditional relations both to institutions and to the economic world, e.g. more established fields in the health sector or in engineering sciences, should be considered before such conclusions can be generalised. Before generalizing hypotheses about the role of institutional and national dimensions on the emergence and development of labs, we advocate that another study should be undertaken on a more ìtraditional“ field, a study which would benefit from the methodological lessons derived from this exploratory work.

The approach to developing the methodology was experimental and an important objective was to test it and make it more robust. Lessons learnt from the development of each approach, which were far from linear, are thus a major result, if not the main result of this part of the project. Both approaches were fruitful, suggesting the existence of contrasted configurations of research groups and highlighting major organisational dimensions which shape their interactions with the wider national systems. We also found that there can be a major element of complementarity between ìtop-down“ and ìbottom-up“ approaches. A major lesson from both approaches is that the "top down" research must focus on the research field under study. The ‘top-down’ part of the PSR project was not designed as such, and embraced the whole of public sector research. Further work should ensure a coherence between both approaches to take full advantage of their complementarity. The second major lesson was recognising the imperative need for the questionnaire and case study approaches to be carried out sequentially, and to allow sufficient time for this in future projects. Specific lessons learned about the way to implement each approach follow.

(a) The postal questionnaire: The development of the postal questionnaire is a major achievement of the study. The application and analysis of the questionnaire and the parallel case studies helped to remedy some weaknesses. The significance of the approach is shown by its adoption for a new French project and its use as the basis for a potential comparative international project (see section 5). This does not mean that the questionnaire can be used as it is in other settings: the information to be collected must be shaped to the activity under review. What is the use of clinical dimensions to assess computer labs’ involvement in innovation in collective goods? The section of the questionnaire which seeks to investigate relations with the outside world, should reflect appropriate modes of collaboration for the activity under review.

The identification of labs. Bibliometric approaches proved feasible but were time consuming (taking much longer than had been anticipated). It was not possible to make use of existing scientometric software to harmonise and match addresses. There is thus an urgent need to develop software focusing on lab identification through databases (articles or patents). This is a major requirement if larger research areas are to be analysed. The second problem faced was to identify names of the current heads of labs: this is time consuming, but the generalisation of websites should greatly facilitate this task.

Contacting actors and gathering answers. Two classical lessons were learnt yet again. First, the involvement in the questionnaire of a well-known authority in the area under review, greatly improved the return rate in the country where this happened. Second a two-step process (as used in co-nomination methods with a first very short one page questionnaire) might be a better way to delineate the active labs in the area under consideration (it could also be a good way to identify the span of other disciplinary or problem-oriented competences attracted by the area under review).

Building ìactivity profiles". Primary data was used to construct ìaggregate indexes of involvement" in each of the four worlds taken into account. The results of the study underline two major advantages of this approach. By considering relative involvement, it avoids reliance on pre-defined norms: Norms are generated through the analysis and remain flexible since practical aggregation rules remain open for change and can thus be adapted to other patterns of coordination. What proved more difficult, and where standard statistical methods did not appear to work well, lay in the identification of patterns. The project thus adopted a step by step approach to analyse involvement mixes and identify the main productive configurations, finding four major ìactivity profiles". The step by step approach adopted was feasible with 400 labs, but should a larger enquiry (with some thousands of labs) be launched, the limitations of standard statistical methods should be thought of in advance.

(b) The case studies: The comparative case studies of research units in the field of human genetics had two general objectives within the methodology of the overall project. Firstly, case studies are a well-established instrument for checking the results derived from analyses at the macro-level of national research systems. Reports dealing with the institutional structures, funding and government arrangements and policies for public sector research provide a broad picture of the main features, issues and problems of science and technology policy and public research, but tell us nothing about the dynamics and challenges to knowledge production at the micro level. To analyse how the factors driving national research policy and the organisational development of PSR are perceived and influence the work of individual research units, and to understand the relevance of the various factors, one has to study the basic units of production. However, information on the performing level of scientific research is scarce and scattered. Existing laboratory studies mostly cannot be generalised, let alone compared across countries or institutional settings. In addition, the number of potential cases is almost unlimited. In consequence, to produce meaningful case studies with limited resources demanded case studies which

(1) were complementary to the national reports and the questionnaire,
(2) threw light on interesting findings and hypotheses gained from these two approaches and
(3) allowed a cross-national and -institutional comparison of results

It was also necessary to have close co-ordination with the other parts of the project, especially the questionnaire, a careful selection strategy for the scientific field and the research units covered and a standardised format for both data gathering and interviewing as well as the analysis and presentation of data and interviews. By concentrating on these main problems three methodological lessons can be learned:

An ìideal" sequencing of the project would have placed the case studies at the end of a three stage process, so that they could be integrated with the national reports and the questionnaire. The strengths of the case study approach is that it can be used to check or deepen findings from the latter approaches by providing detailed, in-depth information. However, this requires that interesting issues for further study have been identified and agreed. The reports on the national research systems can be regarded as a first step in revealing the major dynamics and challenges of the public research systems in the countries studied (Senker 1998). On this basis a research area for case studies can be selected which is of interest in all or most countries and of which one could expect a particularly good reflection of new scientific and political developments and changes in PSR.. In this way a set of common guiding themes or questions for the case studies is also established. The national reports provided background knowledge about the history and institutional structure of research systems necessary to select research units which are representative of the respective systems. In order to analyse how the factors driving national research policy and the organisational development of PSR are perceived and influence the work of individual research units, and to understand the relevance of the various factors, one has to study the basic units of production. The second step, the questionnaire, served as a valuable instrument to identify and depict the universe of research units in human genetics in the countries studied, which is a precondition for a targeted strategy of case selection. It identified the institutional settings in which human genetics research units operate, their size, staff composition, funding and government arrangements, activities and external relations, and grouped the units into four main configurations of ìactivity profile". Thus the questionnaire produced the information needed to select cases which could be compared across borders and which present ìtypical" units within the research area and national research system. In addition, by conducting in-depth case studies in research units which had participated in the questionnaire one has structured and standardised background information that is extremely valuable for preparing interviews and comparing results.

Instead of this ìideal sequencing", time constraints forced us to run the case studies in parallel to the national reports and the questionnaire. Accordingly the selection of cases had to follow a pragmatic approach based on combining relatively broad institutional settings and activity profiles. Time constraints meant that most partners could carry out only three case studies and a rather diverse sample of cases came together, limiting comparability and generalisation of results. While some partners chose units which were most typical for their research systems, others chose units which showed interesting institutional characteristics or activities, but are rather atypical for the overall population of research units in the specific country. Furthermore the interviewers lacked background information from the questionnaires. This would have helped in selecting units which were active in the same or related research specialities or were similar in size and mission. Last but not least the cases were selected and interviews started before discussion of the national reports had identified a common set of substantial, guiding issues on which to concentrate. Moreover, we found that the broad picture of science and technology policy contained in the national reports had limited relevance for human genetics labs. What was required was fine-grained policy analysis specifically concerned with the field selected and not at a global level.

A second methodological lesson is the need for a commonly agreed case study protocol which should consist of two main elements. The first is an introductory and methodological part setting out the background of the overall project and the specific objectives of the case studies within this project. In addition, this general part should formulate two or three guiding questions which could serve as a ìred line" for organising and conducting interviews. Both aspects are of particular importance if interviewing is delegated to someone not involved in the project who cannot decide on his own when it is relevant to change or to pursue specific subjects. The second is the core of the protocol, which forms the actual interview guidelines, listing the topics which should be covered, sketching the main interest in the individual topics and framing corresponding questions. Of central importance in this context is not that interviewers follow the given sequence of topics and questions, but to establish a standardised reporting format in which interview results are organised and presented. How the results are derived is of secondary importance. Only in this way can the type and volume of information be gained which is necessary for comparison. As the project showed it is a condition *sine qua non* for comparative case studies of research units in national research systems with different historical and cultural backgrounds and in a highly specialised discipline that interviewers develop a ìcommon language" defining the phenomena to be studied and the terms describing them. On this basis each interviewer can translate these phenomena and terms for his or her research system in order to avoid misunderstandings in actual interviews. But findings again have to be translated back into the common language to enable a meaningful interpretation and comparison with cases from other countries. Thus, the development of an interview protocol is a central task for in-depth case studies in different countries and research institutions.

A third important element for ensuring the comparability of cases is an agreement in advance on what constitutes a research unit and what are the appropriate levels of analysis. This was a major issue for discussion from the very beginning of the project . While an ìinstitutionalist" group did not deny that research groups or teams working and publishing together on a common subject in a laboratory are the basic units of knowledge production, they regard the institutional setting and organisational arrangements in which these units operate as significant factors influencing their activities and trajectory. In order to assess if and to what extent ìinstitutions matter", however, it would have been necessary to select cases and interview partners accordingly. However, no precise decisions were made about which levels of organisation should be included in the interview series and how the sample of cases should be put together to gain general findings on the institutional dimension. Some cases supported the institutionalist hypothesis, others saw no or only marginal influence from organisational factors. But this may be a reflection of the position of the project partner in the debate, which affected their interviews and case study reports, rather than the results of an unbiased analysis.

4.4 National PSR and Wider Relationships

The fourth objective of the study was to throw light on the relationship between national and supra-national organisations in the support of PSR and to identify any tensions between inward-looking, nationally-networked public research and the potential emergence of a distributed European knowledge production network based on outward-looking and inter-linked national scientists and centres. These are very ambitious aims. Bibliometrics offer some scope for identifying, mapping and measuring scientists' national and international research links, and the evolution of these links over time. As pointed out by Katz and Hicks (1996), however, such bibliometric work is difficult and to date there have been few comprehensive analyses, even at the national level. Moreover, even if this work were to be carried out, it would not reveal whether national or supra-national organisations supported the collaborative research identified by bibliometric analysis.

The focus of national reports on the changing structure, organisation and nature of PSR systems was on national policy, and its evolution in recent years. The results of the national studies therefore allow us to reflect on national policy for research links, but not on the outcome of that policy. The investigation of the human genetics research community, both the questionnaires and the case studies, provide partial answers, but it must be remembered that this material cannot be generalised to all research fields.

All the national reports show that policies to promote collaboration of all types is a common feature of European PSR systems. National and/or regional policies have given increased emphasis to two types of national collaboration: the first is the encouragement of closer links between the various sectors of PSR (for instance between universities and research institutes). The intention appears to be to improve integration and knowledge flow between national researchers working in the same broad fields, as well as to save costs by requiring that they share expensive new scientific equipment. The results of the questionnaire show that these collaborations are central for the majority of human genetics research groups. The case studies indicate that "trans-disciplinarity" or close collaboration between specialists from different disciplinary backgrounds are significant in human genetics research, a field which transcends disciplinary boundaries. Collaboration is demanded because even the largest research units may not have all the skills, expertise, equipment and research material demanded to carry out competitive research. Collaborations can make up for this by providing access to external know-how and equipment, or by dividing up research problems among units according to their specific expertise. The second type of collaboration is the promotion of closer interaction between PSR and industry, as well as with other users. The intention is for PSR to be more responsive to national needs so that it can strengthen the economy by contributing to industrial innovation, and is also able to provide expertise to address social or environmental problems. The results of the questionnaire on human genetics research groups show that half the research group have long-standing relationships with hospitals and 17% have strong links with industry but 43% have no strong relationship with any type of socio-economic actor. Similar research in other fields is needed to identify whether the effects of this policy are similar in other areas.

National policy also supports foreign collaboration. This has been a component of national policy for many years, and it has been especially important in small countries, where researchers would otherwise have difficulty in finding colleagues with complementary interests. The two main factors affecting national policies for international collaboration are firstly, the increasing cost of "big science" in areas such as space, nuclear energy and particle physics research and, more recently, some areas of environmental and biological sciences. Collaborative European laboratories have minimised the heavy costs previously borne by individual countries which tried to maintain national facilities, and helped them to maintain their expertise in these areas. The second influence is the impact of the funds and research opportunities offered by the EC's Framework Programmes. These programmes generally require that research be carried out by researchers in more than one country, and/or have an industrial partner. Although EC funds account for only a small part of most countries' overall public sector research budgets, it appears that the availability of funds for these EC programmes is accelerating the growth in intra-European research collaboration. Some national reports note that these European collaborations may be substituting for previous collaborations with the US. What the reports cannot identify is whether these intra-European collaborations would persist in the absence of EC programme funds, or whether US collaborations would be a preferred option, should funds be made available on a similar scale for collaborating with the US.

In an environment where collaboration of all types is increasing, and where researchers increasingly wish to interact with colleagues working at the frontiers of knowledge wherever they are located, it is important to identify the wider influence of EC Framework Programmes. Does the expertise developed in EC research programmes help European scientists to collaborate with international experts in their fields? Alternatively, does the focus on European collaboration drive out the other international collaborations which would help European scientists keep abreast of major development around the world?

The case studies in the second part of the project, on the practices of the European human genetics research community in Germany, Ireland, Norway, Spain, Sweden and the UK, provided some partial answers to these questions. They show that scientists in small developed European countries, such as Sweden and Norway, have benefited from national policies which encourage international collaboration. Their scientists have been enabled to maintain close contacts with world centres through study and work abroad, enabling these countries to establish "niches of excellence". Both large and small less developed countries (Ireland and Spain) have yet to develop such strategies. From this point of view, both countries have benefited from the EC's Framework Programs. Participation by Irish and Spanish researchers in joint EC research projects and programmes has provided access to international research networks and the latest knowledge and techniques. The experience of these two countries also suggests that the existence of European programmes provided both the incentives and resources for poorer countries to develop a national research effort in human genetics, hitherto neglected by research policy or funding agencies. Our study indicates that there is extensive PSR networking within countries as well as strong linkages throughout Europe and the rest of the world. It is not clear whether European linkages reflect the potential emergence of a distributed European knowledge production network.

4.5 PSR, public welfare and safety

Our study indicates that policy for PSR throughout Europe is privileging industry and the promotion of innovation, and appears to be assigning a lower priority to its responsibility to act as a "watchdog" in matters concerning research which may affect public safety, the environment, sustainability, and so on. This neglect may be related to governments taking increased control over the governance of PSR at a time when a series of disasters connected with deficient scientific advice has led to public loss of trust in the advice of scientific "experts". It also appears to reflect problems connected with the shift from modern to postmodern paradigms for science and technology policy.

The former paradigm started to founder in the 1980s. It had developed from ideas expressed by Vannevar Bush in *Science: the Endless Frontier* (1945) and represented a social contract between governments and science. It was based on a linear model of innovation and led to the development of linear indicators of outputs such as bibliometrics, patents and to counting scientific personnel in terms of full-time equivalents. The ideals of the paradigm enshrined unfettered basic science to be performed without thought of practical ends, a disciplinary basis for knowledge production, the autonomy of the scientific community, free diffusion of knowledge, altruism and the use of expert peers as the sole judges of research excellence. The post-modern paradigm is based on new modes of multidisciplinary and interdisciplinary knowledge production and a non-linear, complex and interactive model of innovation. Moreover, it rests on a new social contract where the relationship between government and science is not only more direct but mediated by social and economic demands and needs.

Disasters such as global warming, Bhopal, Seveso, Chernobyl, BSE have raised public concern about the application of new technologies. In particular, criticisms are voiced about the potential harm inflicted on the environment, health and employment by scientific and technological progress. The public increasingly recognises the shortcomings of science and is unwilling to accept the reassurances of the scientific-political establishment (Beck, 1992; Lash et al, 1996). Beck suggests that these attitudes characterise "risk society", characterised by pervasive insecurity, a preoccupation with technological threats because of the failure to develop effective institutional controls or to recognise the limitations of reductionist science. Cohen (1997) outlines a more optimistic scenario - ecological modernisation - which describes societies which recognise the shortcomings of scientific inquiry, emphasise technologies that support social learning and promote institutional flexibility. The ability to switch from the former to the latter scenario is dependent on preserving scientific rationality, now under attack from competing epistemologies, as the dominant knowledge system. Social capital, or the degree or trust and association between a society's members, and the ability to formulate political consensus around problem situations facilitate the move to ecological modernisation.

This analysis indicates that governments which fail to give sufficient attention to public welfare and safety aspects of research, or to involve the participation in risk analysis of all interested and affected parties may find their PSR policies increasingly open to public challenge. It also identifies the need for science and technology funding agencies to take account of public perceptions and risk assessment in assessing new bids. Moreover, PSR policy which continues to privilege industry may perpetuate "risk society", and hinder rather than promoting industrial innovation. This is not the only reason for advocating PSR policies which assist the development of social capital. Lack of social trust, and the growth of risk society may also deter some of Europe's most able young students from studying or pursuing careers in this area, and lead to shortages of trained scientists and engineers for both the public and private sectors.

4.6 Policy implications

This project is relevant to policy in a number of ways. It attempted, for the first time, to understand the relationshiop between "top-down" science and technology policy and "bottom-up" responses by PSR researchers, and identified the way in which such an approach should be implemented in future. Despite the limitations of the approach adopted (considering all national policy for PSR and not focusing on the research field under study), we found that some researchers manage to take advantage of policy to promote their own interests, re-emphasising the need for future projects to be mindful of the role of researchers in shaping science policy

The results of the project are of particular relevance to funding agencies in several ways. They emphasise the growing significance of biology, and of genetics in particular, within science and technology budgets in the most advanced countries, in supranational organisations and in foundations. In addition, the methodologies developed meet funding agencies' need for instruments to assess the outputs from the research they fund. The tools developed (aggregate indexes and case studies) can also trace the logic behind the actions of the actors involved in PSR and provide new indicators to identify and assess scientists' internal and external research links.

The project also identified common trends affecting PSR in most countries which raise a set of inextricably linked policy implications.

- There is an urgent need to rectify the current over-emphasis on PSR to promote industrial innovation. More attention should be given to developing social capital by allocating funds to PSR programmes which investigate topics connected with public welfare and safety. Such programmes should not be open to PSR institutions or researchers receiving more than a very small percentage of their income (e.g. 5%) from industry (for industrial research contracts, acting as consultants etc.) There is also a need for science and technology funding agencies to take account of public perception and risk assessment in assessing new bids.

- The convergence of activities and the blurring of the "missions" of the various sectors of PSR carry inherent dangers. In particular there are great doubts about the ability of disciplinary-based universities based on short-term contract researchers to provide government ministries with the impartial, long-term, in-depth and interdisciplinary background expertise previously on-tap from dedicated research institutions, as the need arose.
- There are concerns that the increasing emphasis on economic returns from investment in PSR, and related instruments may concentrate resources on short-term or oriented research and lessen the availability of resources for long-term, uncertain basic research - research for the advancement of knowledge. Trends in this direction may dissuade promising young scientists and engineers from careers in European PSR. Moreover, concentration on short-term issues of current concern to industry may lead to neglect of longer term research whose potential may only be realised at some time in the distant future.
- Technological support for industry and other users was traditionally provided by specialist sectoral institutes. There are doubts about the capability of universities to replace these specialist institutes, and especially about who will take care of the needs of small companies. Universities have not typically been very good at this, and it is uncertain whether universities will be either interested or capable to meet SME needs. A second problem will be the difficulty for users, especially SMEs, to find specific sources of expertise in the widely dispersed university sector.
- The casualisation of scientific manpower may adversely affect the output of PSR, the ability to accumulate, share and apply research results, programme continuity and research driven by scientific curiosity. A more insidious effect of casualisation may be the loss of promising young scientists from research careers, either in the public or private sectors. Policies for training highly skilled research personnel must therefore run in parallel with policies for their secure employment, both in PSR and in industry. In particular, there is a need for policies to encourage commerce and industry to demand such skills, especially in some of the less developed countries. In the absence of such demand-side policies, countries which invest in the training of highly skilled staff may lose them to foreign employers.

The second set of issues concerns the way in which PSR is managed, both at a national and local levels:

- The development of new management practices should take account of national PSR strengths and weaknesses. Each country can learn from others; but what it learns cannot be adopted unchanged but must be tailored to the specific conditions of its own system of PSR.
- Policies to improve coordination of PSR are best served by following several parallel approaches from a variety of relatively independent policy-makers, rather than one unified policy. Diversity can protect the fostering of new initiatives, flexibility in the PSR system and a degree of autonomy for research institutions and researchers.
- Further research is required is understand how local management practices, and in particular how researchers are allocated to different duties, affect the activity profiles of research units. This could be undertaken by carrying forward the human genetics work, and undertaking complementary in-depth studies on ìsimilar“ labs (i.e. labs sharing the same ìactivity profiles“), especially focusing on the issues which both case studies and questionnaire analysis suggested were important to explore.

5. Dissemination and/or exploitation of results *(2/3 pages)*

Section 7 shows that numerous dissemination activities occurred during the course of the project, including publications and conference presentations. For instance a special session of the 1998 EASST Conference in Lisbon dedicated to 'Public Sector Research in Transition' was organised by Jacqueline Senker; eight papers in this session were based on project work. Other plans are in the pipeline, as indicated in Table 3. A special issue of *Science and Public Policy,* to be guest-edited by Jacqueline Senker, is planned for 2000. The contents will comprise papers by partners on cross-cutting themes which have emerged from the project. It is also planned that the national reports and overall synthesis will be edited to form a book; Edward Elgar has expressed interest in publishing this book. Researchers from the human genetics community who completed the questionnaire or participated in the case studies, and who expressed interest in the results of these studies, are being sent summary results. Down-loadable copies of the full reports are to be made available on websites. Several other partners, such as NIFU and SPRU are planning to publish their national reports.

The methodology used to study the activities of PSR through its research collectives which was piloted in this project, has been judged sufficiently relevant for a similar study to be initiated in France. The new project is studying higher education research units in the fields of agronomics, veterinary science and the agro-food industry, and a permanent observatory to carry out similar studies is under consideration. The approach also forms the basis for a potential comparative international project, to be discussed at a forthcoming symposium to be held in Sweden in September. The symposium is funded by the Bank of Sweden Tercentenary Foundation. An preliminary symposium on a similar theme was also based on this project and supported by the European Office of the US Office of Naval Research.

The project has aroused great interest among other academic colleagues, and there have been several requests for early access to the results from the national studies. Access has been granted to Arie Rip and Heide Hackmann of University of Twente for a related project. Professor Ron Johnston of the University of Sydney, NSW, Australia requested and was given a copy of the draft synthesis report on the national reports after hearing the presentation based on this report to the Australian Academy of Technological Sciences and Engineering in Melbourne in June 1999.

Table 3: Dissemination activities - follow-up of results, by partner

Partner	Future dissemination activities
EC-funded partners USUSS.SPRU	Guest-editing a special edition of *Science and Public Policy*. Preparing a book based on work package 1 Publishing UK national report as a booklet.
ARMINES	Organisation of "Understanding the Dynamics and Role of Public Sector Research. Towards a Unified Framework for International Comparative Analysis of Research 'Collectives'", international workshop, Paris 30 June-3 July, 1998 Organisation (with University of Linkoping) of "Framework and Design of an International Study of Research Collectives" Symposium, forthcoming, 4-9 September, 1999, Sigtuna, Sweden P Laredo & E. MuÒoz, 'A New Environment for Public Sector Research Performance. Research Collectives as Actors and Drivers for Change', paper for special edition of *Science & Public Policy*
CIRCA (Tom Higgins)	"Public Sector Research, Technology and Innovation Activities" Workshop with Forfas, the Irish industrial and technology policy body, Dublin, 14 February, 1999. To assist Forfas in preparing a statement for the Irish Council for Science, Technology and Innovation (ICSTI) (Task Force on Innovation Infrastructure) on the future development of PSR in Ireland. A paper (Draft Council Statement and Recommendations) was subsequently prepared for Forfas based on the workshop discussions and an ICSTI paper based on this (Public Research and Technology Services for Innovation in Enterprise) is to be considered for publication by ICSTI.
NIFU	Publication of Scandinavian national report as a book H. Skoie, 'The Role of Research in Higher Education - Current Practice and Future Perspectives in the Scandinavian Countries', paper for special edition of *Science & Public Policy*
CSIC.IESA	P Laredo & E. MuÒoz, 'A New Environment for Public Sector Research Performance. Research Collectives as Actors and Drivers for Change', paper for special edition of *Science & Public Policy*
MPG-IGESF	M. Winnes & U. Schimank, 'Empirical Exploration into "Mode 2". Case Studies of Human Genetics Research in Seven European Countries' and U. Schimank & M. Winnes, 'An uneasy Partnership or Back to the Past?, papers for special edition of *Science & Public Policy*
Hungary (SPRU sub-contractor)	Katalin Balazs and Halla Thorsteinsdottir, ' PSR in Small Countries' - Does Size Matter?', paper for special edition of *Science & Public Policy*
Self-funded partners CNR, Italy	B. Poti & E. Reale, 'Convergence and Differentiation among European PSR: the Decline of Public Research Institutes', paper for special edition of *Science & Public Policy*
Research Policy Group, University of Linkoping, Sweden	Organisation (with ARMINES) of "Framework and Design of an International Study of Research Collectives" Symposium, forthcoming, 4-9 September, 1999, Sigtuna, Sweden M. Benner & U. Sandstrom, 'Changing Organisation of Public Sector Research; What is Happening to the Research Council System?', paper for special edition of *Science & Public Policy*
Iceland	Katalin Balazs and Halla Thorsteinsdottir, ' PSR in Small Countries' - Does Size Matter?', paper for special edition of *Science & Public Policy*

6. Acknowledgements and References

We acknowledge the support from all the institutions which contributed towards the costs of this project. The main funder was the EC's TSER programme, but the following institutions also contributed: SPRU,

University of Sussex, UK; ARMINES-CSI, France; CSIC-IESA, Spain, the Norwegian Institute for Studies in Research and Higher Education, Norway; Max Planck Institut fur Gesellschaft, Germany and the CIRCA Group Europe Ltd., Ireland. We are especially grateful to the following instutions and people who fully funded their contribution to the project: CNR, Italy;
TEMA, University of Linkoping, Sweden; and Halla Thorsteindottir, Iceland (now in Canada).

Numerous researchers were involved in the project, particularly in Work Package 2. We acknowledge the help of Marie-AngËle de Looze of INRA/SERD, Grenoble, who carried out bibliometric analysis and to Martine Lecoeur of GMV Conseil, Paris who analysed the questionnaire. Other researchers who participated include Keith Sequeira of SPRU, University of Sussex, Catharina Landstrom, Mats Benner and Agneta Tisell of Research Policy Group, Linkoping University, and Victor Diaz of IESA/ CSIC, Madrid.

We are also very grateful to two EC scientific officers from whom we received invaluable help during the course of the project. Svend Remoe, and his replacement since late 1997, Maria Carvalho Dias. We also wish to thank Forfas, the Irish industrial and technology policy body, which hosted a workshop in June 1998.

We also wish to thank all the secretaries and administrators who have contributed to preparing reports, organising workshops and dealing with coordination issues. We are especially grateful to Steff Hazlehurst of SPRU, in charge of overall administration of the project, including cost statements.

References

U. Beck (1992), *Risk Society: Towards a New Modernity,* Sage, London.

J. I. Bell (1999), 'Clinical research is dead; long live clinical research', *Nature Medicine*, vol. 5(5) pp 477 - 478

V. Bush (1945), *Science: the Endless Frontier.* A report to the President on a program for postwar scientific research. National Science Foundation, Washington, D.C.

M. J. Cohen (1997), "Risk society and ecological modernisation. Alternative visions for post-industrial nations", *Futures,* Vol. 29(2), pp. 105-119

M. Gibbons, C. Limoges, H. Nowotny, S. Schwartzman, P. Scott & M. Trow (1994), *The New Production of Knowledge,* Sage Publications, London, Thousand Oaks, Calif. and New Delhi.

M. S. Granovetter (1973), 'The strength of weak ties', *American Journal of Sociology,* Vol. 78, pp. 1360-80.

A. Heidenheimer, H. Heclo and C. Adams (1990), *Comparative Public Policy. The Politics of Social Choice in America, Europe, and Japan,* St. Martin's Press, New York.

J. S. Katz and D. Hicks (1996), 'A systemic view of British science', *Scientometrics*, Vol. 35(1), pp. 133-154.

P. LarÈdo, U. Schimank and M. Winnes (1999), *An Approach to Public Sector Research through its Research Collectives - Overview.* Interim Report B., ARMINES/CSI, Paris and Max-Planck-Institute for the Study of Societies, Kˆln.

P. LarÈdo & P. Mustar (1996), 'Laboratory configurations: an exploratory approach", Paper presented to EASST/4S Conference, Bielefeld, October.

S. Lash, B. Szerszynski and B. Wynne (1996), *Risk, Environment and Modernity: Towards a New Ecology,* Sage, London.

OECD (1998), *Basic Science and Technology Statistics. 1997 Edition,* OECD, Paris.

OECD (1997), *Main Science and Technology Indicators,* No. 2, OECD, Paris.

OECD (1989), *The Measurement of Scientific and Technological Activities. R&D Statistics and Output Measurement in the Higher Education Sector: Frascati Manual - Supplement,* OECD, Paris.

J. Senker (1998), *Changing Structure, Organisation and Nature of European PSR Systems*, Synthesis Report of the TSER Project "European Comparison of Public Research Systems", SPRU, University of Sussex, Brighton.

7. Annexes

List of Project Outputs

a) <u>Publications</u>

De Marchi M., Reale E., Rocchi M., Scarda A.M., 'Il Sistema scientifico in Italia', in rapporto del Ministero Affari Esteri, *Scienza e tecnologia italiane all'estero. Il ruolo dell'addetto scientifico*, Roma, 1999.

De Marchi M., PotÏ B. M., Reale E., Rocchi M., Scarda A.M., *Il Sistema scientifico pubblico in Italia. Cambiamenti e tendenze*, F. Angeli, Milano, 1998.

E MuÒoz, M-J. Santesmases & J. Espinosa de los Monteros (1999), *Changing structure, organisation and nature of public research system. Their dynamics in the cases of Spain and Portugal,* IESA, CSIC, Madrid.

Rocchi M., Scarda A.M., 'Il Sistema scientifico in Italia', in *Analysis* (forthcoming) Roma, 1999.

J Senker (1999), *University Research Financing*, A report prepared for the OECD, SPRU, University of Sussex, Brighton.

J Senker (1998), 'Commentary: Turmoil in Public Sector Building Research - Part of a Wider Problem', *Building Research & Information,* Vol. 26(6), pp. 383-385

b) <u>Conference Presentations</u>

K. Bal ·zs (1998), 'Comparison of PSR in three small countries', presentation to EASST Conference, Lisbon, 1-3 October

De Marchi M., Reale E., Rocchi M., Scarda A.M., 'Public Research in Italy: Its Role within a Changing Society', presented at EASST Conference ìCultures of Science and Technology: Europe and the Global Context", 30 September-3 October 1998, Lisbon.

B Martin & J Senker (1999), *Science and Technology Policy Developments in European Countries*, presentation to Australian Academy of Technological Sciences and Engineering, Melbourne, June

B Martin & J Senker (1998), *The Changing Nature and Context of UK Science Policy*, Presentation to the CNRS and OST, Paris, May.

B Martin and J Senker (1998), *Evaluating Investments and Performance in UK Research*, presentation to the 23rd American Association for the Advancement of Science (AAAS) Colloquium on Science and Technology Policy, Washington D.C., 29 April - 1 May

E. MuÒoz (1999), 'New Science and Technology Policy', presentation to European Interuniversity Association on Society, Science and Technology (ESST), Lausanne, May.

E. MuÒoz, M. Santesmases & J. Espinosa de los Monteros, (1998), 'Organisational detours for building up an efficient public research system. The case of Spain and Portugal, an endless story?' presentation to EASST Conference, Lisbon, 1-3 October

E. MuÒoz (1998), 'Public Funding of Public Research; Beyond the "Peer-Reviewed Call for Proposals" Model', presentation to "Understanding the Dynamics and Role of Public Sector Research. Towards a Unified Framework for International Comparative Analysis of Research 'Collectives'", international workshop, Paris 30 June-3 July.

PotÏ B. M., Reale E.,'Convergenza e diversit‡ tra sistemi pubblici europei di ricerca: il caso del declino degli istituti di ricerca', presented at the XII Concegno biennale AISSEC (Associazione italiana per lo studio dei sistemi economici comparati), Siena, 3-5 maggio 1999.

PotÏ B. M., Reale E., 'The PSR Transition Toward Autonomy in Italy: Political Orientations and Endogenous Behaviours of Research Agents', presented at EASST Conference ìCultures of Science and Technology: Europe and the Global Context", 30 September-3 October 1998, Lisbon.

Reale E., 'Public Sector Reform: The Case of Scientific Research in Italy' presented at the International European Evaluation Society Conference on ìEvaluation: Profession, Business or Politics?ì 29-31 October 1998, Rome.

U. Sandstrom & B. Persson (1998), 'Swedish Public Sector Research - Islands of Change in a Constant Sea', presentation to EASST Conference, Lisbon, 1-3 October

U. Schimank & M. Winnes (1998), 'An uneasy partnership or back to the past? The relationship between research and teaching and the development of European University Systems 1980-1995', presentation to EASST Conference, Lisbon, 1-3 October

J Senker (1999), 'European Public Sector Research: What is the Reason for the Restructuring?' presentation to ìCurrent Issues in Science and Technology Policy" workshop, University of Sussex, 29 June.

J Senker (1998), *Is There a Structural Explanation for Transitions in Public Research Systems?*, presentation to EASST Conference, Lisbon, October
H. Skoie (1998), 'The role of research in universities and other institutions of higher education - some developments in the Scandinavian countries', presentation to EASST Conference, Lisbon, 1-3 October

c) Reports

K. Bal ·zs (1998), *Changing Structure, Organisation and Nature of Public Research System (PRS) in Hungary,* Technopolis, Brighton.
The CIRCA Group Europe Ltd. (1998), *The Changing Structure, Organisation and Nature of PRS System. Ireland,* CIRCA Group, Dublin
P. LarÈdo & B. de Laat (1998), *Public Sector Research in France,* Centre de sociologie de l'innovation, Ecole Nationale SupÈrieure des Mines, Paris.
P. LarÈdo (1999), *Report on the Development of a Reproducible Method for the Characterisation of a Large Set of Research Collectives. A Test on Human Genetics Research in Europe,* ARMINES/CSI, Paris.
P. LarÈdo, U. Schimank & M. Winnes (1999), *Interim Report B. An approach to Public Sector Research through its Research Collectives - Overview,* ARMINES/CSI, Paris and Max-Planck-Institut f¸r Gesellschaft, Kˆln.
De Marchi M., PotÏ B. M., Reale E., Rocchi M., Scarda A.M. (1998), *Changing Structure, Organisation and Nature of PSR Systems. Italy,* CNR, Rome.
E. MuÒoz, M-J. Santesmases & J. Espinosa de los Monteros (1999) *European Comparison of Public Research Systems. The Dynamics of PSR in Spain and Portugal,* IESA, CSIC, Madrid.
U. Schimank & Markus Winnes (1999), *National Report. Federal Republic of Germany*, Max-Planck-Institut f¸r Gesellschaft, Kˆln
U. Schimank & Markus Winnes (1999), *Public Sector Research in Europe: Comparative Case Studies on the Organisation of Human Genetics Research. Synthesis Report,* Max-Planck-Institut f¸r Gesellschaft, Kˆln
J Senker (1998), *Changing Structure, Organisation and Nature of European PSR Systems. Synthesis Report,* SPRU, University of Sussex, Brighton.
J Senker (1998), *Changing Structure, Organisation and Nature of European PSR Systems. United Kingdom*: A report for the European Commission, SPRU, University of Sussex, Brighton
H. Skoie (1998), *The Scandinavian Countries and their Systems of Public Research,* NIFU, Oslo
H. Thorsteinsdottir (1998), *European Comparison of Public Research Systems. Report on Iceland.*

b) Deliverables

All completed, as shown, with slight amendment to the content of State of the art paper B.

WORK PACKAGE 1

J Senker & B Martin (1997), *Changing Structure, Organisation and Nature of European PSR Systems. Background Briefing Paper 1,* SPRU, University of Sussex, Brighton, July (State of the Art paper A)
J Senker (1998), *Changing Structure, Organisation and Nature of European PSR Systems. Synthesis Report,* SPRU, University of Sussex, Brighton, May (interim Report A).

WORK PACKAGE 2

State of the art paper B abandoned in favour of P. LarÈdo & B. de Laat (1997), *Proposal and Background Papers for Work Package 2,* CSI/ARMINES, Paris.
P. LarÈdo, U. Schimank & M. Winnes (1999), *Interim Report B. An approach to Public Sector Research through its Research Collectives - Overview,* ARMINES/CSI, Paris and Max-Planck-Institut f¸r Gesellschaft, Kˆln.

WORK PACKAGE 3

J. Senker, K. Bal ·zs, T. Higgins, P. LarÈdo, E. MuÒoz, B. PotÏ, U. Sandstrom, M. Santesmases, A. Scarda, U. Schimank, H. Skoie, H. Thorsteinsdottir and M. Winnes (1999), *Final Report. European Comparison of Public Research Systems* (Final Report C), SPRU, University of Sussex, Brighton.